FERTILIZER MANAGEMENT OF MINOR TUBER CROPS IN COCONUT BASED CROPPING SYSTEM

By

R. PUSHPAKUMARI

THESIS

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Department of Agronomy
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DECLARATION

I hereby declare that this thesis entitled "FERTILIZER MANAGEMENT OF MINOR TUBER CROPS IN COCONUT BASED 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.

Vellayani

April, 1989

(R. PUSHPAKUMARI)

CERTIFICATE

Certified that this thesis, entitled "FERTILIZER MANAGEMENT OF MINOR TUBER CROPS IN COCONUT BASED CROPPING SYSTEM" is a record of research work done independently by Smt. R. Pushpakumari under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

(Dr. V.K. SASIDHAR)
Chairman, Advisory Committee
Professor of Agronomy

Mannuthy
April, 1989

APPROVED BY:

Chairman:

Dr.V.K. SASIDHAR

Members:

1. PROF.E.P.KOSHY

2. Dr.C. SREEDHARAN

3. Dr.R.S. AIYER

4. Dr.(Mrs.) P. SARASWATHY

External Examiner

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Introduction

INTRODUCTION

The vast majority of farmers in Kerala belong to the category of small and marginal farmers. In almost all the holdings, coconut palm forms the base crop and the average size of a coconut holding in Kerala is less than 0.22 ha (Coconut Bulletin, 1970). The paucity of land compell the farmers to use every inch of the land including the inter spaces of coconut. Thus intercropping in perennial plantations like coconut and arecanut gardens was prevalent in this state since very olden days.

Under normal situations about 85 per cent of the roots of an adult bearing coconut palm are concentrated laterally within a radius of 2 m from the base and vertically within 30-120 cm depth. Thus the top 30 cm layer is practically devoid of functional roots (Kushwah *et al*., 1973). However, coconut palms are generally grown with a spacing of 7.5 m x 7.5 m (56.25 m^2) due to their special morphological feature. This clearly indicates that 77.7 per cent of the total available land area in a pure stand of coconut is not effectively utilized to the fullest extent by the coconut roots (Nair, 1979).

Another important consideration is the transmission of sunlight through the coconut canopy. In the pre-bearing stage of the palm, the shade effect caused by the coconut canopy is practically negligible. When the palms are about 8-25 years old, the sunlight transmitted is only 25 per cent and as the palms grow up the light transmission increases progressively and the canopy coverage of ground decrease, thereby permitting more sunlight to percolate down. By the time the palms are about 40 years old, the light transmission increases to 50 per cent. As the palm gets older about 1/3 of the total number of leaves in the crown bend downward. The drooping leaves which intercept less radiation and may probably reflect more sunlight to the ground. Studies conducted at the Central Plantation Crops Research Institute, Kasargod, Kerala have shown that while the young bearing palms permit only less than 20 per cent incident radiation to reach the ground, the middle aged palms allow about 30 per cent and pre-bearing and old palms upto 80 per cent (Thampan, 1982).

Although the shade effects is more under young palms the high reflectance of the thick cuticled coconut leaves and the position of leaflets cause scattering of incident radiation in all direction and as a result the light intensity at the plantation floor, even directly under the canopy shade of coconut could be higher than that would be expected (Nair, 1979). These observations clearly indicate that the space below the coconut canopy is in a position to accommodate a number of other crops both in terms of soil and solar radiation.

The experiments conducted at Central Plantation Crops Research Institute, Kasargod, Coconut Research Station, Pilicode and Coconut Research Station, Nileswaram revealed that there was no deleterious effect on the productivity of palms by growing intercrops and that intercropping proved to be of great economic advantage. A number of intercrops have been tried at Central Plantation Crops Research Institute, Kasargod and according to them the most promising intercrops were tubers and rhizome species.

The importance of subsidiary food crops like tuber crops are evident as they can meet the food needs partially and at the same time can earn additional income. On account of the unique ability of these crops to draw solar radiation to a greater extent, to synthesise carbohydrate and store them as underground tubers make them the most suitable intercrops for growing under partial shaded situation especially under coconut garden conditions.

Tropical root crops are a major source of food in the world. From an economic appraisal of root crops in developing countries (Horton *et al.*, 1984) reported that total yields of root crops generally excel those of cereals and gross return per hectare illustrated superiority of root crops over the cereals. Under the same level of inputs, tropical root crops are capable of producing more kilo joules ha^{-1} unit $time^{-1}$, than any other crop except perhaps sugarcane (Chandra, 1984).

Cassava, sweet potato, yams and taro are the most important tropical root crops produced and consumed in the world. Historically these crops have received little attention from the scientists and policymakers (Coursey and Haynes, 1970).

At present, authoritative information on the management of tuber crops other than cassava is very little and that too is only under open situations. Since these crops are mostly grown as intercrops under the coconut plantation in the state, further investigation to evolve suitable management practices under partial shade situation assumed greater importance and as such the present experiment on "fertilizer management of minor tuber crops in coconut based cropping system" was taken up with the following objectives.

(1) to screen the minor tuber crops viz. greater yam, lesser yam, tannia and elephant footyam under different intensities of shade,

(2) to assess the performance of different tuber crops in coconut garden,

Review of Literature

(3) to find out the optimum dose of fertilizer nutrient for tuber crops under partially shaded conditions,

(4) to estimate the uptake of major nutrients by different tuber crops, and

(5) to work out the economics of cultivation of different tuber crops

2. REVIEW OF LITERATURE

Tapioca and sweet potato are the major tuber crops in Kerala. The minor tuber crops like greater yam, lesser yam, cocoyam and elephant footyam are generally grown under partial shaded condition in the state.

This review is classified under two sections. The first section reviews the literature available on the response of different crops to varying intensities of shade. The second section reviews the response of minor tuber crops to major plant nutrients both in the open and under partially shaded conditions.

2.1. Response of different crops to varying intensities of shade

2.1.1. Plant height

Moursi and Gawad (1963) observed that in sesame plant, the stem height was maximum at 50 per cent light intensity, In the case of ginger, Aclan and Quisumbing (1976) observed that plants grown under full sunlight were shorter than those in the shade. Similar effect was observed by Tarila et al. (1977) also.

Batista and Alvim (1981) in their study with cocoa plants concluded that 36 per cent light intensity was best for the growth of cocoa plants. Lalitnabai (1981) observed an increase in the plant height due to increase in shade intensity upto 50 per cent for coleus and turmeric upto 75 per cent in ginger. Shaded plants were reported to be taller than unshaded plants in the case of tomato (Syed Kamaruddin, 1983).

Ramanujam et al. (1984) reported that in cassava, plant height continued to increase for all the cultures of cassava under shade. He also observed that the stem length of the short statured type C 1590 was almost doubled under shade.

Palis and Bustrillos (1976) observed a decrease in plant height with increasing levels of shade from 0 to 50 per cent. Kulasegaram and Kathiravet Pillai (1976) reported that shade and restricted water supply reduced terminal bud activity and checked the increase in height. In colocasia, Lalithabai (1981) reported maximum plant height at full illumination and this was on par with 25 and 50 per cent shade and significantly superior to 75 per cent shade.

Tamaki and Naka (1972) observed different responses to shading at different stages. Plants shaded until flowering elongated more rapidly than control and plants shaded during flowering did not show that effect.

2.1.2. Number and size of leaves

Porter (1937) reported that leaf area was increased consequent to shading in tomato plants. Hardy (1958) studied the nature of leaves of cocoa seedlings under varying intensities of shade and observed that leaves produced under heavy shade were much larger, often attained a length of 20-24" and were thinner, heavier and contained higher proportions of water.

Matusiewiez (1967) in his pot culture study on sugarbeet observed that the number of leaves which dried during the vegetative period and total dry matter of leaves were increased by shading. Panilkar et al. (1969) observed that in tobacco, length and breadth of leaves were increased by 15.1 and 17.6 per cent respectively under shade as compared to unshaded plants. Guers (1974) reported that the leaves of cocoa grown in full sun were smaller, thicker and had a higher dry matter content, and their photosynthetic capacity per unit leaf area was also greater.

Gumbs and Ferguson (1976) reported that for yam crop, leaf development was not affected initially by light treatments but 15 weeks after planting, plants whose tubers developed in darkness, had larger number of leaves and leaf area per plant.

Aclan and Quisumbing (1976) also observed shorter and fewer number of leaves for plants grown under full sun in the case of ginger. In a pot trial in Trinidad Caesar (1980) tested Xanthosoma sagittifolium and Colocasia esculenta var. antiquorum for tolerance to shade and water stress and observed that Xanthosoma sagittifolium produced highest drymatter yield under shade and full water supply by developing long petioles and large leaf blades and the opposite was the case with Colocasia esculenta var. antiquorum.

Lalithabai (1981) observed significantly lower LAI for colocasia 120 days after sprouting in the full sunlight (open) when compared to shaded treatments.

Moursi and EL Gawad (1963) studied the effect of light intensities ranging from 20% to 100% of natural day light on the growth of [illegible] and observed that the number of leaves and dry weight of leaves were highest at 100 per cent intensity.

Petrov-Spiridonov (1964) found that sunflower and maize grown in shade had smaller leaves than those in sunlight.

Boyer (1970) stated that the flushing intensity, leaf number and total foliar surface per tree were greater in unshaded trees than those under light or moderate shade.

Kulasegaram and Kathiravet Pillai (1976) observed a reduction in the number of leaves, total leaf area, leaf thickness and dry matter of leaves under conditions of shade. Parila et al. (1977) reported that in cowpea, higher light intensity improved leaf area and plant size. maximum leaf area index (LAI) was exhibited in the treatment without shade and minimum LAI under highest shades in the case of sweet potato (Lalithabai, 1981).

Ramanujam and Jose (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.

Reported results are also available where the crops did not show any significant influence for different intensities of shade.

In pineapple, Radha et al. (1980) reported that the number of leaves produced per plant did not differ significantly due to different shade intensities.

Leaf area indices of crops viz. ginger, turmeric and coleus were also observed to be not influenced by different shade intensities (Lalithabai, 1981).

In an experiment with sweet potato where all plants were established in full sunlight for two weeks and there after shade treatments of full light, 25 per cent shade, 50 per cent shade, and 73 per cent shade were given. Roberts-Nkrumah et al. (1986a) observed no significant difference in mean total leaf area among treatments.

2.1.3. Chlorophyll content

Increased chlorophyll content in the leaves of shaded plants was reported by several workers in different crops such as in cocoa by Evans and Murray (1953) and Guers (1971), in tea by Ramaswamy (1960) and Venkatamani (1961), in oranges by Shimizu and Torikata (1972) and in apple by Tansev (1976). Okali and Owusu (1975) observed that in cocoa plants, the chlorophyl content per unit leaf fresh weight was significantly greater under deep shade.

Chlorophyll content per unit weight of leaf was found to increase in the case of plants grown at lower light intensities, but the chlorophyll content per unit area of leaf surface was very often lower than the plants grown in open (Bjorkman and Holmgren, 1963). Guers (1974) observed that the chlorophyll contents and particularly chlorophyll 'b' increased with increasing shade. Radha (1979) observed that chlorophyll 'a', 'b' and total chlorophyll content of leaves were found to be increased with increase in intensity of shade in pineapple.

Moon and Pyo (1981) reported that chinese cabbage leaves in all shade treatments contained 0.69 to 0.82 mg chlorophyll g^{-1} leaf compared with 0.47 mg for leaves of plants grown in full sunlight. But they observed that the chlorophyll content was not affected by shade treatments in spinache leaves.

Lalithabai (1981) reported that the content of chlorophyll 'a', 'b' and total chlorophyll increased with increasing shade intensities in the case of coleus, ginger and turmeric while no general trend was observed in colocasia. She also pointed out that the ratio of chlorophyll 'a' and 'b' remained almost constant in sweet potato, coleus and ginger while in turmeric, the ratio increased with increasing shade upto medium shade and then decreased.

Ramanujam and Jose (1984) studied the influence of light intensity on chlorophyll distribution and anatomical character of cassava leaves and found that the leaves grown under low light (6000 lux) recorded higher concentration of total chlorophyll per unit leaf weight. They also observed that low light favoured the concentration of chlorophyll 'b' and thus the ratio of chlorophyll 'a' to 'b' was reduced significantly.

Vijayakumar et al. (1985) observed that the chlorophyll content of exposed leaves of pepper was 44 per cent below the content of shaded leaves. They also reported that leaves coated with lime contained 39 per cent more chlorophyll than exposed leaves.

Contrary to the above reports, Higazy et al. (1975) observed that the concentration of total chlorophyll as well as its components 'a' and 'b' decreased by increasing shade intensity in cowpea. Moursi et al. (1976a) observed that the ratio of chlorophyll 'a' and 'b' remained constant at all shade intensities, though significant reduction in all pigments with shade was observed.

2.1.4. Photosynthesis and drymatter accumulation

Singh (1967) reported that exposure of ginger to intense light is detrimental to photosynthesis. In arabica coffee seedlings, Silveria *et al*. (1973) observed maximum drymatter production with 50 per cent light. Individual leaves of green panic grass grown under light intensities of 100, 60 and 40 per cent of full sunlight showed greater photosynthetic activity under shaded conditions than under full sunlight (Wong and Wilson, 1980).

Contrary to the above reports, in tomato plants, Porter (1937) observed that total amount of photosynthates decreased with decrease in light energy. Plants of *Agropyron crystatum*, *A. smithil* and *Boutelona gracilis* had smaller dry weight shown when grown in shade, as reported by Benedict (1941).

Blackman and Wilson (1951a,b) reported that the ability of plants to tolerate shade depends on the efficiency of total drymatter production.

Monteith (1969) demonstrated that the maximum amount of dry matter accumulated by a crop was strongly correlated with the amount of radiation intercepted by its foliage.

Baker and Hardwick (1973) observed high photosynthetic rate per unit chlorophyll in the case of cocoa at high light intensities. The photosynthetic capacity per unit leaf area was greater in leaves of cocoa plants grown under full sun (Guers, 1974). Crockson _et al_. (1975) recorded 38 per cent reduction in photosynthesis of bean leaves due to shading, mainly because of increase in stomatal and mesophyll resistance to diffusion of Co_2.

Photosynthetic activity of the individual leaf is primarily influenced by the input of light energy and the efficiency of individual leaf for the conversion of light energy varies with light intensity as observed by Roberts (1976) for maize, cocksfoot and oak.

Moursi et al. (1976b) found that the efficiency of solar energy conversion in wheat decreased with increasing shade (100 to 20 percent full sunlight) from 1.44 to 0.37. Palis and Bustrillos (1976) observed a decrease in total drymatter in the case of grain sorghum with increase in shade. Patterson (1979) studied the effects of shade on the growth and photosynthetic capacity of the exotic noxious weed, itchgrass and found that at 40 days after planting, plants grown in 2, 25 and 60 per cent sunlight had 0.3, 16 and 55 per cent respectively of the dry weight of the plants grown at 100 per cent sunlight.

Wong and Wilson (1980) reported that the leaves of shade grown Siratro had a lower photosynthetic potential than under the full sunlight treatment. Crops like ginger, turmeric, colocasia, coleus and sweet potato were reported to show a declining trend in the total dry weight of plant with increase in shade (Lalithabai, 1981).

Tsuno _et al_. (1983) reported that the photosynthetic rate of cassava was similar in the morning and afternoon at light intensities more than 30 klx and showed a peak at 28°C at the optimum light intensity of 25-40 klx.

Ramanujam et al. (1984) suggested that the drymatter accumulation in the shoots of sun and shade grown cassava plants were on par with each other, while marked differences were observed for dry matter accumulated in tuber. The reason attributed to this is that most of the photosynthates of shade grown cassava plants were utilized for shoot growth affecting tuber growth significantly. From their work they suggested that the rate of photosynthesis and tuberisation limit the productivity of cassava grown under shade.

Ramanujam and Jose (1984) conducted a study with four cassava varieties under different intensities of shade and observed that the photosynthetic apparatus per unit leaf area was curtailed under low light intensity.

Radha _et al_. (1980) observed no significant difference in the percentage of dry weight of pineapple plants grown under different intensities of shade. Escalente _et al_. (1982) pointed out that in the case of _Phaseolus vulgaris_ artificial shading of 50 and 76 per cent in relation to unshaded control did not cause significant changes in cumulative dry weight of above ground part. Hilton (1983) pointed out that in barley under simulated shade conditions the efficiency of photosynthesis was maintained by the absorption of more light by the accessory pigments and by increasing the amount of chlorophyll 'b'.

2.1.5. Growth analysis

According to Blackman and Wilson (1951a,b) photosynthetic efficiency is maintained in shade if the reduction in NAR (net assimilation rate) which normally occurs is fully compensated by increased leaf area ratio (LAR). In the case of cocoa, Evans and Murray (1953) recorded greatest relative growth rate (RGR) at a light intensity between 30 to 60 per cent of full day light.

Okali and Owusu (1975) observed that RGR was maximal for cocoa plant grown under medium shade. Janardhanan and Murthy (1980) observed that in rice under low light conditions LAI, LAR and relative leaf growth rate (RLGR) were increased whereas RGR, NAR and specific leaf weight (SLW) were reduced. Lalithabai (1981) observed significantly lower LAI values for colocasia in the open.

Ramanujam et al. (1984) compared the mean values of 12 cultivars of cassava on various growth characters under shade with the values obtained from similar experiment in the open and observed that LAI, SLW and crop growth rate (CRG) were 2.19, 5.6 mg cm^{-2} dry $weight^{-1}$ and 5.3 g m^{-2} day^{-1} respectively in the open and 2.40, 3 mg cm^{-2} dry $weight^{-1}$ and 1.8 g m^{-2} day^{-1} respectively in shade. They also suggested 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 Jose (1984) reported that under low light though the leaf blades were slightly broader, the LAR was very high.

Roberts-Nkrumah et al. (1986a) reported that under 73 per cent shade LAR and LWP were significantly higher than those for full sunlight and 25 and 55 per cent shade. Specific leaf area (SLA) was also reported to be higher for plants under 25 and 55 per cent shade than for plants under full sunlight. Cultivar differences were also observed by them in their ability to tolerate 55 and 73 per cent shade.

Several workers reported negative responses on the above characters due to shade.

Hardy (1958) observed lowest NAR at highest shade level. Nosberger and Humphries (1965) reported that in the case of potato shading reduced NAR more at the beginning of the experiment than at later.

Moursi et al. (1976b) found that NAR of wheat decreased with increasing shade intensities from 5.7 to 3.2

and from 11.9 to 0.8 g m^{-2} day^{-1} at 80 to 95 and 95 to 100 days respectively when the light intensity was brought down from 100 to 20 per cent of full sunlight.

Palis and Bustrillos (1976) observed that when a crop of grain sorghum was subjected to 0, 25 or 50 per cent shade, the LAI was found to decrease with increase in shade. RGR and NAR were reduced under conditions of shade and restricted water supply (Kulasegaram and Kathiravet Pillai, 1976).

Wong and Wilson (1980) observed a decreased LAI in shaded siratro. NAR of sweet potato and coleus went on increasing with decrease in shade (Lalithabai, 1981). Escalante et al. (1982) observed that in Phaseolus vulgaris the mean LAR decreased with 76 per cent shading at mid flowering and mean RGR increased between 59 and 99 days and decreased from 89 to 127 days in the shaded plants. They suggested the operation of a mechanism to adjust total drymatter production so that it remains constant.

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 were observed to be reduced significantly by 57 to 62 per cent (Ramanujam and Jose, 1984). Roberts Nkrumah et al. (1986a) reported that in sweet potato NAR and RGR values tended to decline with increasing shade and lower values were recorded in 73 per cent shade.

There were reports of non-significant influence of growth analysis factors due to shade.

Gopinathan (1981) observed that NAR was not influenced by increase in shade intensity ranging from 25. to 75 per cent. Turmeric and ginger showed no general trend in NAR with increasing shade levels (Lalithabai, 1981).

Escalante et al. (1982) studied the effect of artificial shading on several growth parameters of bean (Phaseolus vulgaris L.) by shading at the beginning, middle and end of flowering and could not observe any significant changes in LAI and LAD.

2.1.6. Yield and yield attributes

Edmond et al. (1964) conducted shade experiment in tomato and maximum yield was obtained from plants receiving only 45 per cent of full sunlight. Boneta Garcia and Bosque Lugo (1973) observed that more yield was obtained when coffee was grown in partial shade. Joseph (1979) observed that the tea clones under shade gave much higher yield than in exposed plots.

Miura and Osada (1981) reported that corm dry weight was increased by shading and was positively correlated with maximum leaf area. Turmeric and ginger gave maximum yields at 50 and 25 per cent shade intensities respectively (Lalithabai, 1981).

Togari (1950) reported that in shade the cambial activity and tuberisation were supressed in sweet potato roots. Nosberger and Humphries (1965) reported that in intact plants the loss of weight by shading was mainly from tubers and in plants without tubers it was mainly from stems and leaves.

Matusie Wiez (1967) conducted a pot culture study on sugarbeet and observed that shading for the whole growing period reduced root weight to 28.7 per cent of the control. Sakiyama (1968) observed that the greater the shading the lower was the fruit weight, when the light intensity was lowered to 50 or 25 per cent of full light. Green house studies showed that heavy shade inhibits tuberisation in sweet potato (Martin, 1985).

Shading effect on the growth of sesame plant was studied by Moursi and Gawad (1963) and observed that the number of fruits and dry weight of fruits was highest at 100 per cent light intensity.

It has been reported that yield reduction in the sweet potato when intercropped with corn (Escobar-Carranza, 1975; Lizarraya Herrera, 1976 and Moreno, 1982) and coconuts

(Zara *et al*., 1982) has been attributed to shade imposed by taller crop. Caesar (1980) reported that in *Xanthosoma sagittifolium* and *Colocasia esculenta*, the corm grew only under shade conditions and the growth of cormels was negligible. Cormel yield was only 50 per cent of that of corm under shade, as against twice the yield of cormel as that of corm in full sunlight and good water supply. He observed the enhanced ability of the plants grown under shade to survive stress conditions but only with a low yield of edible material.

Sweet potato recorded a drastic decrease and coleus recorded a linear decrease in yield with increase in shade intensity (Lalithabai, 1981). The effects of shading and mulching on the yield of potatoes was studied by Asandhi and Suryadi (1982) and reported that shading had no beneficial effect on potato growth and reduced dry matter production and tuber yield. Blanc (1983) reported that the rate of tuberisation increased with increase in the duration of exposure to light.

The time taken for tuber initiation under open and shade conditions was observed for 12 cultivars of cassava by Ramanujam et al. (1984). They observed a considerable delay in tuber initiation under shade when compared to the open condition. They opined that the yield reduction of the varieties due to shade effect ranged from 65 to 94 per cent. They observed less number of tubers per plant in cassava grown under coconut garden. It was suggested that most of the photosynthates of shade grown cassava plants were utilised for shoot growth affecting tuber growth.

Igbokwe et al. (1985) studied the intercropping effect of cocoyam with plantain and observed that intercropping reduced the yields of both *Colocasia esculenta* and *Xanthosoma sagittifolium* when compared to pure stands.

Responses of four sweet potato cultivars to different levels of shade was studied by Roberts-Nkrumah et al. (1986b) and pointed out that although overall differences in tuber fresh weight among plants in the shade treatments were not significant, tuber fresh weight in 50 per cent shade was markedly lower and little tuberisation occurred in 75 per cent shade. Significantly lower potential tuberisation index values were recorded in 73 per cent shade, though they observed no significant difference for the above charactors among the treatments, open, 25 and 55 per cent shade. Number of tubers and percentage of tuberisation index also were reported to be significantly lower under 73 per cent shade. They also observed a decrease in the size of the tuber with increase in shade intensity and significantly lower tuber weight ratio for plants grown under 73 per cent shade than in other treatments.

Aclan and Quisumbing (1976) observed no difference for rhizome yield in ginger between plants grown under full sunlight, 25 per cent and 50 per cent shade, but heavier shading of 75 per cent reduced the yield. Radha (1979) observed that the fruit weight of pineapple with crown was not influenced by shading. But the contribution of crowns to the fruit weight increased as the intensity of shade increased. Consequently there was a reduction in fruit weight without crown. It was also observed that shading above 25 per cent was beneficial to the extent of reducing peel and core weight of the fruits. Colocasia did not show any marked decrease in yield with increase in shade upto 50 per cent of full light (Lalithabai, 1981).

2.1.7. Quality of produce

Myhr and Saebo (1969) observed that in some grass species the crude ash and protein contents were approximately doubled by shading to 10 to 15 per cent of the intensity of natural light whereas the sugar contents approximately halved. Serious lodging occurred as a result of reduction in fibre content.

Tamaki and Naka (1972) observed that shading (30 per cent day light) lowered the carbohydrate content and especially sugar contents of plants particularly of the stem and lowered the carbohydrate and especially the starch content of the pods, but seed carbohydrate was little affected. Palis and Bustrillos (1976) observed in grain sorghum plants subjected to 0, 25 or 50 per cent shade that protein increased while carbohydrate decreased with decrease in light.

Aclan and Quisumbing (1976) recorded lowest starch content in rhizomes under 75 per cent shade in ginger. Shading was found to increase the concentration of total soluble and protein nitrogen in the grain tissue when 20 to 100 per cent full light was tried on wheat, (Moursi et al., 1976c).

Hozyo and Kato (1976) observed that the roots of sweet potato when exposed to sunlight resulted in the decrease in the starch content of exposed parts.

Graded shade levels of 20, 47, 63, 80 and 93 per cent on soybean was found to have little effect on oil and protein content of seeds except at 93 per cent shade where the protein content was highest and oil content was lowest (Wahua and Miller, 1978).

Leelavathi (1979) reported that shading in black-gram resulted in increased carbohydrate status of the seeds and a larger pool of soluble nitrogen.

Radha (1979) observed that quality of fruits in general decreased in pineapple under shaded conditions.

Fong *et al*. (1980) in Taiwan conducted experiments on tea crops and concluded that 75 per cent shading for 2 to 3 weeks improved the quality of green teas. An (1982) studied the effect of light intensity on groundnut and observed that shade increased the oil content of older fruits and starch and reducing sugar contents of seeds.

Sansamma George (1982) observed no significant effect on protein content and protein yield due to shade for groundnut, blackgram and cowpea.

Shading which reduced the light intensity by 45 per cent for 24 hours reduced sugar levels in leaves, stems and pod walls by 43, 35 and 42 per cent respectively and reduced leaf starch content by 70 per cent (Setter *et al*. 1984).

2.1.8. Nutrient content

Kraybill (1922) recorded higher contents of moisture and nitrogen in shaded leaves of apple. The potassium content of some grass species when grown under 85 to 90 per cent shade was nearly double than those in full day light (Myhr and Saebo, 1969). Phosphorus, calcium and magnesium contents also increased under shading. In cocoa leaves also the nitrogen and moisture contents were higher when plants were grown under shade (Guers, 1971).

Cantliffe (1972) observed that in spinach the concentration of potassium in the tissues increased with reduction in light intensity. Tamaki and Naka (1972) reported that plant nitrogen especially soluble nitrogen was slightly raised by shading. In the roots soluble nitrogen rose and in nodules the protein fraction was increased by shade. In pods and seeds nitrogen content and composition were little affected by shade treatments.

The uptake pattern of major nutrients in pineapple was not found to be greatly influenced by shading (Radha, 1979). It was also observed that shading increased the magnesium content of leaves at all stages of growth and nitrogen content at later stages of growth.

Plant contents of nitrogen phosphorus and potassium were found to be significantly affected by shade (Oladokun, 1980) and Wong and Wilson (1980) observed marked improvement in nitrogen accumulation by green panic. According to Lalithabai (1981) contents of nitrogen, phosphorus and potassium in all the plant components of coleus, colocasia, sweet potato, turmeric and ginger increased with increasing intensities of shade.

In soybean, total leaf and stem nitrogen contents were largely and negatively correlated with shade. (Wahua and Miller, 1978; Trang and Giddens, 1980). Wong and Wilson (1980) reported that the nitrogen yield of siratro in pure sward declined with shading. Gopinathan (1981) observed higher percentage of nitrogen, phosphorus and potassium in cocoa seedlings grown under direct sun light than in the shaded plants.

2.2. Response of minor tuber crops to major plant nutrients

Experiments carried out from the early 1950's revealed that the response of yams to nitrogen, phosphorus and potassium was dependent on the soil type and also it was found to vary from location to location (Irving, 1950; Obihara, 1962).

2.2.1. Growth attributes

Purewal and Dargan (1959) reported that with the application of 56 kg nitrogen hectare^{-1}, the length of vines in sweet potato significantly increased over no nitrogen. Increased plant height with nitrogen application was reported in potato by Dubey and Bharadwaj (1971) and Krishnappa and Shivashankara (1981) and in colocasia by Hossain and Rashid (1982).

Enyi (1970) showed that nitrogen had positive effect on leaf area development and mean relative growth rate in Dioscorea esculenta. Kamel (1975) reported that phosphorus and potash deficiency in soil decreased leaf area in potatoes. Azih (1976) revealed that the maximum leaf area per plant was found in plants receiving 80 lb nitrogen and 160 lb potassium per acre in yams. Ngongi (1976) reported increase in plant height, leaf area and leaf size due to incremental dose of nitrogen.

Saiev (1978) found that leaf area plant^{-1} increased with increase in the rate of applied NP and NPK in potato. Hafizuddin and Haque (1979) found that length of vine per plant was not affected by nitrogen and potash treatment in sweet potato. Geetha (1983) observed significant influence of nitrogen and very little influence of potassium on plant height of coleus.

2.2.2. Dry matter production

Nambiar et al. (1976) reported no significant effect on the weight of vine in sweet potato due to increased fertilizer application. Krishnappa and Shivasankara (1981) obtained increased fresh weight on haulm in potato with increased nitrogen application. Geetha (1983) opined that N @ 60 kg and K @ 120 kg ha^{-1} was sufficient to produce highest dry matter yield in coleus.

In an experiment for comparing the fertilizer levels viz. 60:60:90; 80:80:120 and 100:100:150 kg NPK ha^{-1}. Sasidharan (1985) reported no significant difference due to fertilizer levels on the length of vine, LAI and total dry matter production.

2.2.3. Yield and yield attributes

Wormer (1934) reported that abundant supply of nitrogen will favour top growth (stem and leaves) and impair the process of tuberisation by diverting more energy to vegetative growth, while relatively low doses of nitrogen can reduce vigorous top growth and hasten the process of tuberisation. Wilson (1964) and Krochmal and Samuel (1967) reported similar results in cassava.

2.2.3.1. Size and number of tubers

Pena (1967) reported that corm density was decreased by nitrogen application and increased by phosphorus in taro.

Application of 120 lb N + 90 lb P_2O_5 + 60 lb K_2O acre^{-1} produced the maximum number of grade A tubers in potato (Miah *et al*., 1974). In a trial with tannia where P at 100 kg ha^{-1} and all combination of 0, 50, 100 or 200 kg N and 0, 25, 50 or 100 kg K ha^{-1} was given Karikari (1974) reported that number of cormels increased with application of upto 100 kg N and 50 kg K ha^{-1}. White *et al*. (1974) reported that increased rates of nitrogen and potash resulted in increased total yields and percentage of 'A' size tubers.

Gupta and Saxena (1975) stated that increasing nitrogen rates from 0 to 240 kg ha^{-1} increased the percentage of large tubers in potato, while application of 0 to 80 kg

P_2O_5 ha^{-1} had no effect on the yield of various grades of tubers. Loue (1979) pointed out that nitrogen and potassium fertilizers increased the size of tubers in potato.

Kpeglo et al. (1981) observed that a combination of NPK @ 45:0:30, 90:25:30 and 90:50:30 kg ha^{-1} produced marketable tubers of 38.43, 34.03 and 34.28 t ha^{-1} respectively in white yam. He also noted that nitrogen and phosphorus application resulted in significantly large tubers.

Hossain and Rashid (1982) studied the response of *Colocasia esculenta* to 160 and 320 kg of N ha^{-1} and observed that number of cormels $hill^{-1}$ was increased by the higher dose of nitrogen ha^{-1}. Potassium fertilization raised the percentage of marketable tubers of *Dioscorea spp* (Obigbesan et al., 1982).

Geetha (1983) found that in coleus highest marketable tubers were obtained by N and K each at the rate of 120 kg ha^{-1}. Fertilizer levels were reported not to influence the length and girth of tuber in lesser yam (Sasidharan, 1985).

2.2.3.2. Yield

According to Irving (1956) and Obihara (1962) on leached acid sandy soils of Eastern Nigeria, the response in yams could be observed only with nitrogen and potash.

From experiments conducted on yams in Eastern Nigeria it was found that the optimal rate of potash was 26.9 kg K_2O ha^{-1} when nitrogen and phosphorus applied @ 36.9 kg ha^{-1} (Anon, 1962). But when nitrogen and phosphorus were increased to 53.8 kg each ha^{-1} the optimum rate rose to 80.7 kg ha^{-1}.

Application of amonium sulphate @ 763.6 kg ha^{-1} 3 months after planting along with the application of phosphorus or potash as basal dressing gave an increase in the yield of white yam (Dioscorea rotundata) from 16 t ha^{-1} to 20.57 t ha^{-1} (Chapman, 1965).

The fertilizer trails conducted at Umudike Research Station in 1966 and 1967 showed that yams responded significantly only to nitrogen and not to phosphorus and potassium. Similar results were also obtained by Umanah (1973) in experiments carried out at Ibadan.

Greig (1967) found that for sweet potato in sandy loam soils of Kansas, the optimum dose of nitrogen, phosphorus and potassium were 28, 125 and 67 kg ha^{-1} respectively. The highest yield of upland taro was obtained when fertilized with 560:560 and 1120 kg NPK ha^{-1}. The rates of nutrients tried in this experiment were 0, 280, 560 and 1120 kg each of N, P and K ha^{-1} (Lena and Plucknet, 1967).

Mandal and Saraswat (1968) reported that a fertilizer dose of 25 t farmyard manure + 80 kg N + 80 kg P_2O_5 + 120 kg K_2O ha^{-1} gave the highest yield while the most economical fertilizer usage was found to be 25 t farmyard manure + 40 kg N + 40 kg P_2O_5 + 80 kg K_2O ha^{-1} for sweet yam (Amorphophallus companulatus).

Mandal et al. (1969) found that the tuber yield in Dioscorea esculenta increased progressively with the increase in N application upto 80 kg ha^{-1} and K at 120 kg ha^{-1} but declined with further increase in N and K. Yong (1970) reported that N, K and NPK increased yield of tuber in potato while P had no effect.

In small scale field experiments with yams on more than 100 farms, Geoding (1971) observed that the application of 20 lb N + 22 lb P_2O_5 + 51 lb K_2O $acre^{-1}$ increased yield by about 9 per cent. Ferguson and Haynes (1971) reviewed the fertilizer trials on yams and noted relatively low but positive yield response with nitrogen and organic manures and in some cases responses to low rates of potassium and apparent yield effect for phosphorus. Mandal et al. (1972) observed that for colocasia, the tuber yield increased significantly with increasing levels of N and K upto 120 kg ha^{-1} each but economic dose was found to be 80 kg N and 120 kg K_2O ha^{-1}. He also reported that for cocoyams the dose of NPK @ 100:50:100 kg ha^{-1} gave significantly higher yield.

Singh et al. (1973) studied the response of *Dioscorea esculenta* to different levels of nitrogen and potash and observed that the tuber yield increased progressively with increase in application up to 80 kg N ha^{-1} and 120 kg K_2O ha^{-1}, but declined with further application of nitrogen and potassium.

USDA (1974) pointed out that potassium is particularly needed during tuberization. In an experiment with potato, Sukla and Singh (1975) reported that high application of potassium was found to improve tuber efficiency thus giving higher tuber bulking rate.

Azih (1976) reported that nitrogen depressed the yield in yams when it was combined with potassium at the highest levels. A gradual increase in weight of tuber was also noted along with increase in nitrogen and potassium application. Maximum weight of tubers was obtained in plants receiving 89.6 kg N ha^{-1} and 89.6 kg K_2O ha^{-1}. He also observed that application of 67.2 kg N + 134.4 kg K_2O ha^{-1} to yellow yam (*Dioscorea cayonensis*) gave the highest average tuber yield of 21 t ha^{-1} compared to 16.5 t ha^{-1} without any fertilizer.

Nair and Mohankumar (1976) observed that NPK at 120:80:80 kg ha^{-1} were optimum for securing high tuber yield and good quality tubers for *D. alata*. Shyu ad Chen (1978) found that tuber yield in *D. alata* increased with increasing rates of both P and K ie. with 50 kg P_2O_5 + 100 kg K_2O ha^{-1}.

Steeghs (1979) was of opinion that under Trivandrum condition, potassium is the most critical nutrient so far as yield of sweet potato is concerned. According to him 75 kg K_2O ha^{-1} was optimum for sweet potato.

Phosphorus requirement of yams was studied by Zaag *et al*. (1980) and reported that the external P requirements of yams ranged from 0.005 to 0.02 ppm P in soil. *D. alata* had the highest P requirement but also gave the highest tuber yields. *D. esculenta* and *D. rotundata* which produced lower yields did not respond to applied P.

In the case of *Dioscorea rotundata*, Kpeglo *et al*. (1981) reported that 90:50:30 kg NPK ha^{-1} gave the highest yields and optimum was found to be 90:25:30 kg NPK ha^{-1}. Aduoyi and Okpon (1980) reported that for *Dioscorea rotundata* tuber yield was highest at 200 kg N ha^{-1}.

Ramaswamy *et al*. (1982) observed that for *Colocasia esculenta* NPK level at 40:60:120 kg ha^{-1} resulted in highest tuber yield of high quality tubers.

Dioscorea spp showed economic responses to N and K and best results were obtained when the application corresponded with the period of maximum plant metabolism and no response was observed for phosphorus application (Lyonga, 1982).

Mandal *et al*. (1982) showed that the optimum nitrogen and potash rates for *Colocasia antiquorum* were 100 and

144 kg ha^{-1} respectively. Geetha (1983) reported that nitrogen @ 60 kg ha^{-1} and K @ 120 kg ha^{-1} were sufficient to produce high tuber yield ha^{-1} for coleus.

Lyonga (1984) observed that nitrogen based and potassium based fertilizers significantly increased yam yields and reported that nitrogen at 160 units ha^{-1} and K at 120-240 units ha^{-1} caused significantly improved yields of Dioscorea spp.

In the experiment conducted by Sasidharan (1985) the lowest level of 60:60:90 kg NPK ha^{-1} produced a tuber yield of 19.2 t ha^{-1} of tuber while higher level of 80:80:120 and 100:100:150 kg NPK ha^{-1} recorded 20.57 and 21.49 t ha^{-1} of tuber respectively. He was of opinion that since the difference in yield were not statistically significant, the lower level of 60:60:90 kg NPK ha^{-1} can be considered sufficient to D. esculenta when grown under open condition.

Villanueva (1986) reported that for yams in its early stages of growth, the developing shoot is sustained by food resources of the tuber and therefore few or no additional nutrients are needed during the first week of growth. Thereafter large quantities of nitrogen is needed to stimulate vegetative growth. During tuber formation potassium becomes the limiting element. Yams appear to be very efficient in extracting phosphorus from the soil and seldom need added quantities.

2.2.4. Effect on nutrient uptake

Pena (1967) reported that application nitrogen increased the nitrogen content of taro leaves, but decreased their phosphorus and potassium contents. At the same time, application of phosphorus increased the phosphorus content but decreased the potassium content and application of potassium increased potassium content but decreased Ca and Mg contents, increased nitrogen content in leaves of upland rainfed taro and decreased it in leaves of submerged taro. He also observed an increase of protein corm by 93.5 per cent due to increased nitrogen fertilizer.

Sobulo (1972) estimated that a yam crop of 26 t ha^{-1} removed 133, 10 and 84 kg ha^{-1} of N, P and K respectively. Varis (1973) reported that nitrogen fertilization to potato increased the uptake of nitrogen, phosphorus, potassium, calcium and magnesium, potassium application had no effect on phosphorus or potassium uptake, but the uptake of phosphorus was reduced by a heavy NPK application.

The mean nutrients removed per tonne of dry matter produced by Dioscorea alata were 14.2 kg nitrogen and 17.9 kg K and by D. Cayanensis were 9.0 kg N and 11.9 kg K where as D. rotundata removed 11.5 to 12.8 kg N and 12.7 to 14.7 kg K (Obigbesan and Agboola, 1978).

Obigbesan *et al*. (1982) observed that nitrogen and phosphorus constitute the major nutrients removed in large amounts by yams (*Dioscorea spp*). The average nutrient removed via the tuber ranged between 128 and 155 kg N, 16.9 kg P_2O_5 and 155 to 184 kg K_2O ha^{-1} uptake of nitrogen upto 163 kg ha^{-1} by yam crop also had been reported (CTCRI, 1983).

2.2.5. Effect on quality of produce

2.2.5.1. Starch content

Mandal *et al*. (1969) reported that the starch content in *D. esculenta* showed slight increase upto 40 kg N ha^{-1}. In the case of potassium, starch content responded upto 120 kg K_2O ha^{-1} while sugar content increased upto 80 kg K_2O ha^{-1}.

Mazur and Dworakwoski (1979) found that increasing rates of NPK tended to decrease the starch content of potato tuber.

Nair and Mohankumar (1976) observed that starch content of tuber did not show any significant variation in *D. esculenta*.

2.2.5.2. Protein content

Mandal *et al*. (1969) reported that crude protein content showed an increase upto 80 kg N and 40 kg K_2O ha^{-1}

in *D. esculenta*. The protein content of tuber was found to be enhanced by nitrogen application in *D. esculenta* (Nair and Mohankumar, 1976).

Shyu and Chen (1978) observed an increase in root protein content with phosphorus application in *D. alata* while a decrease in protein content was observed with potassium application.

Geetha (1983) observed that the application of nitrogen and phosphorus at 90 kg ha^{-1} each enhanced the protein content and starch content in coleus.

Carveho *et al*. (1983) observed no significant effect of fertilizer treatments on crude protein and crude fibre contents of sweet potato.

Materials and Methods

3. MATERIALS AND METHODS

Field experiments were carried out to study the fertilizer management practices and shade responses of minor tuber crops viz. greater yam (*Dioscorea alata*), lesser yam (*Dioscorea esculenta*), tannia (*Xanthosoma sagittifolium*) and elephant footyam (*Amorphophallus companulatus*). There were two field experiments.

I Screening of minor tuber crops under varying intensities of shade, and

II Fertilizer management practices of minor tuber crops in coconut based cropping systems

3.1. Experimental site

The first experiment was conducted at the Instructional Farm, Vellayani and second experiment was conducted at the farm of Coconut Research Station, Balaramapuram. Both locations are in Trivandrum District. The Instructional Farm, Vellayani is located at 8°N latitude and at an altitude of 29 m above mean sea level. The Coconut Research Station, Balaramapuram is situated at 8°N latitude and 76° 57' E longitude, at an altitude of 64 m above mean sea level.

3.2. Soil

The soil of these experimental locations is red loam belonging to the Vellayani series and texturaly classed as sandy clay loam. The physical and chemical characteristics of the soil are given in Table 1.

Table 1. Soil characteristics of experimental fields

		Experiment I	Experiment II
A. Mechanical composition			
Coarse sand	(percentage)	13.60	34.55
Fine sand	(percentage)	33.15	33.16
Silt	(percentage)	27.86	4.06
Clay	(percentage)	25.39	28.04
B. Chemical properties			
Available nitrogen	(kg ha^{-1})	174.00	180.00
Available P_2O_5	(kg ha^{-1})	39.45	32.20
Available K_2O	(kg ha^{-1})	123.12	51.23
pH		5.30	5.60

3.3. Nature and Cropping History

The experimental sites were lying fallow during the previous year. Prior to that, the land used for Experiment I was under coleus. The coconut palms in the garden selected for the experiment II were spaced at 7.5 m and were of 20-25 years of age. Intercropping was not practised in this coconut garden since last five years prior to the commencement of the experiment.

3.4. Season

The first experiment was conducted from May to January in the year 1985-86 and the second experiment was conducted from May to January in the years 1985-86 and 1986-87. The four tuber crops were planted during the last week of April in both the experiments.

3.5. Weather conditions

The area enjoys a typical tropical climate. The total annual rainfall was 1587.3 mm during the first year and 1533.2 mm during the second year. The meteorological data for these periods are presented in Appendix I and Fig.I.

3.6. Materials

3.6.1. Planting materials

Locally popular cultivars of the crops were used for the experiment. For greater yam seed tuber pieces weighing 300-350 g were used for planting. Medium sized whole tubers weighing 100-150 g were used for planting lesser yam. In the case of tannia, side tubers each weighing 40-45 g were planted and for elephant footyam, cut pieces of one kg each were used for planting.

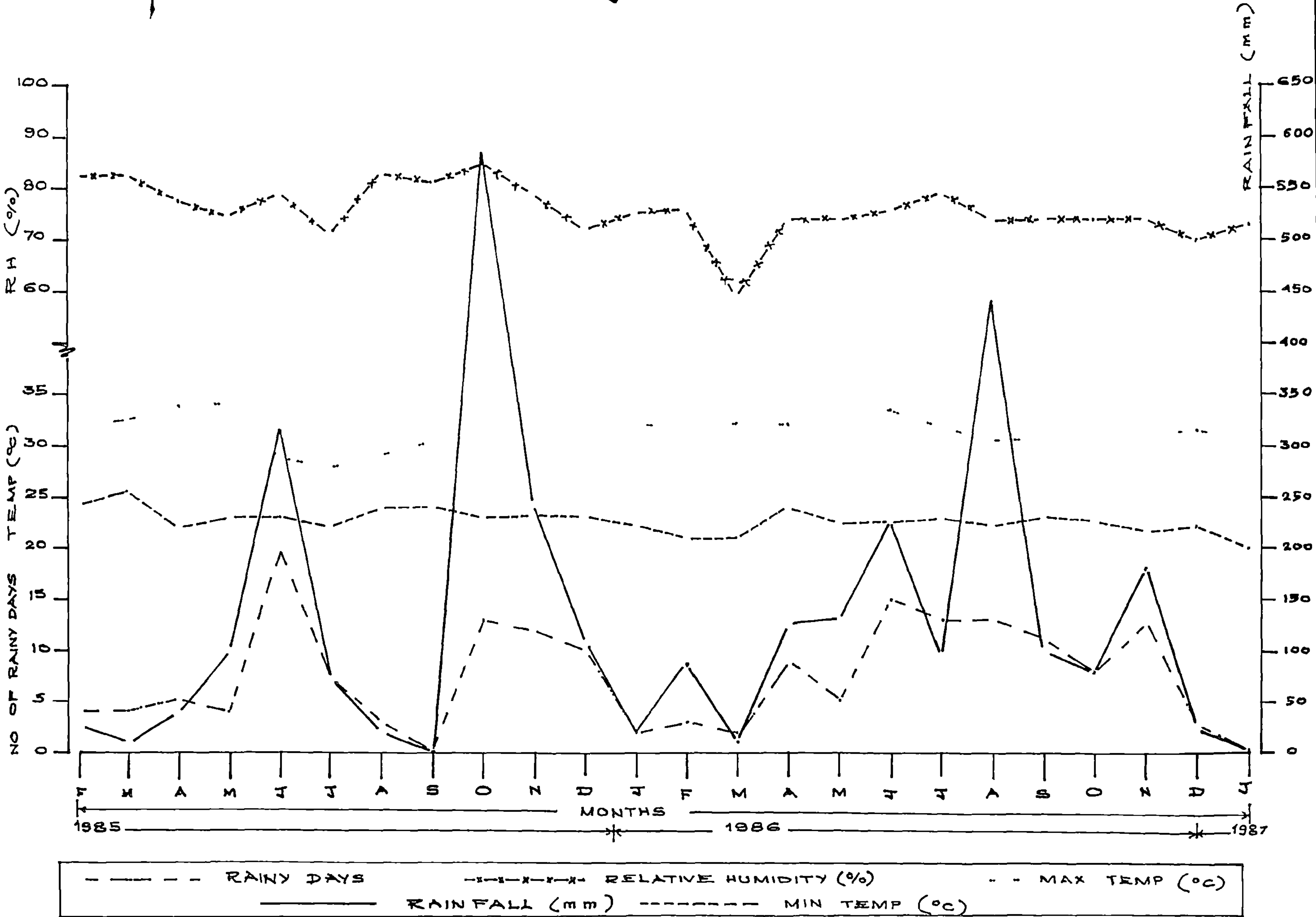


FIG 1 WEATHER CONDITIONS DURING THE CROP PERIOD

3.6.2. Fertilizers

In Experiment I, each of the crops received the respective cultural and manurial practices as per the package of practices recommendations of the Kerala Agricultural University (KAU, 1981). In Experiment II, the crops were manured as per the treatments. Fertilizers with the following grades were used for the experiments.

Urea	-	46 per cent nitrogen
Super phosphate	-	16 per cent P_2O_5
Muriate of potash	-	60 per cent K_2O

3.6.3. Shading

Artificial shading to the desired level as per the treatments was obtained by placing coir mats on erected pandals. Anjengo mesh matting of mesh size 1/3", 3/4" and 1" were used for getting the light intensities of 75 per cent, 50 per cent and 25 per cent respectively.

Pandals of size 25 [illegible] m were erected separately for each shade level. Sufficient space (3 m) was provided between treatments so that mutual shading was minimised to the extent possible. Each pandal was covered on all the sides with unplated coconut leaves except for 60 cm from the ground level. Raised beds were taken between different crops to avoid the border effect considerably. An Aplab luxmeter was used for adjusting the shade intensities.

3.7. Methods

3.7.1. Layout of the experiment

The experiment I was laid out in split plot design with 4 replications. The main plot treatments were different intensities of shade and the sub plot treatments were the crops. The net plot size was 4.5 x 4.5 m. The layout plan is given in Fig.2. Shade was allotted to mainplots from the management point of view of the experiment. A common border row was left out for arriving at the net plot size

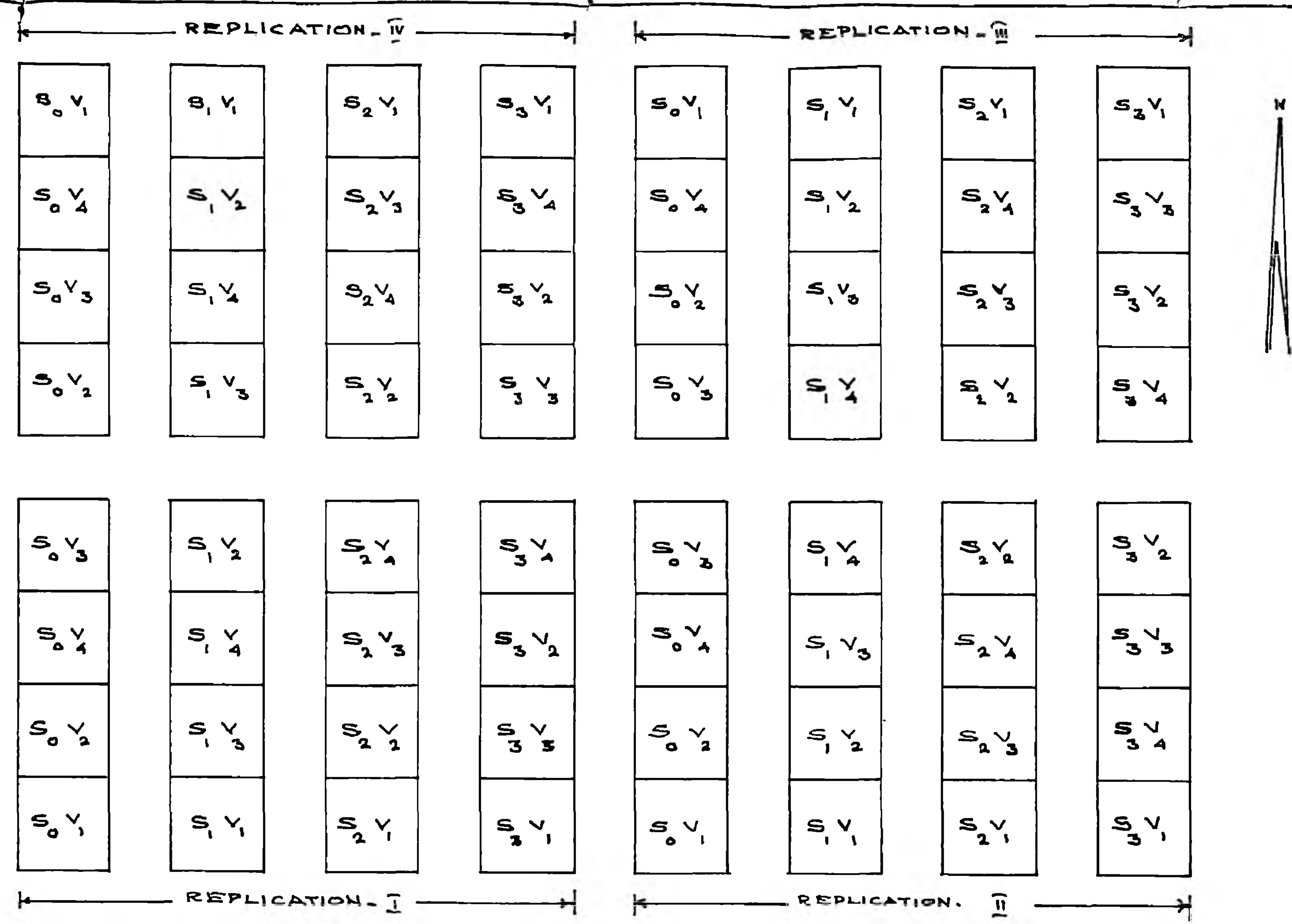
Treatments

Main plot treatments	Sub-plot treatments
S_0 - 0 per cent shade (open)	V_1 - Greater yam
S_1 - 25 per cent shade (low)	V_2 - Lesser yam
S_2 - 50 per cent shade (medium)	V_3 - Tannia
S_3 - 75 per cent shade (high)	V_4 - Elephant footyam

Treatment combinations - 16

T_1 - S_0V_1	T_5 - S_0V_2	T_9 - S_0V_3	T_{13} - S_0V_4
T_2 - S_1V_1	T_6 - S_1V_2	T_{10} - S_1V_3	T_{14} - S_1V_4
T_3 - S_2V_1	T_7 - S_2V_2	T_{11} - S_2V_3	T_{15} - S_2V_4
T_4 - S_3V_1	T_8 - S_3V_2	T_{12} - S_2V_3	T_{16} - S_3V_4

The experiment II was laid out in randomised block design with three replications in the interspaces of coconut palms leaving two meters radius from the base of the palms. The net plot size was 4.5 x 4.5 m.



TREATMENTS

LEVELS OF SHADE

S_0 - 0 PERCENT SHADE

S_1 - 25 PERCENT SHADE

S_2 - 50 PERCENT SHADE

S_3 - 75 PERCENT SHADE

VARIETIES

V_1 - GREATER YAM

V_2 - LESSER YAM

V_3 - TANNIA

V_4 - ELEPHANT FOOT YAM

FIG 2 LAYOUT PLAN OF EXPERIMENT - I

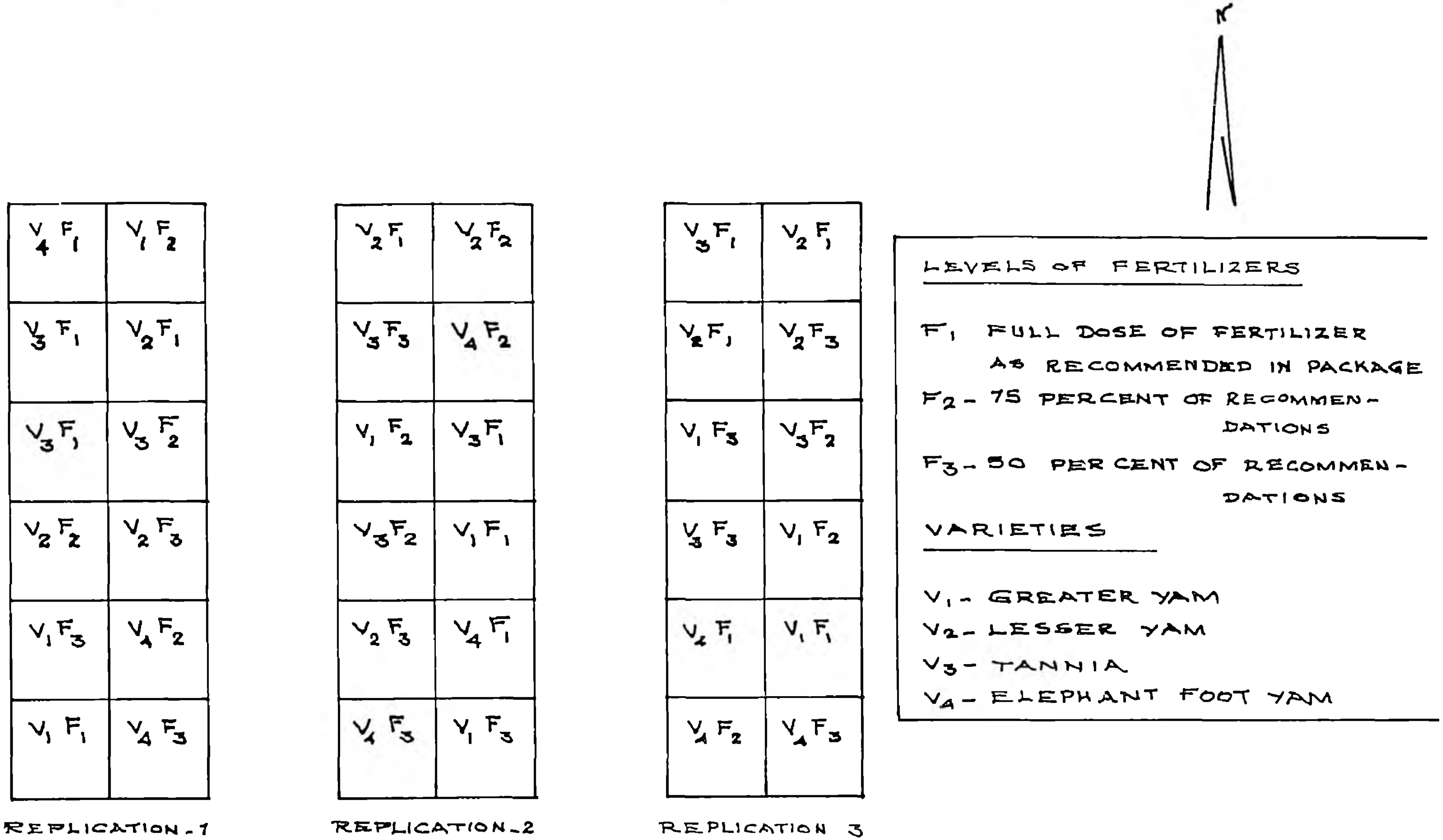


FIG 3 LAY OUT PLAN OF EXPERIMENT - II

Treatment details

Treatments included 4 crops viz. greater yam, lesser yam, tannia and elephant footyam and three levels of fertilizers viz. (1) full dose of package of practices recommendation (2) 75 per cent of package recommendation and (3) 50 per cent of package recommendation.

Crop	Fertilizer dose
V_1 - Greater yam	F_1 - Fullfertiliser dose of package of practices recommendations of KAU (high)
V_2 - Lesser yam	F_2 - 75 per cent " " (medium)
V_3 - Tannia	F_3 - 50 per cent " " (low)
V_4 Elephant footyam	

Treatment combinations - 12

T_1 - V_1F_1	T_5 - V_2F_2	T_9 - V_3F_3
T_2 - V_1F_2	T_6 - V_2F_3	T_{10} - V_4F_1
T_3 - V_1F_3	T_7 - V_3F_1	T_{11} - V_4F_2
T_4 - V_2F_1	T_8 - V_3F_2	T_{12} - V_4F_3

3.7.2. Land preparation and planting

Greater yam

Pits of size 45 x 45 x 45 cm were made on previously dug soils at a distance of 90 x 90 cm. Farm yard manure was applied to each pit at the rate of 1½ kg after mixing with top soil. The cut pieces of seed tuber dried under shade after dipping in cowdung slurry were placed in the pits and the pits were covered with little soil and dried leafy material. Population - 25 plants /20 25 sq m

Lesser yam

After digging the land to a depth of 15-20 cm, mounds were prepared at a spacing of 75 x 75 cm incorporating farm yard manure at the rate of 1 kg per mound. Medium sized whole seed tubers were planted at the top of the mound at the rate of one in each mound and completely covered with soil. Population 36 plants / sq m

Tannia

Planting was done using side corms as seed material in pits of size 45 x 45 x 45 cm made at a spacing of 90 cm on either side. Farm yard manure at the rate of 1 kg per pit was applied and incorporated well with top soil before planting. Population - 25 plants / sq m

Elephant footyam

Pits of size 60 x 60 x 45 cm were dug at a spacing of 90 cm on either side. Farm yard manure at the rate of 2 kg per pit was applied and mixed well with top soil. The cut tuber pieces of 1 kg each dipped in cowdung slurry and dried under shade were used for planting. Population - 25 plants/sq m

3.7.3. Methods of manuring

Greater yam

A fertilizer dose of 80:60:80 kg of NPK ha^{-1} was given for the crop. Half of the nitrogen and potash and full dose of phosphorus were applied within a week after sprouting. The remaining quantities of nitrogen and potash were given one month after the first application along with weeding and earthing up.

Lesser yam

Methods of manuring was the same as that of greater yam.

Tannia

The fertilizer dose of 80:50:100 kg NPK ha^{-1} was given for the crop. Full dose of phosphorus and half dose of nitrogen and potash were applied within a week after sprouting and the remaining half dose of nitrogen and potash were given one month after the first application along with weeding and earthing up.

Elephant footyam

The recommended fertilizer dose of 80:60:100 kg NPK ha^{-1} was applied to this crop. Forty five days after planting, full dose of phosphorus and half the dose each of nitrogen and potash were applied along with intercultivation and weeding. The remaining nitrogen and potash were given one month after the first application along with intercultivation and earthing up.

3.7.4. Trailing

Trailing was done for greater yam and lesser yam within 15 days after sprouting using coir rope and G.I. wire. Observation plants were trailed individually.

3.7.5. Plant protection

Since there was no incidence of pest and diseases, plant protection measures were not taken up.

3.8. Biometric observation

3.8.1. Length of the vine/height of the plant

Individually trailed sample plants were uprooted and length of the vine was measured from the base of the sprout to the tip of the main vine at bi-monthly intervals in the case of greater yam and lesser yam. The height of tannia was measured from the base of the plant to tip of longest leaf and elephant footyam was measured from the base to the tip of the plant.

3.8.2. Number of leaves plant

This was counted for greater am, lesser yam and tannia in experiment II.

3.8.3. Leaf area index (LAI)

Leaf area index (LAI) was worked out following the gravimetric method (Ruck and Bolas, 1956). From the destructive sample plants leaves were separated and selected at random and their area was measured using leaf area meter. The entire leaves were dried separately in a hot air oven at 70 to 80°C to constant weight. The total leaf area per plant was calculated using the weight to area relationship and total dry weight of leaves. Then LAI for each of the crop was calculated at different stages using the following equation.

$$LAI = \frac{\text{Total leaf area of a plant}}{\text{Land area occupied by the plant}}$$

3.8.4. Dry matter production

Leaves, stem + petioles and tubers of uprooted plants were separated and dried to constant weights at 70 to 80°C in a hot air oven. The sum of the dry weights of all the plant parts gave the total dry matter yield expressed as kg ha^{-1}.

3.8.5. Net assimilation rate (NAR)

The procedure given by Watson (1958) as modified by Buttery (1970) was followed for calculating the NAR. The following formula was used to arrive at the NAR expressed as g m^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{(t_2 - t_1)\ \frac{(A_1 + A_2)}{2}}$$

W_2 = Total dry weight of plant g m^{-2} at time t_2

W_1 = Total dry weight of plant g m^{-2} at time t_1

$(t_2 - t_1)$ = Time interval in days

A_2 = Leaf area index at time t_2

A_1 = Leaf area index at time t_1

3.8.6. Crop growth rate

It was worked out using formula of Watson (1958)

CGR = NAR x LAI expressed as g m^{-2} day^{-1}

3.9. Yield and yield attributes

3.9.1. Length and girth of tuber

This was taken only for greater yam and lesser yam from the sample plant harvested.

3.9.2. Number of tubers per plant

The number of tubers from the observational plants was counted and their average number was worked out in lesser yam and tannia.

3.9.3. Yield of tuber per hectare

The yield of tuber obtained from each crop was recorded from the net area and expressed in t ha^{-1} of fresh weight.

3.9.4. Top weight

The yield of top (vegetative parts) in individual crops was recorded from the net area and expressed as t ha^{-1}.

3.9.5. Bulking rate

The rate of bulking in tuber was worked out on the basis of increase in dry weight of tuber (g) per plant per day and expressed as g day^{-1} $plant^{-1}$.

$$B.R. = \frac{W_2 - W_1}{t_2 - t_2}$$

W_2 = dry weight of tuber at time t_2

W_1 = dry weight of tuber at time t_1

3.9.6. Utilisation index or tuber efficiency

It is the ratio of the tuber weight to the top weight (Obigbesan, 1973). This as worked out from the fresh weights of tuber and top part.

3.10. Chemical analysis

3.10.1. Chlorophyll content of leaves

Chlorophyll 'a', 'b' and total chlorophyll content of each crop of the experiment I were estimated at 70, 130 and 190 DAS by spectrophotometric method as described by Starnes and Hadley (1965).

One gram of the representative sample collected from the sample plants was taken in a mortar and ground well by adding 1 ml of water in small quantities. From this, 5 ml was taken and mixed with 45 ml of acetone. The acetone dissolves the pigment. The super natant solution was collected after centrifuging and the optical density (A) of an aliquot was measured using a spectrophotometer (Spectronic-20) at wave length of 645 nm and 663 nm. The contents of chlorophyll 'a', 'b' and total chlorophyll (mg g^{-1} fresh weight) were then estimated using the following relationships.

Total chlorophyll (Chlorophyll a+b) - $8.05\ A_{663} + 20.29\ A_{645}$

Chlorophyll 'a' - $12.72\ A_{663} - 2.58\ A_{645}$

Chlorophyll 'b' - $22.87\ A_{645} - 4.67\ A_{663}$

3.10.2. NPK contents of plant parts

The samples of plant parts collected for recording the dry weight were used for chemical analysis. The nitrogen content of leaf, stem + petiole and tubers at different growth stages was determined by modified microkjeldahl method, phosphorus content by the vanadomolybdo - phosphoric yellow colour method and potassium by flame photometry (Jackson, 1967).

3.10.3. Uptake of NPK nutrients

The total uptake of nitrogen, phosphorus and potassium by the plant and individual plant parts was calculated at different growth stages from the dry weights and the NPK contents of the different plant parts and expressed as kg ha^{-1}.

3.10.4. Starch content of tubers

The starch content of tuber was estimated by using potassium ferricyanide methods (Ward and Pigman, 1970) and expressed as percentage of the dry weight.

3.10.5. Protein content of the tuber

The protein content of the tuber was calculated from the per cent of nitrogen in tuber by multiplying with the factor 6.25 (Simpson et al., 1965).

3.11. Soil analysis

The soil was analysed for available nitrogen, available phosphorus and available potassium contents before and after the experiment. Before the experiment, composite soil samples from different replication and after the experiment, treatmentwise soil samples were collected for analysis.

3.12. Statistical analysis

The data pertaining to various characteristics were subjected to statistical analysis using appropriate statistical tools following Cochran and Cox, 1967. Biometric observations viz. length of the vine/height of the plant, number of leaves, length and girth of tuber, number and weight of tubers per plant etc. were analysed separately for each crop as RBD as these observations cannot be combined because of the peculiarity of each crop and for other characters viz. LAI, chlorophyll content of leaves, matter production, NAR, CGR, tuber yield, top yield, bulking rate, utilisation index, uptake of nutrients, starch and protein content of tuber and nutrient status of the soil after the crop, combined analysis was carried out to reveal crop variation in respect of above characters.

Correlations were also worked out between yield and uptake of nutrients. The economics of intercropping different tuber crops at varying levels of fertilizers was also worked out.

Results

4. RESULTS

4.1. Experiment I

Results of the experiment 'Screening of minor tuber crops under varying intensities of shade' are presented below.

4.1.1. Growth character

4.1.1.1. Length of vine/height of plant

The data on length of vine/height of plant of greater yam, lesser yam, tannia and elephant footyam are presented in Table 2.

Greater yam

Length of the vine was found to be significantly influenced by different intensities of shade at all stages of growth (Table 2) of greater yam. Vine length increased with increase in shade intensity upto 50 per cent (medium shade) at 190 DAS. After that a drastic decline in vine length was observed at 75 per cent shade (intense shade) which was statistically on par with that of '0' per cent shade (open) at the initial stages.

The vine length was found to increase with advancing age.

Lesser yam

Shade had significant influence on the length of vine of lesser yam only at 190 DAS (Table 2b). In general

Table 2 (a) Effect of shade on length of vine/height of plant in cm at 70 DAS

Shade levels		Greater yam	Lesser yam	Tannia	Elephant foot yam
S_0	'0' percent shade	705.50	276.00	62.25	41.12
S_1	25 "	1020.00	316.00	92.12	43.50
S_2	50 "	1107.25	339.50	83.00	48.50
S_3	75 "	767.00	324.00	82.75	75.75
F test		S	NS	S	S
CD (0.05)		273.57	-	19.22	6.37
SE		85.52	27.95	6.01	1.99

S - Significant NS - Not Significant

Table 2 (b) Effect of shade on length of vine/height of plant in cm at 130 DAS

Treatments	Greater yam	Lesser yam	Tannia	Elephant foot yam
S_0	917.00	288.25	63.00	48.75
S_1	1157.00	325.75	102.75	52.38
S_2	551.00	334.50	94.00	65.75
S_3	813.00	340.50	100.75	75.75
F test	S	NS	S	S
CD (0.05)	279.57	-	14.47	19.93
SE	87.38	19.74	4.52	6.23

S - Significant NS - Not Significant

Table 2 (c) Effect of shade on length of vine/height of plant in cm at 190 DAS

Treatments	Greater yam	Lesser yam	Tannia	Elephant foot yam
S_0	979.00	293.50	87.75	53.00
S_1	1162.00	312.00	119.25	53.40
S_2	1166.00	417.00	119.25	68.50
S_3	825.00	437.50	114.50	80.25
F test	S	S	S	NS
CD (0.05)	74.98	109.24	15.57	-
SE	23.44	34.15	4.87	10.32

S - Significant NS - Not Significant

there was an increase in vine length with increasing shade intensities. With advancing age, the length of vine increased at all shade levels.

Tannia

The height of plant at different stages of growth was found to be significantly influenced by shading. The plants grown under shade were significantly taller than plants grown in the open at all stages of growth. There was no perceptible difference in the height of the plants grown under different shade levels. With ageing of the crop the height was also increased.

Elephant footyam

Elephant footyam was taller under shade situations than in the open showing significant difference upto 130 DAS. At 70 DAS, the plants grown under 75 per cent shade was significantly taller than all other treatments. At 130 DAS the plants under 50 per cent and 75 per cent shade were on par. At the later stage of the crop, the treatments lacked statistical significance on this character.

4.1.1.2. Girth at the base of the stem

The data for tannia and elephant footyam are presented in Table 3.

Table 3 (a) Effect of shade on girth at the base of the stem in cm at 70 DAS.

Treatments	Tannia	Elephant foot yam
S_0	20.25	15.88
S_1	29.00	15.75
S_2	25.00	15.75
S_3	24.88	16.25
F test	S	NS
CD (0.05)	5.05	-
SE	1.77	0.52

Table 3 (b) Effect of shade on girth at the base of the stem in cm at 130 DAS

Treatments	Tannia	Elephant foot yam
S_0	21.50	14.63
S_1	31.75	14.38
S_2	27.50	14.75
S_3	28.50	16.25
F test	S	NS
CD (0.05)	3.55	-
SE	1.11	0.80

Table 3 (c) Effect of shade on girth at the base of the stem in cm at 190 DAS

Treatments	Tannia	Elephant foot yam
S_0	33.75	14.75
S_1	40.75	15.40
S_2	34.00	14.75
S_3	32.00	16.25
F test	NS	NS
CD (0.05)	-	-
SE	2.12	0.91

S - Significant NS - Not Significant

Tannia

The girth at collar was significantly influenced by shade in tannia upto 130 DAS. The girth of plant under 25 per cent shade showed significant superiority over open at 70 DAS and 130 DAS but over 50 per cent shade at 130 DAS only. But at later stage, there was statistical parity between these treatments though the highest value was recorded by 25 per cent shade level.

Girth at collar was found to increase with age of the crop and maximum value was reported at 190 DAS. The extent of increase in girth was more conspicuous at lower shade intensities.

Elephant footyam

The effect of shade on the girth at the base of the stem was not significant at any of the growth stages. The highest value was recorded by the intensely shaded (75 per cent shade) plants.

4.1.1.3. Leaf area index (LAI)

The data for greater yam, lesser yam, tannia and elephant footyam are presented in Table 4 and Fig.4.

The main effect of shade significantly influenced the LAI at all stages of growth. LAI was found to be minimum at '0' per cent shade and at 75 per cent shade. Between stages, the LAI showed an increasing trend.

Table 4 (a) Effect of shade on leaf area index at 70 DAS

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Mean
S_0	1.94	0.68	0.12	0.39	0.78
S_1	4.87	0.77	0.28	0.52	1.61
S_2	2.07	0.83	0.24	0.49	0.91
S_3	2.40	0.31	6.20	0.32	0.81
Mean	2.82	0.65	0.21	0.43	
F test	S	S	NS	NS	S

	CD (0.05)	SE
crops	- 0.15	0.05
shade	- 0.21	0.07
combination	- 0.29	0.10

S - Significant NS - Not Significant

Table 4 (b) Effect of shade on LAI at 130 DAS

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Mean
S_0	3.71	0.63	0.55	0.40	1.32
S_1	4.76	1.83	1.85	0.52	2.24
S_2	4.52	2.22	1.32	0.46	2.13
S_3	3.64	1.20	1.04	0.42	1.56
Mean	4.15	1.47	1.19	0.45	
F test	S	S	S	NS	S

	CD (0.05)	SE
crops	- 0.19	0.06
shade	- 0.25	0.09
combination	- 0.24	0.08

S - Significant NS - Not Significant

Table 4 (c) Effect of shade on leaf area index at 190 DAS

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Mean
S_0	6.98	1.18	1.03	1.63	2.69
S_1	6.17	3.31	1.77	2.89	3.54
S_2	9.25	2.57	2.01	0.35	3.55
S_3	5.48	0.76	1.84	0.38	2.12
Mean	6.97	1.96	1.66	1.31	
F test	S	S	NS	S	S

	CD (0.05)	SE
crops	- 0.96	0.35
shade	- 1.14	0.36
combination	- 1.96	0.68

S - Significant NS - Not Significant

LAI differed significantly between crops also showing significantly higher LAI by greater yam than all other crops at all growth stages. Lesser yam recorded the next higher LAI and was significantly superior to tannia and elephant footyam at the initial growth stages but lacked statistical significance at later stage. Elephant footyam recorded the lowest LAI values and greater yam the highest. Effect of shade levels on individual crops was also significant as could be seen from the interaction effects of greater yam and lesser yam.

Greater yam

Greater yam recorded the maximum LAI value of 9.25 for plants under 50 per cent shade at 190 DAS which was significantly superior to all other shade intensities.

Lesser yam

Unlike greater yam, the highest LAI (3.31) in the case of lesser yam was for 25 per cent shade which was significantly superior to all other shade levels excepting 50 per cent shade at 190 DAS

Tannia

LAI of tannia differed significantly only at 130 DAS recording higher values by 25 per cent shade.

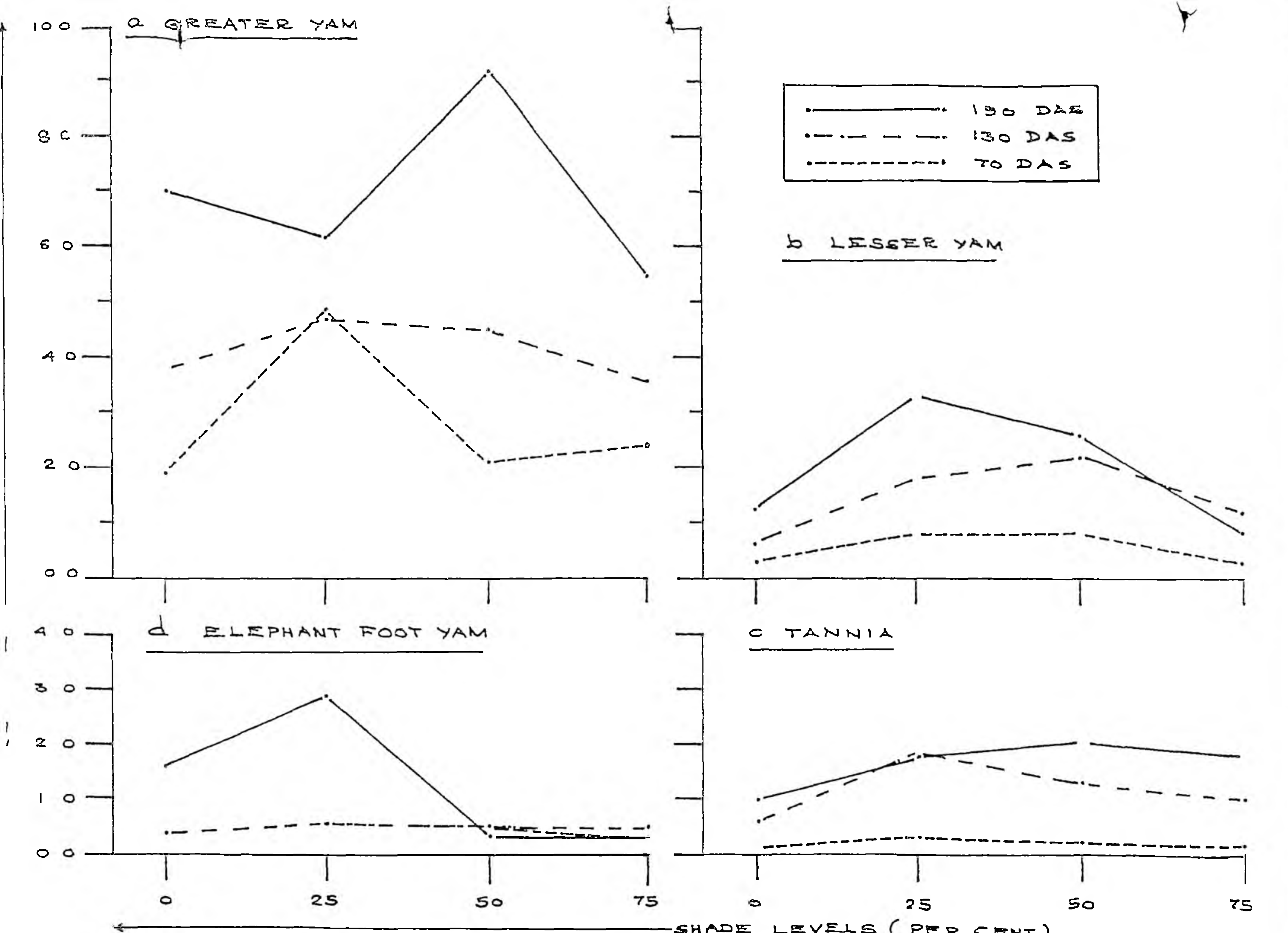


FIG 4 EFFECT OF SHADE ON LEAF AREA INDEX

Elephant footyam

Shade had no effect on the LAI of elephant footyam upto 130 DAS. At 190 DAS, 25 per cent shade recorded significantly higher LAI. LAI went upto maximum at 190 DAS for '0' per cent shade and 25 per cent shade.

4.1.1.4. Net assimilation rate (NAR)

The data on net assimilation rate are presented in Table 5 and Fig.5.

It is seen that shade significantly influenced the net assimilation rate of crops during both the stages. Between 70 and 130 DAS, the highest NAR was reported under 50 per cent shade which was significantly superior to all other treatments. The lowest NAR was recorded by lowest shade level which was on par with that in the open. Between 130 and 190 DAS, NAR was maximum for open treatment which was significantly superior to all other treatments. NAR also showed a decreasing trend with increase in shade and was statistically on par with that of 50 per cent shade and 25 per cent shade.

Between crops also NAR differed significantly, the maximum being recorded by elephant footyam during both the growth phases. The lowest NAR was reported by lesser yam during the initial stage and by greater yam during the later stages. NAR went on increasing with the ageing of the crop excepting for greater yam and tannia.

Table 5 Effect of shade on Net Assimilation Rate (g $m^{-2} day^{-1}$)

Shade levels	Greater yam		Lesser yam		Tannia		Elephant foot yam		Mean	
	Between		Between		Between		Between		Between	
	70 and 130 DAS	130 and 190 DAS	70 and 130 DAS	130 and 190 DAS	70 and 130 DAS	130 and 190 DAS	70 and 130 DAS	130 and 190 DAS	70 and 130 DAS	130 and 190 DAS
S_0	0.53	2.06	0.21	6.21	2.96	3.73	0.88	7.01	1.68	8.02
S_1	2.19	0.40	0.74	1.15	0.88	2.31	4.64	5.93	2.47	5.08
S_2	1.92	0.26	0.89	0.42	5.37	2.18	4.55	6.53	4.72	3.94
S_3	1.09	0.50	0.17	0.55	1.25	0.95	0.90	1.45	1.20	2.12
Mean	1.43	0.80	0.52	2.08	2.62	2.30	2.74	4.98		
F test	NS	NS	NS	S	S	NS	S	S	S	S

	CD (0.05)		SE	
	Between 70 and 130 DAS	Between 130 and 190 DAS	Between 70 and 130 DAS	Between 130 and 190 DAS
crops -	1.18	1.50	0.31	0.52
shade -	0.46	1.70	0.14	0.53
combination -	1.76	3.00	0.61	1.05

S - Significant NS - Not significant

Shade effect on individual crops was also studied and the results are given below.

Greater yam

Shade did not influence the NAR of greater yam at any of the growth stages. The highest and lowest NAR in the early stage was recorded by 25 per cent shade and '0' per cent shade respectively. At later stage, the NAR went upto the maximum in the open ('0' per cent shade). From the data it could also be observed that the NAR showed an increasing trend only in the open while drastic reduction in NAR was experienced with the ageing of the crop for all the other treatments.

Lesser yam

The effect of shade on NAR of lesser yam was significant only between 130 and 190 DAS. The trend was almost the same as that of greater yam. The treatment in the open which recorded a lower value during early stages recorded the maximum value at harvest stage. All other treatments were on par and significantly inferior to that at open. Over the stages, the NAR was found to increase at all shade levels excepting 75 per cent shade.

Tannia

The results indicated that shade had significant influence on NAR only at the initial growth stage. The

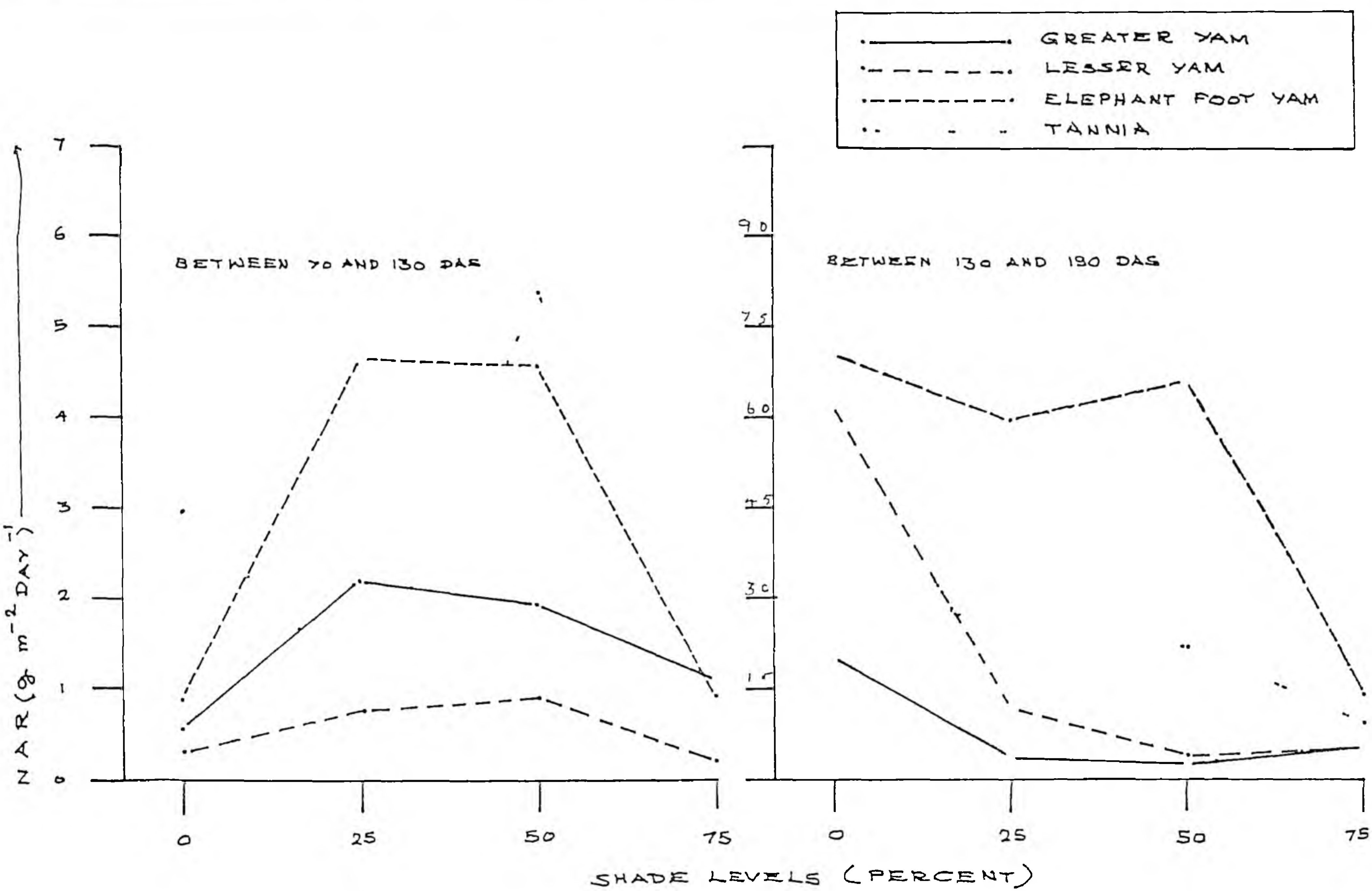


FIG 5 EFFECT OF SHADE ON NET ASSIMILATION RATE ($g\ m^{-2}\ DAY^{-1}$)

highest NAR value was recorded by 50 per cent shade at the initial stages and by open at the later stage.

NAR increased with ageing of the crop for the treatments '0' per cent shade and 25 per cent shade.

Elephant footyam

The NAR of elephant footyam was significantly influenced by the shade during both growth phases. Open and intensely shaded treatments recorded almost similar NAR values which were significantly inferior to 25 and 50 per cent shade treatments which were on par at the first growth phase (between 70 and 130 DAS). But during the later stage (between 130 and 190 DAS) NAR of open was the highest although was on par with all other treatments excepting that of intense shade.

With advancing age all the treatments recorded increasing trend in NAR values. However, the rate of increase was very high in the open while all other treatments recorded only very little improvements.

4.1.1.5. Crop growth rate (CGR)

The data on crop growth rate at different growth stages are given in Table 6 and Fig. 6.

The results revealed that shade significantly influenced the CGR during both the growth phases. While the treatment under open recorded significantly lower values at the first growth phase, it was maximum for this treatment at the second growth phase. During the second stage, CGR decreased with increase in shade intensity recording the lowest value by 75 per cent shade which was statistically on par with that of 50 per cent shade and significantly inferior to '0' per cent and 25 per cent shade.

Crops differed significantly in CGR and maximum CGR was recorded by greater yam during the first growth phase (6.17 g m^{-2} day^{-1}) and tannia during the second growth phase (2.52 g m^{-2} day^{-1}).

The shade effect on the CGR of individual crops are as follows.

Greater yam

Shade significantly influenced the CGR of greater yam at both the growth phases. During the first growth phase 25 per cent shade recorded significantly superior value (10.41 g m^{-2} day^{-1}) followed by 50 per cent shade (8.72 g m^{-2} day^{-1}) and open treatment recorded lowest value of 2.08 g m^{-2} day^{-1}. But during second growth phase, open treatment recorded higher CGR value of 3.72 which was on par with that of 25 per cent shade and significantly superior to 50 per cent and 75 per cent shade.

Table 6 Effect of shade on crop growth rate (g m^{-2} day^{-1})

Shade levels	Greater yam Between		Lesser yam Between		Tannia Between		Elephant foot yam Between		Mean Between	
	70 and 130 DAS	130 and 190 DAS	70 and 130 DAS	130 and 190 DAS	70 and 130 DAS	130 & 190 DSA	70 and 130 DAS	130 and 190 DAS	70 and 130 DAS	130 and 190 DAS
S_0	2.08	3.72	0.05	4.11	0.38	1.90	0.36	2.52	0.71	3.06
S_1	10.41	2.09	1.34	0.88	0.24	4.23	1.13	2.55	3.28	2.44
S_2	8.72	0.48	2.05	0.35	1.46	2.68	2.12	2.27	3.59	1.45
S_3	3.96	1.21	0.20	0.18	0.23	1.28	0.38	0.45	1.49	0.78
Mean	6.17	1.87	0.91	1.38	0.58	2.52	1.00	1.95		
F test	S	S	S	S	NS	S	S	S	S	S

	CD (0.05) Between 70 and 130 DAS	CD (0.05) Between 130 and 190 DAS	SE Between 70 and 130 DAS	SE Between 130 and 190 DAS
crops	0.62	0.94	0.22	0.33
shade	0.55	0.68	0.17	0.21
combination	1.25	1.89	0.44	0.66

S - Significant NS - Not Significant

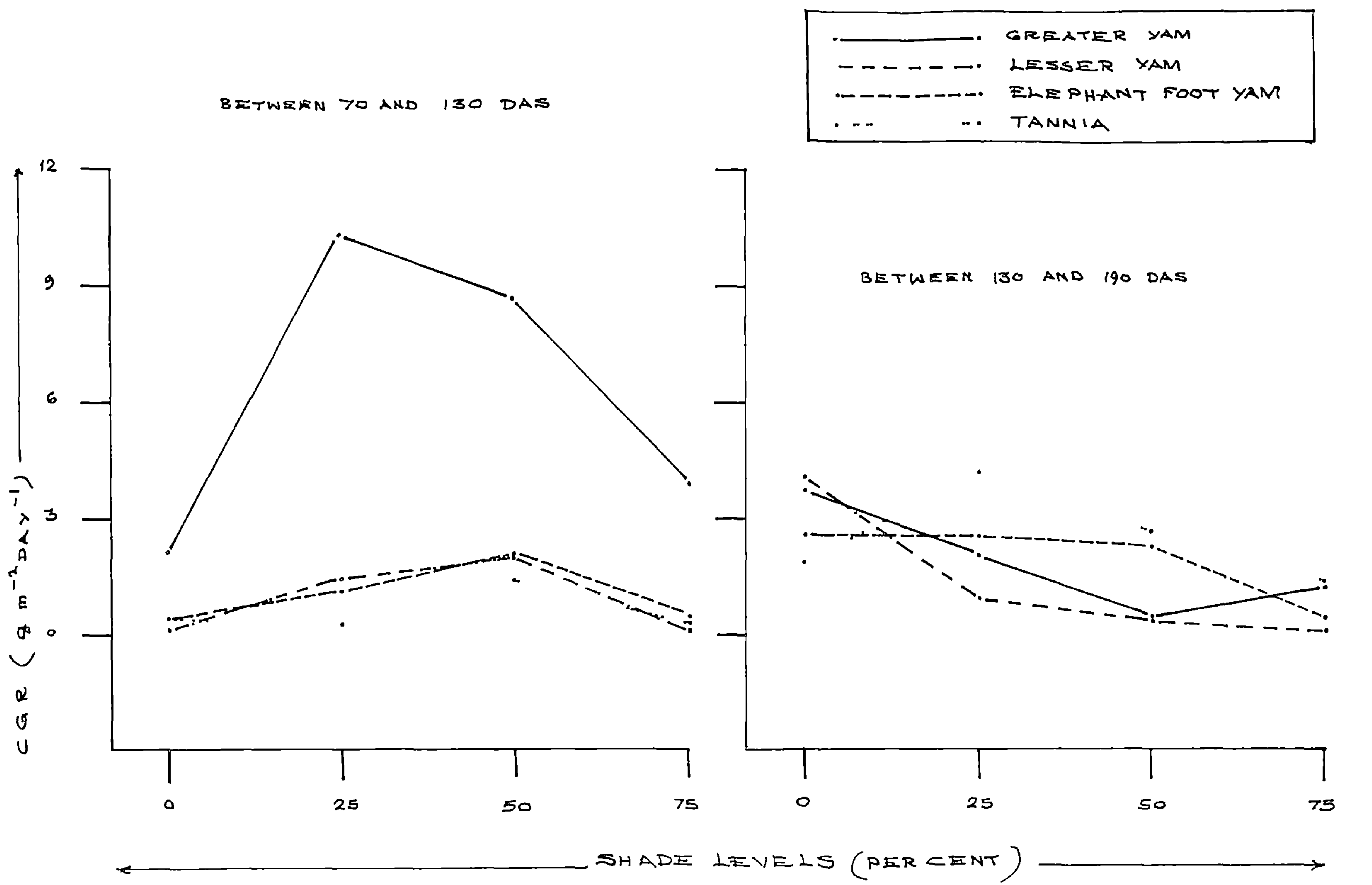


FIG 6 EFFECT OF SHADE ON CROP GROWTH RATE ($g\ m^{-2} DAY^{-1}$)

Lesser yam

There was significant difference in the CGR of lesser yam due to shade. Open treatment which recorded the lowest value in the first growth phase recorded the highest CGR in the second growth phase (4.11 g m^{-2} day^{-1}) which was significantly superior to all the other treatment.

Tannia

CGR of tannia differed significantly during the second growth phase and 25 per cent shade recorded significant superiority over the other treatments excepting 50 per cent shade. During the first growth phase 50 per cent shade recorded higher value but was on par with all the other treatments.

Elephant footyam

Shade influenced the CGR of elephant footyam significantly at both the growth phases recording highest value by 50 per cent shade and 25 per cent shade in the first and second growth phases respectively. 25 per cent shade was on par with 0 per cent shade and 50 per cent shade and significantly superior to 75 per cent shade at second growth phase.

4.1.1.6. Total dry weight

The data on total dry weight at different growth stages of the four tuber crops are presented in Table 7 and Fig.7.

Table 7 (a) Effect of shade on total dry weight in kg ha^{-1} at 70 DAS

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Means
S_0	4382.75	1044.75	767.00	1309.00	1875.88
S_1	4608.25	1536.50	2202.50	913.50	2315.18
S_2	2993.75	1035.50	1346.00	1172.75	1637.00
S_3	1483.00	1315.50	802.50	751.25	1088.06
Mean	3367.00	1233.00	1280.00	1036.62	
F test	S	NS	S	NS	S

		CD (0.05)	SE
crops	-	323.62	112.84
shade	-	265.69	83.05
combination	-	647.25	225.75

S - Significant NS - Not Significant.

Table 7 (b) Effect of shade on total dry weight in kg ha^{-1} at 130 DAS

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Treatment mens
S_0	5549.75	1069.00	1445.75	1708.50	2412.00
S_1	10420.00	2569.00	2907.50	1056.00	4238.13
S_2	7753.00	2529.75	2612.25	2404.75	3825.00
S_3	3903.75	636.75	1372.25	1056.25	1742.30
Mean	7406.63	1697.00	2084.44	1556.40	
F test	S	S	S	S	S

	CD (0.05)	SE
crops	- 609.76	212.60
shade	- 495.40	154.86
combination	- 1219.52	425.36

S - Significant

Table 7 (c) Effect of shade on total dry weight in kg ha^{-1} at 190 DAS

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Means
S_0	11176.25	7076.50	3516.75	6870.75	7160.06
S_1	10916.50	5069.75	5962.00	9795.50	7935.97
S_2	14852.20	2776.00	4630.00	3009.50	6317.00
S_3	4464.40	1031.50	2431.25	712.50	2160.00
Mean	10352.00	3988.00	4135.00	5065.80	
F test	S	S	S	S	S

	CD (0.05)	SE
crops	- 1662.01	605.87
shade	- 1847.13	577.59
combinations	- 3324.02	1159.40

S - Significant

Table 7 (d) Effect of shade on total dry weight in kg ha^{-1} at harvest.

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Means
S_0	17727.50	6572.50	2757.50	5940.00	8249.38
S_1	13045.00	7742.50	4600.00	5145.00	7633.12
S_2	15667.50	3737.50	3152.50	1767.50	6081.25
S_3	5537.50	1087.50	1842.50	1622.50	2522.50
Mean	12994.00	4785.00	3088.00	2895.00	
F test	S	S	NS	S	S

		CD (0.05)	SE
crops	-	1600.80	983.56
shade	-	1932.70	604.35
combination	-	3201.59	1116.70

S - Significant NS - Not Significant.

The total dry weight was significantly influenced by different shade levels at all growth stages for all the tuber crops. The total dry weight at 25 per cent shade was superior to all other treatments throughout the growth stages except at harvest where in open treatment ('0' per cent shade) recorded maximum dry weight which was on par with 25 per cent shade. Drastic decline in dry weight was also observed under intense shade level.

There was significant difference between crops in total dry matter production and greater yam was found to be significantly superior to the other three crops at every stage of growth.

Shade interaction with crop was also influenced significantly.

Greater yam

Shade had significant influence on total dry matter of greater yam. The total dry weight was maximum under 25 per cent shade during the initial stages and at harvest stage open treatment gave maximum dry weight. Plants grown under intense shade recorded significantly lower dry weight.

Plant dry matter production increased with advancing age of the crop at all growth stages.

Lesser yam

There was significant influence of shade on total dry weight of lesser yam at all growth stages excepting at 70 DAS. The dry weight under low shade level (25 per cent) was higher than that of all shade levels at all growth stages excepting 190 DAS. During this stage, plants grown under open was highest in dry matter production. Barring the initial stages, drastic decline in dry weight was observed under intense shade.

Over the stages the plant dry weight increased upto harvest for most of the treatments. Plants in the open recorded a decrease in total plant dry weight at harvest. The increment in dry weight upto 130 DAS was lower in the open than at low and medium shade levels. But after that period very drastic increase was observed as compared to other shade levels.

Tannia

The dry weight at 25 per cent shade was significantly superior to that at intense shade, but it was on par with 50 per cent shade in most growth stages of the crop. With increase in shade intensity from 25 per cent the dry weight declined steadily at all growth stages.

With advancing age the dry weight increased upto 190 DAS and the increment was marked between 130 and

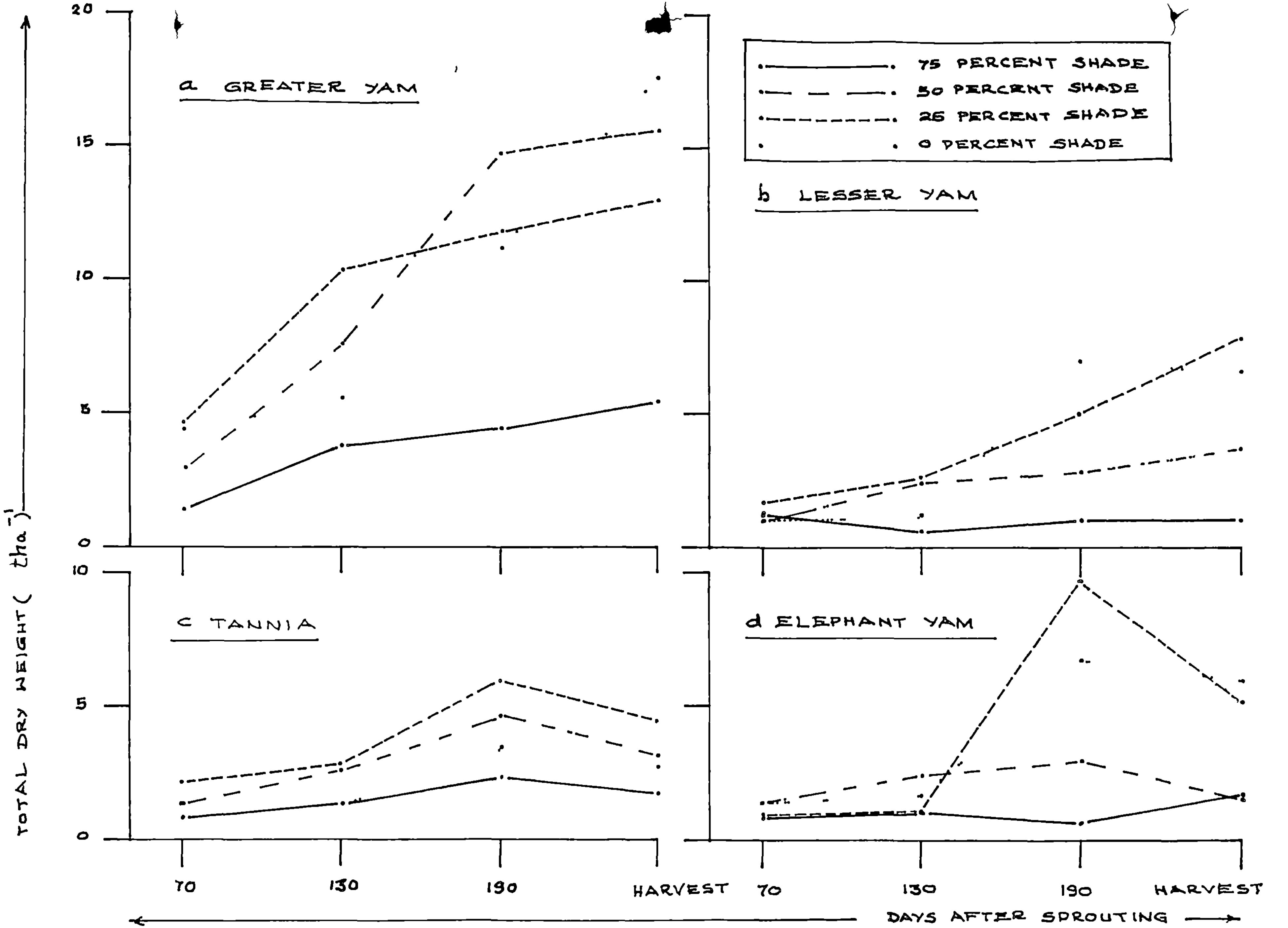


FIG 7 EFFECT OF SHADE ON TOTAL DRY MATTER PRODUCTION

190 DAS and a decline thereafter at harvest at all shade levels.

Elephant footyam

Unlike tannia and lesser yam higher dry weight was recorded by plants in open which was significantly superior to 50 per cent shade and 75 per cent shade but was on par with 25 per cent shade at harvest stage. The dry weight decreased with increasing shade intensities during the harvest stage.

As in the case of tannia, elephant footyam also recorded increase in dry weight over the stages upto 190 DAS for the treatments 0, 25 and 50 per cent shade and a decline thereafter. The extent of dry weight increase between stages was most marked during the period from 130 and 190 DAS for plants in open and under 25 per cent shade.

4.1.2. Yield and yield attributes

The data on yield and yield attributes of greater yam, lesser yam and tannia and presented in Table 8a, 8b and 8c.

4.1.2.1. Length and girth of tuber

Table 8 (a) Effect of shade on the length and girth of tuber in greater yam

Shade levels	Length of tuber (cm)	Girth of tuber (cm)
S_0	29.03	38.57
S_1	28.00	34.21
S_2	25.00	33.00
S_3	23.83	35.00
F test	NS	NS
CD (0.05)	-	-
SE	1.72	1.88

NS - Not Significant

Table 8 (b) Effect of shade on the length, girth, number of tuber and weight of tubers per plant in lesser yam

Treatments	Length of tuber (cm)	Girth of tuber (cm)	Number of tubers	Weight of tubers per plant (g)
S_0	12.55	8.88	23.75	1037.50
S_1	12.13	10.53	16.00	772.50
S_2	9.12	9.43	12.25	435.00
S_3	6.86	8.26	7.50	160.00
F test	S	NS	S	S
CD (0.05)	1.95	-	5.18	248.00
SE	0.61	0.75	1.62	77.54

S - Significant N S - Not Significant.

Table 8 (c) Effect of shade on the number and weight of cormels per plant in Tarnia

Treatments	Number of cormels per plant	Weight of cormels per plant (g)
S_0	5.75	110.5
Shade S_1	9.25	545.0
Shade S_2	8.25	862.5
Shade S_3	3.75	265.0
F test	S	S
CD (0.05)	2.41	323.5
SE	0.75	101.16

S - Significant

Greater yam

The data revealed that shade had no significant influence on the length and girth of tuber. The value ranged from 23.83 cm (75 per cent shade) to 29.03 cm ('0' per cent shade) for length and 33.00 cm (50 per cent shade) to 38.57 ('0' per cent shade) for girth of the tuber.

Lesser yam

Length of tuber differed significantly while girth of tuber remained statistically on par in lesser yam. Maximum mean length of 12.55 cm was recorded by '0' per cent shade which was statistically on par with 25 per cent shade and significantly superior to 50 per cent shade and 75 per cent shade. The lowest value was recorded by 75 per cent shade (6.86 cm) which was significantly inferior to all other treatments.

The girth of tuber ranged 8.26 cm (75 per cent shade) to 10.53 cm (25 per cent shade).

4.1.2.2. Number and weight of tubers plant^{-1}

Lesser yam

Shade significantly influenced the number and weight of tubers per plant and maximum was recorded by '0' per cent shade which was significantly superior to the other treatments.

The values ranged from 7.50 (75 per cent shade) to 23.75 ('0' per cent shade) for number of tubers and 160 .00 (75 per cent shade) to 1037.50 ('0' per cent shade) g plant^{-1} for weight of tubers per plant.

4.1.2.3. Number and weight of cormels (side tubers) plant^{-1}

Tannia

There was significant difference in the number and weight of tuber plant^{-1} due to shade in tannia. The highest number of cormel plant^{-1} was recorded by 25 per cent shade which was on par with 50 per cent shade and superior to 0 per cent and 75 per cent shade. The number of cormels plant^{-1} ranged from 3.75 (75 per cent shade) to 9.25 (25 per cent shade).

The weight of cormels plant^{-1} was highest for 50 per cent shade followed by 25 per cent shade which themselves were on par and significantly superior to 0 per cent shade and 75 per cent shade. While the number of cormels plant^{-1} was lowest for 75 per cent shade (3.75) it was for 0 per cent shade which recorded the lowest weight of cormel plant^{-1} (110.5 g).

2.1.2.4. Tuber yield

The data on tuber yield are presented in Table 9.

The yield of tuber was significantly influenced by shade. The yield declined with increasing shade intensities. The plants in the '0' per cent shade gave the highest mean tuber yield of 23.34 t ha^{-1} which was significantly superior to 50 per cent and 75 per cent shade intensities, and was on par with 25 per cent shade.

The crops also differed significantly in tuber yield due to different shade levels. The greater yam recorded the highest yield which was significantly superior to elephant footyam which in turn was significantly superior to tannia and lesser yam which were statistically on par.

Greater yam was the top yielder producing a mean yield of 27.76 t ha^{-1} followed by elephant footyam which gave an yield of 18.33 t ha^{-1}. Tannia and lesser yam produced a mean yield of 11.53 and 10.93 t ha^{-1} respectively.

The shade effect was significant for the tuber yield of individual crops also.

Greater yam

The plants in '0' per cent shade gave the highest yield which was significantly superior to all the other treatments excepting 25 per cent shade. At 75 per cent

Table 9 Effect of shade on tuber yield (t ha^{-1})

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Means
S_0	37.00	19.73	7.86	28.75	23.34
S_1	32.54	15.24	16.27	20.78	21.21
S_2	25.40	6.43	15.93	14.55	15.57
S_3	16.10	2.30	6.06	9.74	8.55
Mean	27.76	10.93	11.53	18.60	
F test	S	S	S	S	S

	CD (0.05)	SE
crops	- 2.38	0.83
shade	- 3.89	1.22
combination	- 4.76	1.67

S - Significant

shade, the yield was less than half and that of 0 per cent shade. The yield obtained at the low, medium and high shade levels were 87.95, 68.65 and 43.51 per cent respectively of that of the open. The influence of shade on yield of greater yam tuber was explained by the linear regression given (Fig. 8a).

$Y = 38.235 - 0.2179x$ with a coefficient of determination (R^2) = 0.9809.

Lesser yam

The effect of shade on the tuber yield of lesser yam was significant and the highest yield was for plants in the open which was on par with that at 25 per cent shade. But under 50 and 75 per cent shade, the yield reduction was very drastic and a lower yield of only 2.3 t ha^{-1} could be obtained from the intensely shaded plots. The percentage of yields obtained for the various shade treatments over open were 6.22, 32.59 and 77.25 for intense, medium and low shade levels respectively. The influence of shade on the tuber yield of lesser yam was explained by the linear regression (Fig. 8b).

$Y = 20.09 - 0.2446x$ with a coefficient of determination $R^2 = 0.9787$.

Tannia

Tannia revealed an entirely different picture, reporting highest yield under 25 per cent shade, with an

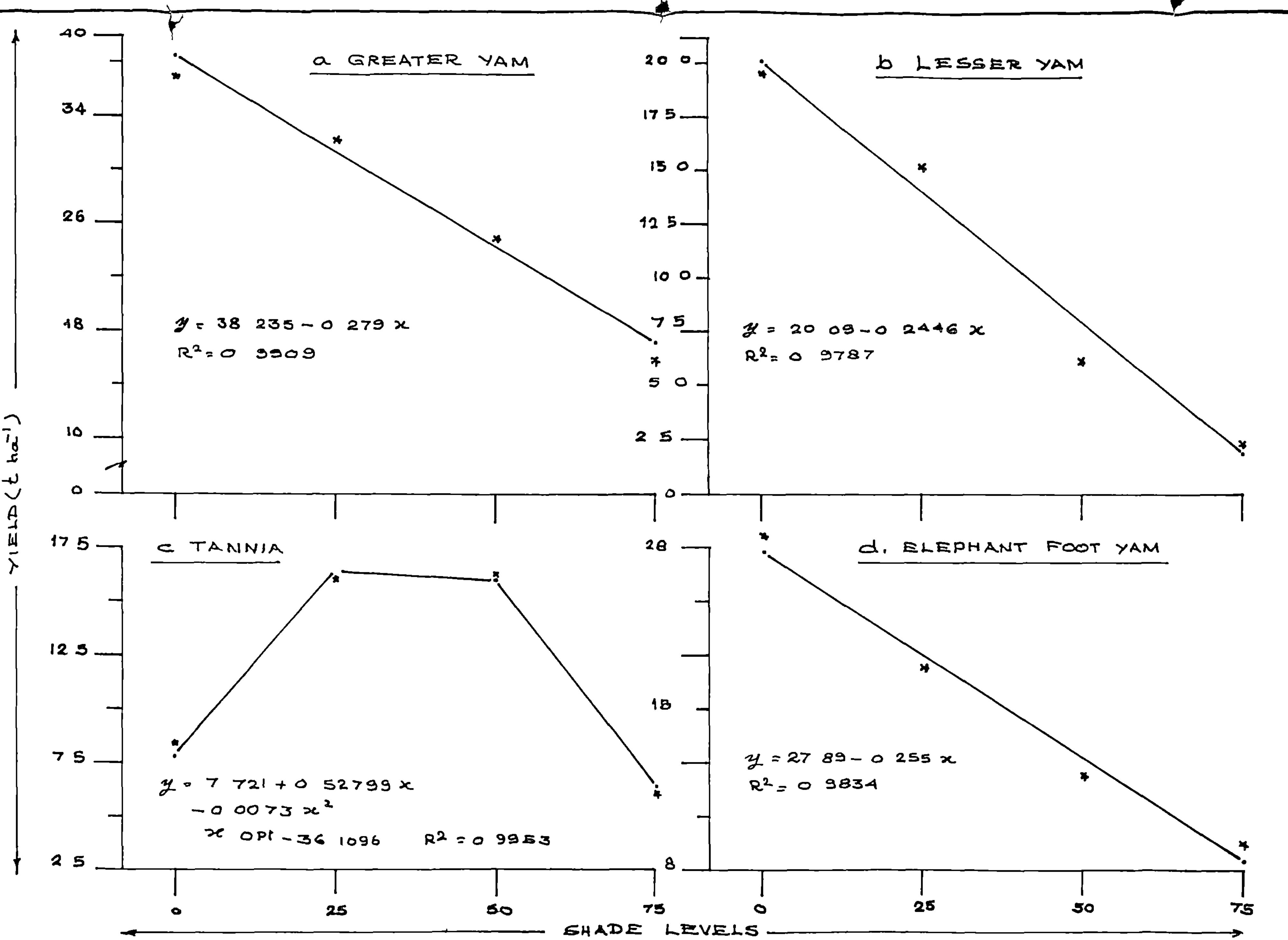


FIG 8 YIELD RESPONSE OF TUBER CROPS TO VARYING LEVELS OF SHADE

almost equal yield under 50 per cent shade. Here also the lowest yield was given by 75 per cent shade, but was on par with that of open. The yield expressed as percentage of open were 207.00, 202.67 and 77.10 per cent respectively for low, medium and intense shade respectively.

The influence of shade on the tuber yield of tannia was explained by the following equation (Fig.8c).

$$Y = 7.721 + 0.52799x - 0.0073x^2$$

The coefficient of determination R^2 is o.9953.

Elephant footyam

Every higher shade level was significantly superior to the next lower level in the case of elephant footyam. The yield data showed a decreasing trend with increasing shade intensity and the maximum yield was for '0' per cent shade and the minimum for 75 per cent shade. The respective percentages of yield at low, medium and high shade levels were 72.28, 48.87 and 33.88 per cent over that of open.

Yield as a function of shade was fitted by the linear regression (Fig. 8d).

$$Y = 27.89 - 0.255x$$

The coefficient of determination R^2 is 0.9834.

4.1.2.5. Top yield

The data on top yield are presented in Table 10.

The top yield was also significantly influenced by shade recording the maximum under 25 per cent shade which was statistically on par with that in the open, but was significantly superior to medium and intense shade. It is seen that under intense shade the top yield was very low (5.68t ha^{-1}).

As in the case of tuber yield, crops differed significantly in top yield also. Greater yam out yielded the other tuber crops in this respect. The crops in the decreasing order of top yield were greater yam, tannia elephant footyam and lesser yam.

Shade effects on individual tuber crops were also significant.

Greater yam

The treatments differed significantly. The trend in top yield was the same as that of tuber yield. The maximum and minimum values were recorded by open and intensely shaded treatments respectively. The yield of top in low, medium and high shade levels were found to be 88.75, 77.17 and 44.37 per cent of that in the open.

Lesser yam

The maximum top yield was recorded in 25 per cent shade which was significantly superior to all other treatments. As in the case of other characters the top

Table 10 Effect of shade on top yield in t ha^{-1}

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Mean
S_0	18.66	5.46	6.34	8.04	9.61
S_1	16.56	8.16	8.58	13.50	11.70
S_2	14.40	4.26	5.40	2.34	6.60
S_3	8.28	2.46	5.28	0.68	5.68
Mean	14.46	5.10	6.30	6.18	
F test	S	S	S	S	S

	C D (0.05)	S E
crops	1.20	0.42
shade	2.0	0.66
combination	2.40	1.20

yield was minimum at intense shade level. The yields obtained at low, medium and high shade levels expressed as percentage of that at the open were 149.46, 78.02 and 45.05 respectively.

Tannia

The trend in top yield was the same as that of lesser yam and as such the maximum and minimum values were recorded by 25 per cent and at 75 per cent shade levels respectively. The treatment 0, 50 and 75 per cent shade were statistically on par and significantly inferior to 25 per cent shade. The yield percentages of that at the open were 144.44, 90.91 and 88.89 respectively.

Elephant footyam

The shade had significant influence on the top yield of elephant footyam and maximum yield was obtained for plants at 25 per cent shade followed by open. Plants in medium and intense shade levels recorded very low yield of 2.34 and 0.68 t ha^{-1} respectively and when calculated as percentage of open were 167.91, 29.10 and 9.70 respectively for low, medium and intense shade levels.

4.1.2.6. Utilisation index (UI)

The data are presented in Table 11 and Fig.9.

Table 11 Effect of shade on utilisation index

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Means
S_0	1.30	5.89	0.54	2.03	2.12
S_1	1.42	5.17	0.90	1.24	2.14
S_2	1.28	2.03	0.77	2.45	1.69
S_3	0.69	1.16	0.31	2.95	1.28
Mean	1.23	3.56	0.63	2.16	
F test	NS	S	NS	NS	NS

	CD (0.05)	SE
crops	- 0.90	0.31
shade	- -	0.35
combination	- 1.80	0.63

S - Significant NS - Not Significant

The shade effect was not significant on utilisation index. Maximum utilisation index was recorded by plants in 25 per cent shade (2.14) followed by plants in the open (2.12). Utilisation index was minimum at 75 per cent shade (1.28).

Crops showed significant difference in utilisation indices and maximum value was for lesser yam and minimum for tannia. Lesser yam was significantly superior to the other three crops under study.

The interaction effect of shade on different crops also showed statistical significance.

Greater yam

Maximum utilisation index was for 25 per cent shade which maintained statistical parity with all the other treatments. The value ranged from 0.69 (75 per cent shade) to 1.42 (25 per cent shade).

Lesser yam

With increasing shade intensity the utilisation index went on decreasing, recording maximum and minimum values by open and intense shade respectively. Utilisation index of 0 per cent shade and 25 per cent shade were on par but were significantly superior to 50 per cent shade and 75 per cent shade which were also on par.

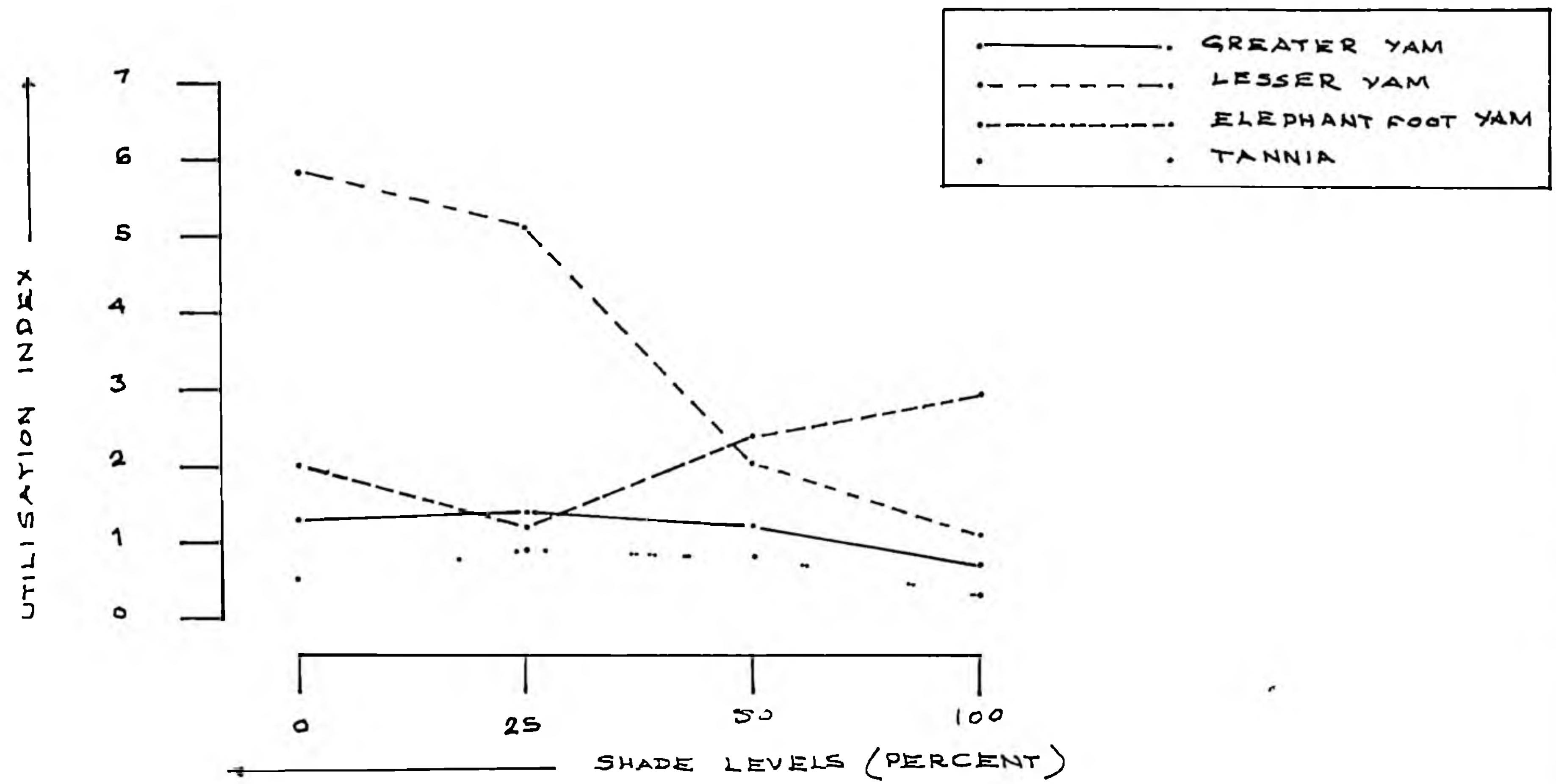


FIG 9 EFFECT OF SHADE ON UTILISATION INDEX

Tannia

Shade had no significant influence on the utilisation index of tannia. The utilisation index values ranged from 0.31 at 75 per cent shade to 0.90 at 25 per cent shade.

Elephant footyam

Elephant footyam recorded highest utilisation index under intense shade followed by 50 p r cent shade level. Here the lowest value was for plants at 25 per cent shade although the effect was not significant.

4.1.3. Chemical analysis

4.1.3.1. Chlorophyll content

The data on chlorophyll 'a', 'b' and total chlorophyll are presented in Table 12.

It is seen that the chlorophyll content was significantly influenced by shade levels at different growth stages. The general trend was an increase in chlorophyll content with increasing shade.

Crops differed significantly in chlorophyll content and a higher content was recorded by elephant footyam followed by tannia. Lesser yam and greater yam recorded lesser chlorophyll contents.

Table 12 (a) Effect of shade on chlorophyll 'a' and 'b' content of leaves at 70 DAS

Shade levels	Greater yam		Lesser yam		Tannia		Elephant foot yam		Treatment Means	
	Chlorophyll 'a'	Chlorophyll 'b'	Chlorophyll 'a'	Chlorophyll 'b'	Cholorophyll 'a'	Cholorophyll 'b'	Chlorophyll 'a'	Chlorophyll 'b'	Chlorophyll 'a'	Chlorophyll 'b'
S_0	1.17	1.20	1.15	1.30	1.18	1.75	1.87	2.11	1.34	1.59
S_1	1.18	1.19	1.26	1.30	1.69	1.98	1.86	2.08	1.50	1.64
S_2	1.19	1.20	1.28	1.36	1.90	2.02	2.04	2.20	1.60	1.70
S_3	1.18	1.19	1.28	1.18	1.79	2.11	1.07	2.20	1.46	1.67
Mean	1.18	1.19	1.24	1.27	1.67	1.91	1.96	2.12		
F test	NS	NS	S	S	S	S	S	NS	S	S

		C D (0.05) Chlorophyll 'a'	C D (0.05) Chlorophyll 'b'	S E Chlorophyll 'a'	S E Chlorophyll 'b'
crops	-	0.11	0.08	0.04	0.03
shade	-	0.15	0.09	0.05	0.03
combination	-	0.22	0.17	0.08	0.06

S - Significant NS - Not Significant

Table 12 (b) Effect of shade on chlorophyll 'a' and 'b' content (mg g^{-1}) of leaves at 130 DAS

Shade levels	Greater yam		Lesser yam		Tannia		Elephant foot yam		Means	
	Chlorophyll		Chlorophyll		Chlorophyll		Chlorophyll		Chlorophyll	
	'a'	'b'	'a'	'b'	'a'	'b'	'a'	'B'	'a'	'b'
S_0	1.21	1.27	1.45	1.63	1.17	1.25	1.53	1.70	1.34	1.49
S_1	1.24	1.42	1.40	1.57	1.52	1.49	1.45	1.07	1.40	1.49
S_2	1.29	1.49	1.50	1.77	1.63	1.91	1.61	2.00	1.50	1.79
S_3	1.39	1.60	1.50	1.78	1.03	1.98	1.77	2.22	1.57	1.90
Mean	1.28	1.44	1.15	1.09	1.49	1.66	1.59	1.91		
F test	S	S	S	S	S	S	S	S	S	S

		C D (0.05)		S E	
		Chlorophyll 'a'	Chlorophyll 'B'	Chlorophyll 'a'	Chlorophyll 'b'
crops	-	0.07	0.12	0.02	0.04
shade	-	0.08	0.11	0.03	0.03
Combination	-	0.13	0.24	0.04	0.08

S - Significant

Table 12 (c) Effect of shade on Chlorophyll 'a' and 'b' contents (mg g^{-1}) of leaves at 190 DAS

Shade levels	Greater yam		Lesser yam		Tannia		Elephant foot yam		Means	
	Chlorophyll		Chlorophyll		Chlorophyll		Chlorophyll		Chlorophyll	
	'a'	'b'	'a'	'b'	'a'	'b'	'a'	'b'	'a'	'b'
S_0	1.04	1.14	1.30	1.41	1.46	1.49	1.54	1.64	1.37	1.42
S_1	1.17	1.19	1.22	1.25	1.46	1.48	1.40	1.43	1.31	1.34
S_2	1.24	1.30	1.25	1.30	1.36	1.45	1.44	1.34	1.32	1.36
S_3	1.31	1.39	1.36	1.45	1.54	1.69	1.60	1.77	1.45	1.64
Mean	1.19	1.26	1.28	1.36	1.46	1.58	1.49	1.55		
F test	S	S	S	S	S	S	S	S	S	S

		CD (0.05)		S E	
		Chlorophyll 'a'	Chlorophyll 'b'	Chlorophyll 'a'	Chlorophyll 'b
crops	-	0.03	0.04	0.01	0.01
shade	-	0.03	0.04	0.01	0.01
combination	-	0.06	0.08	0.02	0.03

S - Significant

Table 12 (d) Effect of shade on total chlorophyll content of leaves (mg g^{-1}) at 70 DAS

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Treatment means
S_0	2.37	2.45	3.25	3.98	3.01
S_1	2.37	2.54	3.46	3.86	3.06
S_2	2.38	2.60	3.87	4.23	3.27
S_3	2.37	2.46	3.90	4.27	3.20
Mean	2.37	2.51	3.57	4.09	
F test	NS	NS	S	S	S

	CD (0.05)	SE
crops	- 0.15	0.05
shade	- 0.18	0.06
combination	- 0.29	0.10

S - Significant NS - Not Significant

Table 12 (a) Effect of shade on total chlorophyll content (mg g^{-1}) of leaves at 130 DAS

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Treatment means
S_0	2.49	3.08	2.42	3.24	2.81
S_1	2.66	2.97	3.01	3.13	2.94
S_2	2.76	3.24	3.54	3.66	3.32
S_3	2.99	3.28	3.61	3.99	3.47
Mean	2.73	3.17	3.15	3.50	
F test	S	S	S	S	S

		C D (0.05)	S E
crops	-	0.17	0.06
shade	-	0.17	0.05
combination	-	0.34	0.12

S - Significant

Table 12 (f) Effect of shade on total chlorophyll content ($mg\ g^{-1}$) of leaves at 190 DAS

Shade levels	Creater yam	Lesser yam	Tannia	Elephant foot yam	Treatment means
S_0	2.19	2.70	2.95	2.96	2.70
S_1	2.36	2.47	2.94	2.83	2.65
S_2	2.64	2.55	2.87	2.78	2.70
S_3	2.70	2.81	3.42	3.37	3.07
Mean	2.47	2.64	3.05	2.98	
F test	S	S	S	S	S

		C D (0.05)	S E
crops	-	0.08	0.03
shade	-	0.09	0.03
combination	-	0.15	0.05

S - Significant

The interaction effect of shade on chlorophyll content of different crops are as follows.

Greater yam

Chlorophyll content of greater yam differed significantly due to shade and there was an increase in chlorophyll content with increase in shade levels at 130 DAS and 190 DAS during the second and third stages. Comparison between stages reported a reduction in the content at 190 DAS.

Lesser yam

The effect of shade on the chlorophyll content of lesser yam was also significant. As in the case of greater yam the chlorophyll content was maximum at intense shade level. In this case also there was reduction in the chlorophyll content at 190 DAS.

Tannia

There was significant difference in chlorophyll content due to shade and the highest value was recorded by 75 per cent shade which was on par with 50 per cent shade and significantly superior to 0 per cent shade and 25 per cent shade at 70 and 130 DAS. At 190 DAS, a general reduction in chlorophyll content was observed and 75 per cent shade was significantly superior to 0, 25 and 50 per cent shade which in turn were statistically on par.

Elephant footyam

There was significant difference in the chlorophyll content of elephant foot yam. An increase in the chlorophyll content with increase in shade level was observed and the treatment 75 per cent shade recorded maximum value.

The highest chlorophyll content was recorded at 70 DAS and a reduction in the content was observed with ageing of the crop.

4.1.3.2. Starch content of tubers

The data on starch content of tubers are presented in Table 13.

Although shade significantly influenced the starch content of tubers no definite trend could be maintained between the different shade levels.

Crops differed significantly in the starch content of tubers. Tannia had the highest percentage of starch and this was significantly superior to all the other crops. The mean starch contents of greater yam and lesser yam tubers were more or less the same and significantly superior to that of elephant footyam which recorded the lowest value of 32.91 per cent.

The shade interaction with the crops was also significant in this respect.

Table 13 Effect of shade on the starch and protein content of tuber in percen

Shade levels	Greater yam		Lesser yam		Tannia		Elephant foot yam		Treatment means	
	Starch	Protein	Starch	Protein	Starch	Protein	Starch	Protein	Starch	Protein
S_0	43.48	7.81	43.48	7.34	50.39	7.88	37.42	11.25	43.70	8.57
S_1	31.47	7.67	45.44	7.19	49.06	7.88	37.15	10.62	40.70	8.34
S_2	49.07	6.69	47.41	9.06	54.04	9.34	31.10	11.62	45.40	9.18
S_3	58.57	10.94	45.18	9.75	40.31	8.38	25.98	11.62	42.76	10.17
Mean	45.65	8.28	45.63	8.37	48.45	8.37	32.91	11.28		
F test	S	S	NS	S	S	S	S	S	S	S

	C D (0.05)		S E	
	Starch	Protein	Starch	Protein
crops	2.68	0.42	0.93	0.15
shade	2.98	0.63	0.93	0.20
combination	5.39	0.90	1.88	0.31

S - Significant NS - Not Significant

Greater yam

The maximum content of starch was recorded by the tubers of intensely shaded plots (58.57 per cent) which was significantly superior to all the other treatments. Starch content ranged from 31.47 per cent (25 per cent shade) to 58.57 per cent (75 per cent shade).

Lesser yam

Shade had no significant influence on starch content and the value ranged from 43.48 per cent (0 per cent shade) to 47.41 per cent (50 per cent shade).

Tannia

Maximum starch content was recorded at 50 per cent shade which was on par with open and 25 per cent shade. All the three treatments were significantly superior to intensely shaded treatment.

Elephant footyam

There was a decreasing trend in starch content of tuber with increasing shade intensities. No significant difference could be seen between open and 25 per cent shade, but were superior to the other two treatments.

4.1.3.3. Protein content of tuber

The data on protein content of tuber are presented in Table 13.

The main effect of shade was significant and there was an increasing trend in the protein content with increase in shade levels.

It is seen that the tuber protein content was different for different tuber crops. Greater yam, lesser yam and tannia recorded an almost equal content ranging from 8.28 per cent to 8.37 per cent. A higher content was recorded by elephant footyam (11.28 per cent) which was significantly superior to others.

Greater yam

Significant difference in protein content due to shade was observed, the maximum being at 75 per cent shade. The value ranged from 6.69 per cent (50 per cent shade) to 10.94 per cent (75 per cent shade).

Lesser yam

Shade significantly influenced the protein content of lesser yam tubers. As in the case of greater yam the highest content was recorded at 75 per cent shade.

Tannia

Tannia also recorded significant difference in the tuber protein content due to shade. The maximum content of 9.34 per cent was recorded by 50 per cent shade.

Elephant footyam

As in the case of other crops, the protein content of elephant footyam tuber was also varied significantly due to shade. The protein contents ranged from 10.62 per cent to 11.62 per cent at different shade intensities, the highest value being recorded by 50 per cent shade and 75 per cent shade which was on par with (11.62 per cent) 0 per cent shade (11.25 per cent) but significantly superior to 25 per cent shade.

4.1.3.4. Total nitrogen uptake

The data on total nitrogen uptake at 70 DAS and at harvest are presented in Table 14 and Fig.10.

The results revealed that there was profound influence on total nitrogen uptake due to different shade levels. Though no definite trend could be maintained at the initial stage, the uptake followed a definite decreasing trend with increase in shade intensities at harvest. The maximum uptake of nitrogen at harvest was recorded by plants in the open which was on par with 25 per cent shade and significantly superior to the other two shade levels.

Crops differed significantly in total uptake of nitrogen with greater yam recording maximum uptake at both stages. The mean values of uptake ranged from

Table 14 Effect of shade on total nitrogen uptake in kg ha^{-1}

Shade levels	Greater yam		Lesser yam		Tannia		Elephant foot yam		Treatment means	
	At 70 DAS	At harvest	At 70 DAS	At harvest	At 70 DAS	At harvest	At 70 DAS	At harvest	At 70 DAS	At harvest
S_0	84.96	194.53	20.50	81.74	15.33	34.02	29.68	90.20	30.62	99.86
S_1	109.20	149.72	22.88	88.60	35.95	61.83	19.47	50.30	46.87	87.61
S_2	68.93	193.50	19.04	39.00	38.18	48.20	27.06	20.65	38.30	75.59
S_3	32.70	38.47	10.68	11.63	24.50	33.13	19.53	24.33	21.85	26.90
Mean	73.75	144.05	18.27	55.24	28.49	44.29	23.93	26.38		
F test	S	S	S	S	S	S	S	S	S	S

	C D (0.05)		S E	
	At 70 DAS	At harvest	At 70 DAS	At harvest
crops	4.01	6.79	1.40	2.02
shade	2.45	16.40	0.77	5.13
combination	8.03	11.58	2.79	4.05

S - Significant

18.27 to 73.95 kg ha^{-1} by lesser yam and greater yam respectively during first stage of sampling and from 44.29 to 144.05 kg ha^{-1} by tannia and greater yam respectively at harvest.

Interaction effect of shade with the crops was also significant.

Greater yam

At the harvest stage the maximum uptake was recorded by plants in the open, though 25 per cent shade recorded the highest value during the initial stage. The uptake followed the same pattern as that of dry matter accumulation which ranged from 38.47 to 194.53 kg ha^{-1} for intense shade and open respectively.

The uptake values went on increasing with advancing age and the harvest stage recorded maximum uptake values. The increase in uptake between stages was maximum for 50 per cent shade while 75 per cent shade recorded only very little improvement.

Lesser yam

In this case, the first three shade levels (0, 25 and 50 per cent) were statistically on par and significantly superior to 75 per cent shade at the initial stage of the crop. At harvest stage the first two shade levels (0 per cent shade and 25 per cent shade) were

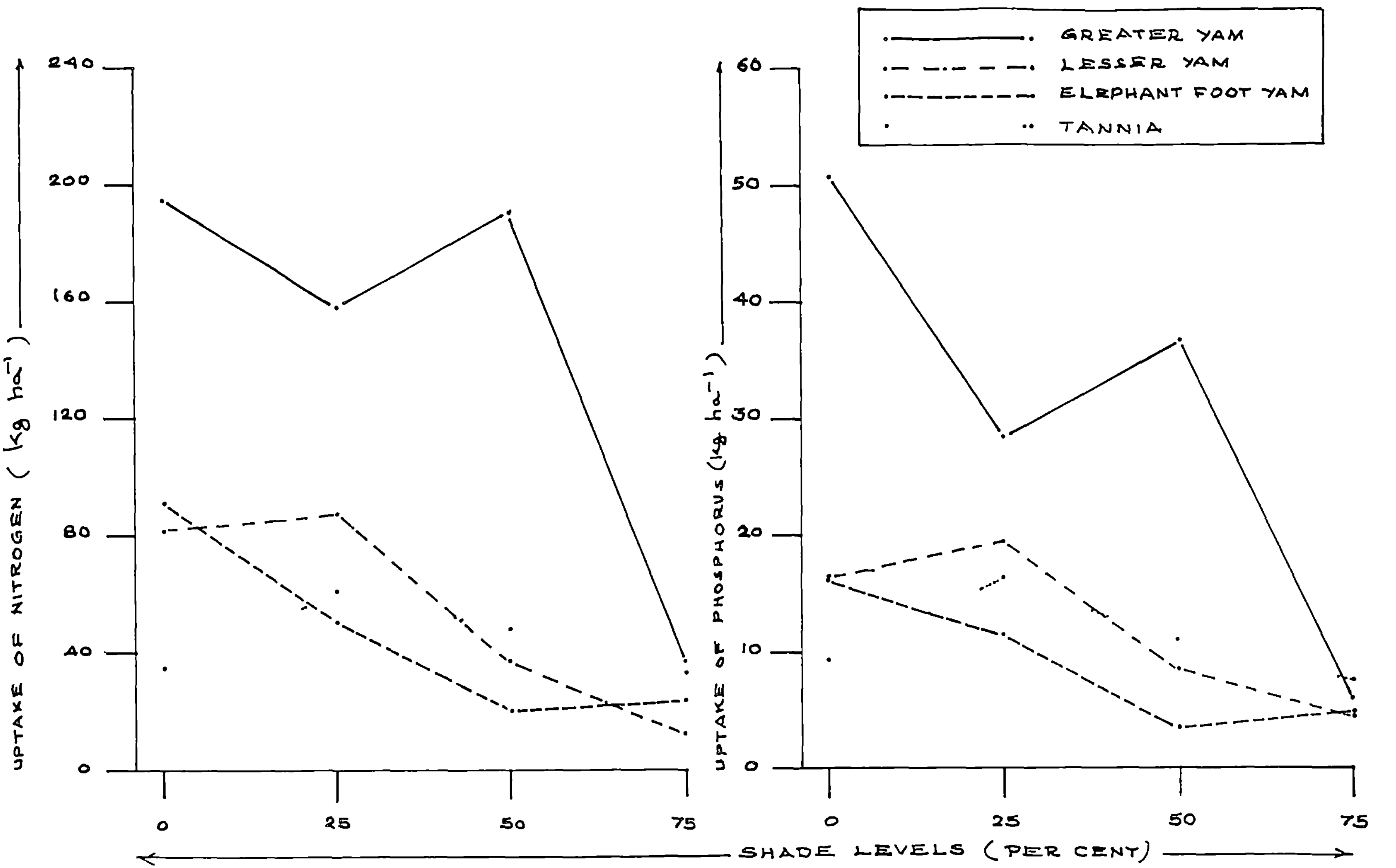


FIG 10 EFFECT OF SHADE LEVELS ON UPTAKE OF NITROGEN ($kg\ ha^{-1}$) AT HARVEST

FIG 11 EFFECT OF SHADE LEVELS ON UPTAKE OF PHOSPHORUS ($kg\ ha^{-1}$) AT HARVEST statistically on par and significantly superior to the other two shade levels. The uptake values ranged from 11.63 to 88.60 kg ha^{-1}.

The maximum uptake values were recorded at harvest stage. The increase in the uptake value from the initial stage was high at low shade level (25 per cent shade). At intense shade level with increase in the shade intensity from 25 per cent, the enhancement rate of uptake decreased rapidly showing only a one kg difference between initial stage and harvest stage.

Tannia

The nitrogen uptake was maximum in 25 per cent shade and was significantly superior to all the other treatments at harvest. At both stages, the uptake values were very low for plants in the open and at intense shade.

The total uptake went on increasing with ageing of the crop, the maximum being recorded at the harvest stage at all the shade levels.

Elephant footyam

The maximum uptake value was for plants in the open both at initial and harvest stages which was significantly superior to all the other treatments at harvest stage. The general pattern was a decrease in the uptake with increase in shade levels. The uptake values ranged from

20.65 kg ha^{-1} (50 per cent shade) to 90.20 kg ha^{-1} (0 per cent shade) at harvest.

4.1.3.5. Total uptake of phosphorus

The data on total uptake of phosphorus are presented in Table 15 and Fig.11.

Significant influence of shade was observed on the total phosphorus uptake by plants. Maximum and minimum values were recorded by plants in '0' per cent shade and at 75 per cent shade respectively. Although the phosphorus uptake did not follow a definite trend during the initial stage, it recorded drastic increase and significant differences between different shade levels at harvest showing a decrease in the uptake with increase in shade intensity.

Crops differed significantly in phosphorus uptake and maximum uptake was for greater yam at both stages. Lesser yam though recorded minimum values in the early stage rose up at harvest and came next to greater yam.

In general, the interaction effect of shade with crops was significant.

Greater yam

The maximum uptake was recorded by plants at 25 per cent shade and in the open at the first stage

Table 15 Effect of shade on total phosphorus uptake in kg ha^{-1}

Shade levels	Greater yam		Lesser yam		Tannia		Elephant foot yam		Means	
	At 70 DAS	At harvest	At 70 DAS	At harvest	At 70 DAS	At harvest	At 70 DAS	At harvest	At 70 DAS	AT harvest
S_0	12.85	50.66	3.90	16.26	4.23	9.29	5.47	16.17	6.63	23.09
S_1	16.31	28.62	4.00	19.38	13.30	16.29	3.84	11.62	9.36	18.98
S_2	12.12	36.80	3.51	8.44	7.37	11.22	4.23	3.58	6.80	15.01
S_3	6.52	5.96	2.82	4.67	5.18	7.50	3.46	4.41	4.49	5.66
Mean	11.95	30.51	3.58	12.19	7.52	11.10	4.25	8.95		
F test	S	S	S	S	S	S	NS	S	S	S

	C D (0.05)		S E	
	At 70 DAS	At harvest	At 70 DAS	At harvest
crops	1.11	2.22	0.43	0.77
shade	1.37	3.55	0.39	1.09
combination	2.22	4.45	0.77	1.55

S - Significant NS - Not Significant

and at harvest respectively. The uptake value decreased rapidly with increase in shade levels. There was increase in the uptake with advancing age of the crop at all shade levels except at intense shade.

Lesser yam

The shade significantly influenced the phosphorus uptake pattern of lesser yam, the maximum being recorded by plants at 25 per cent shade which maintained statistical parity with open. With increase in shade level there was drastic reduction in the phosphorus uptake. The phosphorus uptake pattern increased with time at all shade levels.

Tannia

Tannia followed the same pattern as that of lesser yam. The maximum and minimum uptake values were recorded by the treatment 25 per cent and 75 per cent shade respectively at both the stages. All the shade levels recorded increased uptake with ageing of the crop.

Elephant footyam

Phosphorus uptake was maximum for plants in the open which recorded significant superiority over the other treatments. In general, there was an increase in the uptake level as the plant attained maturity.

4.1.3.6. Total potassium uptake

The data on total potassium uptake are presented in Table 16 and Fig.12.

The main effect of shade was significant for total potassium uptake. During the initial stage 25 per cent shade recorded significant superiority over the other treatments, while at harvest all the three lower shade levels were statistically on par and significantly superior to intense shade.

As in the case of nitrogen and phosphorus uptake pattern, the crops also differed significantly in total potassium uptake and greater yam recorded the maximum value.

Interaction effect between shade and crops was also significant.

Greater yam

It is seen that 50 per cent shade recorded maximum potassium uptake of 481.73 kg ha^{-1} which was statistically superior to all the other treatments. The minimum uptake was recorded by intense shade.

With advancing age, there is a greater increase in the uptake of potassium at all shade levels.

Table 16 Effect of shade on total potassium uptake in kg ha^{-1}

Shade levels	Greater yam		Lesser yam		Tannia		Elephant foot yam		Treatment Means	
	At 70 DAS	At harvest	At 70 DAS	At harvest	At 70 DAS	At harvest	At 70 DAS	At harvest	At 70 DAS	At harvest
S_0	41.91	329.00	27.51	118.33	28.91	93.92	33.00	145.35	32.83	171.65
S_1	68.25	253.43	31.01	176.80	80.08	143.80	27.50	131.38	51.71	175.35
S_2	49.80	481.73	21.05	85.30	53.18	121.25	31.83	33.22	38.96	180.38
S_3	20.60	78.40	11.80	27.00	29.18	81.92	24.08	42.25	21.41	57.40
Mean	45.14	285.64	21.84	101.80	47.84	110.22	29.10	88.05		
F test	S	S	S	S	S	S	NS	S	S	S

	C D (0.05)		S E	
	70 DAS	At harvest	70 DAS	At harvest
crops	6.54	18.50	2.27	6.45
shade	8.27	9.04	2.58	9.05
combination	13.08	37.00	4.56	12.89

S - significant NS - Not Significant

Lesser yam

Though the shade levels upto 50 per cent could not exert any significant influence at the initial stage, the plants under 25 per cent shade recorded significantly higher uptake values at harvest. For the intensely shaded plants the uptake was very low. The uptake went on increasing with ageing of the crop.

Tannia

As in the case of lesser yam, the total potassium uptake was maximum at 25 per cent shade. Here also, the 75 per cent shade recorded the lowest uptake.

Over the stages, the uptake values increased considerably.

Elephant foot yam

The general trend was a decrease in the uptake with increase in shade intensity. The plants in the open were significantly superior to all the other shade treatment except 25 per cent shade with respect to potassium uptake.

The potassium uptake increased with ageing of the plants.

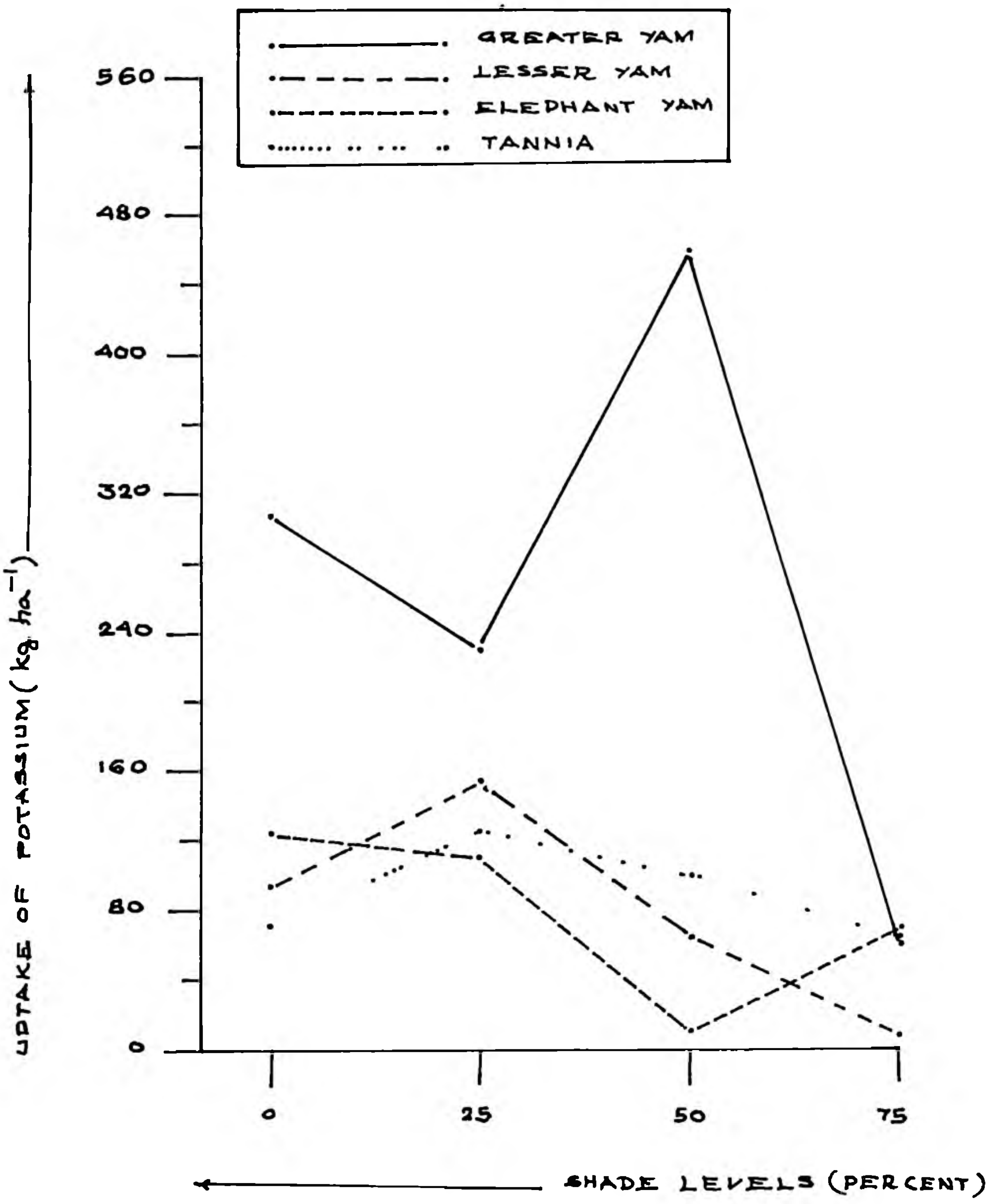


FIG 12 EFFECT OF SHADE LEVELS ON UPTAKE OF POTASSIUM (kg ha^{-1}) AT HARVEST

4.1.4. Soil characters

NPK status of the soil after each crop are presented in Table 17.

There occured significant difference only in the case of available phosphorus content of soil due to different shade levels. However, there was significant difference in available nitrogen and available potassium status of soil due to growing different tuber crops.

Interaction between shade and crops was significant in the nutrient status of soil after different tuber crops.

Greater yam

The different shade levels could influence only the available phosphorus content of soil. In this case, at intensely shaded plot the available phosphorus content of the soil was found to be higher though available nitrogen and available potassium content of the soil did not follow any definite trend.

Lesser yam

Shade exerted significant influence on the available nitrogen, available phosphorus and available potassium content of the soil after growing lesser yam. Nitrogen and potassium status of the soil was highest

Table 17 (a) Effect of shade on available nitrogen in soil (kg ha^{-1})

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Means
S_0	230.81	302.90	216.40	223.60	243.43
S_1	238.02	238.04	252.45	234.43	240.73
S_2	216.38	281.47	266.00	209.17	243.47
S_3	238.02	216.23	259.66	274.09	246.99
Mean	230.81	259.67	248.84	235.32	
F test	NS	S	NS	S	NS

		CD (0.05)	SF
crops	-	24.93	8.69
shade	-	-	7.42
combination	-	49.86	17.39

S - Significant NS - Not Significant

Table 17(b) Effect of shade on available phosphorus in soil (kg ha^{-1}) (c) at 190 DAS

Treatments	Greater yam	Lesser yam	Tannia	Elephant foot yam	Means
S_0	37.77	36.87	39.90	47.08	37.91
S_1	31.91	39.10	36.71	49.48	39.30
S_2	37.24	41.76	58.99	44.95	45.73
S_3	48.68	52.40	45.22	41.23	46.88
Mean	38.90	40.03	45.20	45.68	
F test	S	S	S	NS	S

	CD (0.05)	SE
crops -	5.97	2.08
shade -	5.69	1.78
combination-	11.95	4.17

NS - Not Significant S - Significant.

Table 17 (c) Effect of shade on available potassium in soil (kg ha^{-1})

Shade levels	Greater yam	Lesser yam	Tannia	Elephant foot yam	Means
S_0	120.25	143.00	137.50	145.00	120.44
S_1	126.50	137.00	132.50	130.00	131.50
S_2	130.00	140.00	107.50	120.00	112.80
S_3	118.00	105.25	111.25	109.00	108.44
Mean	123.68	118.25	122.19	126.00	
F test	NS	S	NS	NS	NS

	CD (0.05)	SE
crops	10 25	6.86
shade	-	7.55
combination	37.40	13.73

S - Significant NS - Not Significant

4.2. Experiment II

The results of the experiment, 'Fertilizer management of minor tuber crops in coconut based cropping systems' are presented below.

4.2.1. Growth characters

4.2.1.1. Length of vine/height of plant

The data on mean length of vine/height of plant at various growth stages are presented in Table 18.

Greater yam

There was significant difference in vine length due to different fertilizer levels at 130 and 190 DAS only during the first year of the crop. The vine length was maximum for F_1 during both the years which was significantly superior to the other treatments in the first year. The length of the vine in the second year was considerably lower in all the treatments.

Lesser yam

The effect of fertilizer levels on the length of vine was significant only at 70 DAS during the second year. There was no significant difference in the length of vine during the other stages of crop during both the years. F_2 recorded maximum length of vine during the two years.

Table 18 (a) Effect of fertilizer levels on length of vine/height of plant in cm at 70 D A S

Fertilizer levels (Percentage of recommendation)	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	85-86	86-87	85-86	86-87	85-86	86-87	85-86	86-87
F_1 (100 percent)	564.00	517.50	333.67	232.50	55.67	39.25	61.53	40.80
F_2 (75 percent)	583.67	567.50	306.00	567.50	61.67	51.17	60.00	45.83
F_3 (50 percent)	662.00	442.50	317.67	320.00	53.33	83.33	57.67	37.83
F test	NS	NS	NS	S	NS	NS	NS	NS
CD (0.05)	-	-	-	156.25	-	-	-	-
SE	149.84	21.63	8.17	39.08	6.62	6.01	3.94	3.41

S - Significant NS - Not Significant

Table 18 (b) Effect of fertilizer levels on length of vine/height of plant in cm at 130 DAS

Fertilizer levels	Greater yam 85-86	Greater yam 86-87	Lesser yam 85-86	Lesser yam 86-87	Tannia 85-86	Tannia 86-87	Elephant foot yam 85-86	Elephant foot yam 86-87
F_1	1359.00	730.00	398.00	390.00	64.57	45.50	64.33	60.00
F_2	1194.00	614.33	325.00	544.00	68.67	60.15	61.90	56.75
F_3	1056.00	691.33	406.67	531.33	76.10	43.00	56.80	50.50
F test	S	NS	NS	NS	NS	NS	NS	NS
CD (0.05)	302.43	-	-	-	-	-	-	-
SE	77.03	52.67	25.47	61.95	5.24	6.49	2.83	2.28

S - Significant NS - Not Significant

Table 18 (c) Effect of fertilizer levels on length of vine/height of plant in cm at 190 DAS

Fertilizer levels	Greater Yam 85-86	Greater Yam 86-87	Lesser Yam 85-86	Lesser Yam 86-87	Tannia 85-86	Tannia 86-87	Elephant foot yam 85-86	Elephant foot yam 86-87
F_1	1250.00	785.35	401.00	465.33	77.00	57.70	61.67	69.50
F_2	1015.00	710.00	435.00	585.00	85.27	77.30	59.27	65.50
F_3	1025.00	780.00	404.00	530.00	94.50	68.33	53.07	52.50
F Test	S	NS	NS	NS	NS	NS	NS	NS
CD (0.05)	190.00	-	-	-	-	-	-	-
SE	48.56	22.05	33.12	39.60	5.97	6.67	2.39	3.00

S - Significant NS - Not significant

With ageing of the crop, length of vine also increased and maximum length was recorded at 190 DAS. It was also seen that the vine length was higher during the second year.

Tannia

The different fertilizer levels had no significant influence on the height of plant at any of the growth stages during both the years. It was also observed that there was a gradual increase in the plant height with ageing of the crop. Plant height during the second year was comparatively lower for all the treatments.

Elephant footyam

Plant height was not significantly influenced by the different fertilizer treatments at any of the growth stages during both the years.

The height of plant ranged from 53.07 to 64.33 cm during the first year and from 37.83 to 69.50 cm during the second year.

4.2.1.2. Girth at the base of the pseudostem

This observation was taken only for tannia and elephant footyam and the data are presented in Table 19.

Table 19 (a) Effect of Fertilizer levels on the girth at the base of the stem in cm at 70 D A S

Fertilizer levels	Tannia '85-86	Tannia 86-87	Elephant foot yam '85-86	Elephant foot yam 86-87
F_1	10.43	10.83	18.77	14.33
F_2	11.47	12.00	19.53	15.83
F_3	11.17	12.83	17.87	14.67
F test	NS	NS	NS	NS
CD (0.05)	-	-	-	-
SE	0.84	1.41	0.85	1.67

S - Significant NS - Not Significant

Table 19 (b) Effect of fertilizer levels on the Girth at the base of the stem in cm at 130 D A S

Fertilizer levels	Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	'86-87
F_1	14.11	8.76	18.30	15.25
F_2	15.33	16.00	18.17	14.65
F_3	15.20	9.40	19.23	17.90
F test	NS	NS	NS	S
CD (0.05)	-	-	-	2.72
SE	1.13	2.08	0.45	0.69

S - Significant NS - Not Significant

Table 19 (c) Effect of fertilizer levels on the girth at the base of the stem in cm at 190 D A S

Fertilizer levels	Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87
F_1	23.10	17.33	18.07	15.50
F_2	22.10	16.67	19.27	16.50
F_3	24.23	23.07	17.10	17.50
F test	NS	NS	NS	NS
CD (0.05)	-	-	--	-
SE	0.87	2.53	1.10	0.58

S - Significant Ns - Not Significant

Tannia

There was no significant difference between the different levels of fertilizer treatments on this character during both the years at all stages of crop growth. The maximum girth of 24.23 cm and 23.67cm were recorded by F_3 respectively during first and second year. The girth at the base of the stem increased upto 190 DAS.

Elephant footyam

The data revealed that the treatments did not differ significantly with respect to girth at the base of stem on 70 and 190 DAS. However, during the second year, there was significant difference in this character at 130 DAS. In general, the crop maintained more or less the same girth at the base of the stem through out the growth stages of the crop.

4.2.1.3. Number of leaves plant^{-1}

This observation was taken for greater yam, lesser yam and tannia during both the years at 70, 130 and 190 DAS. The data are presented in Table 20.

Greater yam

There was no significant difference in the number of leaves plant^{-1} at any of the growth stages during both the years.

Table 20 (a) Effect of fertilizer levels on the number of leaves plant^{-1} at 70 D A S

	Greater yam		Lesser yam		Tannia	
	'85-86	'86-87	'85-86	'86-87	'85-86	86-87
F_1	177.00	172.77	51.67	81.79	4.33	2.17
F_2	148.67	202.31	55.50	95.39	4.33	2.00
F_3	108.67	282.31	72.00	87.60	4.33	2.50
F test	NS	NS	S	NS	NS	NS
CD (0.05)	-	-	-	-	-	-
SE	34.55	30.38	3.67	3.82	0.33	0.25

S - Significant NS - Not Significant

Table 20 (b) Effect of fertilizer levels on the number of leaves $plant^{-1}$ at 130 DAS

	Greater yam		Lesser yam		Tannia	
	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	758.50	197.19	105.00	155.46	1.25	3.23
F_2	846.50	185.90	120.00	303.78	2.00	3.07
F_3	755.50	241.02	113.00	194.23	1.75	3.77
F test	NS	NS	NS	NS	NS	NS
CD(0.05)	-	-	-	-	-	-
SE	78.57	13.50	42.30	40.50	0.33	0.37

S - Significant NS - Not Significant

Table 20 (c) Effect of fertilizer levels on the number of leaves plant^{-1} at 190 D A S

	Greater yam		Lesser yam		Tannia	
	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	418.00	245.00	79.50	42.5	4.27	1.00
F_2	673.00	295.00	172.50	175.50	5.00	2.00
F_3	722.00	237.50	221.50	65.00	5.33	2.00
F test	NS	NS	NS	S	NS	NS
CD(0.05)	-	-	-	75.23	-	-
SE	109.58	36.50	40.13	29.17	0.87	0.38

S - Significant NS - Not Significant

The leaf number was ma mum at 130 DAS for all the treatments during first y u and th reafter a reduction was observed. During the second year the number of leaves went on increasing upto 190 DAS. There occurred drastic reduction in the numoer of leaves during second year.

Lesser yam

The effect of the treatments was significant only at 190 DAS during the second year. The general trend was an increase in the number of leaves upto 130 DAS and a decline thereafter. The second year crop recorded higher number of leaves plant^{-1}.

Tannia

The number of leaves plant^{-1} of tannia was not significant at any of the fertilizer level.

The maximum number of leaves was recorded at 190 DAS for all the treatments during the first year. The second year crop produced comparatively lesser number of leaves plant^{-1} and a reduction was observed after 130 DAS.

4.2.1.4. Leaf area index (LAI)

The data are presented in Table 21.

There was significant difference between crops in LAI and the LAI was maximum for greater yam during the first year and lesser yam during the second year.

Table 21 (a) Effect of fertilizer levels on the L A I of crops at 70 D A S

Fertilizer levels	Greater Yam 85-86	Greater Yam 86-87	Lesser Yam 85-86	Lesser Yam 86-87	Tannia 85-86	Tannia 86-87	Elephant foot yam 85-86	Elephant foot yam 86-87
F_1	2.65	1.19	0.68	1.17	0.50	0.23	0.99	0.01
F_2	2.28	0.81	0.85	1.38	0.49	0.38	0.71	0.51
F_3	2.21	1.09	0.98	1.51	0.39	0.14	0.75	0.01
Mean	2.35	0.98	0.84	1.36	0.46	0.22	0.82	0.57
F Test	NS	NS	NS	NS	NS	NS	NS	NS

	C.D. (0.05) 1985-86	C.D. (0.05) 1986-87	SE 1985-86	SE 1986-87
Crops:	0.87	0.40	0.29	0.13
treatments:	-	-	0.27	0.24

S - Significant NS - Not Significant

Table 21 (b) Effect of Fertilizer levels on the LAI of crops at 130 D A S

Fertiliser levels	Greater Yam		Lesser Yam		Tannia		Elephant	Foot yam
	85-86	86-87	85-86	86-87	85-86	86-87	85-86	86-87
F_1	5.40	1.61	1.80	2.34	0.42	0.67	1.79	1.17
F_2	3.71	1.75	1.26	2.97	0.41	0.23	1.15	1.12
F_3	4.02	1.25	0.69	2.21	0.48	0.14	1.08	1.00
Mean	4.37	1.54	1.25	2.51	0.44	0.15	1.34	1.10
F test	S	NS	S	S	NS	NS	NS	NS

	CD (0.05)		SE	
	85-86	86-87	85-86	86-87
Crops	0.36	0.31	0.12	0.11
treatments	0.86	0.53	0.29	0.18

S - Significant NS - Not Significant

Table 21(c) Effect of fertilizer levels on the LAI of crops at 190 DAS

Fertilizer levels	Greater Yam 85-86	Greater Yam 86-87	Lesser Yam 85-86	Lesser Yam 86-87	Tannia 85-86	Tannia 86-87	Elephant footyam 85-86	Elephant footyam 86-87
F_1	2.35	1.99	0.87	0.56	0.90	0.09	1.53	1.29
F_2	3.54	2.92	1.24	1.46	1.06	0.11	2.01	0.67
F_3	2.92	1.29	1.01	0.84	1.23	0.112	0.87	0.69
Mean	2.94	2.07	1.04	0.95	1.06	0.10	1.47	0.88
F test	S	S	NS	S	NS	NS	S	NS

	CD (0.05) 1985-86	CD (0.05) 1986-87	SE 1985-86	SE 1986-87
crops:	0.55	0.36	0.19	0.10
Treatments	0.95	0.63	0.33	0.18

S - Significant NS - Not significant

Greater yam

LAI was significantly influenced by different fertilizer levels at 190 DAS during both the years and at 130 DAS in the first year only. LAI was maximum for the treatment F_1 in the first year and F_2 in the second year.

The comparison between stages recorded highest LAI at 130 DAS and thereafter a decline. The reduction was very rapid for the treatment F_1. LAI ranged from 2.21 to 5.40 during first year and 0.81 to 2.92 during second year, thus recording a general reduction in the value during second year.

Lesser yam

There was significant difference in LAI due to treatments at 130 DAS during the first year and at 130 and 190 DAS during the second year. Maximum LAI of 1.80 and 2.97 were recorded by the treatments F_1 and F_2 during the first and second years respectively.

Between stages, there was a decline in LAI with ageing of the crop after 130 DAS, in all the treatments during both the years excepting F_3 during the first year. LAI of F_3 went on increasing upto 190 DAS during the first year. LAI values were high during the second year.

Tannia

The fertilizer levels did not show any significant influence in the LAI of tannia at any of the growth stages during both the years.

Elephant footyam

The LAI of elephant footyam varied significantly due to different fertilizer levels at 190 DAS only in the first year recording highest value by F_2.

4.2.1.5. Net assimilation rate (NAR)

This observation was taken only in the first phase of growth (between 70 and 130 DAS) since there was defoliation and reduction in leaf area at the later stage. The data are presented in Table 22.

Crops differed significantly in NAR and the maximum value was recorded by tannia in the first year and elephant footyam in the second year.

Greater yam

There was no significant difference among treatments and the high fertilizer level (F_1) recorded the lowest NAR in both the years.

Lesser yam

The treatment effects were not significant in both the years. The value ranged from 0.65 to 1.19 g m^{-2} day^{-1} in the first year and 0.54 to 0.83 g m^{-2} day^{-1} during the second year.

Table 22 Effect of fertilizer level on net assimilation rate in $g\,m^{-2}\,day^{-1}$ between 90 and 130 DAS

Fertilizer levels	Greater Yam 85-86	Greater Yam 86-87	Lesser Yam 85-86	Lesser Yam 86-87	Tannia 85-86	Tannia 86-87	Elephant footyam 85-86	Elephant footyam 86-87
F_1	0.84	0.64	1.19	0.54	1.89	0.20	1.11	1.05
F_2	1.32	1.61	0.65	0.83	3.03	0.21	1.17	1.52
F_3	1.96	0.93	1.06	0.56	1.90	0.91	1.49	1.83
Mean	1.38	1.06	0.97	0.64	2.27	0.44	1.26	1.47
F test	NS	NS	NS	NS	NS	NS	NS	NS

	CD (0.05) 85-86	CD (0.05) 86-87	SE 85-86	SE 86-87
Crops	0.92	0.65	0.31	0.22
treatments	-	-	0.54	0.42

S - Significant NS - Not significant

Tannia

The NAR of tannia did not differ significantly in both the years and a maximum value of 3.03 g m^{-2} day^{-1} was recorded by F_2 in the first year.

As compared to first year the second year crop recorded very poor NAR values. The range in NAR was from 1.89 g m^{-2} day^{-1} (F_1) to 3.03 g m^{-2} day^{-1} (F_2) in the first year and from 0.20 g m^{-2} day^{-1} (F_1) to 0.91 (F_3) g m^{-2} day^{-1} in the second year.

Elephant footyam

The treatments did not differ significantly during both the years under study. The crops exhibited the same trend in both the years, showing an increase in NAR with decreasing levels of fertilizer.

4.2.1.6. Crop growth rate (CGR)

The data on crop growth rate are presented in Table 23.

The crops recorded significant difference in the CGR values. Greater yam recorded highest mean value of 2.4 in the first year while more or less same value was given by all the crops in the second year excepting tannia which recorded only very poor value ranging from 0.01 to 0.10 g m^{-2} d^{-1}.

Table 23 Effect of fertilizer level on crop growth rate in gm^{-2} day^{-1} Between 70 and 130 DAS

Fertilizer levels	Greater Yam 85-86	Greater Yam 86-87	Lesser Yam 85-86	Lesser Yam 86-87	Tannia 85-86	Tannia 86-87	Elephant footyam 85-86	Elephant footyam 86-87
F_1	1.86	0.65	0.81	0.70	0.64	0.06	0.55	0.48
F_2	2.87	1.14	0.55	1.49	1.45	0.01	0.72	0.78
F_3	2.49	0.94	1.04	0.79	0.68	0.10	0.66	1.09
Mean	2.40	0.91	0.80	0.99	0.92	0.06	0.64	0.78
F test	S	S	NS	S	NS	NS	NS	S

	CD (0.05) 85-86	CD (0.05) 86-87	SE 85-86	SE 86-87
Crops	0.52	0.23	0.18	0.08
treatments	0.90	0.40	0.31	0.14

S- Significant Ns - Not significant

Greater yam

The influence of fertilizer on the CGR of greater yam was significant during both the years. As in the case of NAR, CGR was also lowest for F_1 in both the years. CGR value ranged from 1.86 to 2.87 g m^{-2} day^{-1} and from 0.65 to 1.14 g m^{-2} day^{-1} during the first and second years respectively. F_3 and F_2 were on par and were significantly superior to F_1 during both the years.

Lesser yam

Lesser yam also showed the same trend on that of NAR recording minimum and maximum values for F_2 during first and second years of the experiment respectively. The effect was significant only during the second year.

Tannia

There was no significant difference among the treatments in any of the years under study. The medium level fertilizer treatment (F_2) was superior in terms of CGR and F_1 (high) and F_3 (low) recorded lower values of 0.64 and 0.68 g m^{-2} day^{-1} respectively.

In general the second year crop exhibited only very poor CGR ranging from 0.01 to 0.10 g m^{-2} day^{-1}.

Elephant footyam

CGR values differed significantly only in the second year of study. The crop performed differently in the two years recording highest CGR value in F_2 and F_3 during the first and second years respectively. The value ranged from 0.55 g m^{-2} day^{-1} to 0.72 g m^{-2} day^{-1} in the first year and 0.48 g m^{-2} day^{-1} to 1.09 g m^{-2} day^{-1} in the second year.

4.2.1.7. Bulking rate

The data are presented in Table 24 .

The crops differed significantly in tuber bulking rate at all growth stages during both the years. The bulking rate was maximum for greater yam followed by elephant footyam at later growth phase.

Greater yam

The influence of fertilizer levels on the bulking rate of greater yam was significant at the second growth phase (between 130 and 190 DAS) in the first year and initial (between 70 and 130 DAS) and later phase (between 190 and harvest) in the second year.

In the first year though bulking rate at higher fertilizer levels recorded significant superiority over

Table 24 (a) Effect of fertilizer level on bulking rate in g day^{-1} $plant^{-1}$ between 70 and 130 DAS

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	0.73	0.18	0.73	0.92	0.41	0.13	0.49	0.29
F_2	1.02	0.48	0.44	1.03	1.08	0.03	0.64	0.64
F_3	1.05	0.51	0.71	0.63	0.71	0.11	1.17	1.03
Mean	0.94	0.39	0.63	0.86	0.73	0.09	0.77	0.65
F test	NS	S	NS	S	S	NS	S	S

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	0.23	0.18	0.08	0.06
treatment	0.41	0.32	0.14	0.11

S - Significant NS - Not Significant

Table 24 (b) Effect of fertilizer level on bulking rate in g day^{-1} $plant^{-1}$ between 130 and 190 DAS

Fertilizer level	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	5.02	3.45	0.03	0.79	0.10	0.29	6.24	3.70
F_2	5.14	1.62	0.43	0.97	0.09	0.04	8.43	1.72
F_3	0.77	2.49	0.03	0.99	0.38	0.05	4.49	2.17
Mean	3.05	2.52	0.17	0.92	0.19	0.12	6.39	2.53
F test	S	NS	NS	NS	NS	NS	S	S

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	0.74	0.95	0.25	0.32
treatments	1.28	1.64	0.44	0.56

S - Significant NS - Not Significant

Table 24 (c) Effect of fertilizer level on bulking rate in g day^{-1} plant^{-1} between 190 DAS and harverst

Fertilizer level	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	5.54	12.50	1.35	0.59	1.63	0.38	1.55	2.92
F_2	4.52	5.10	1.71	1.27	1.06	0.10	0.97	3.36
F_3	0.88	0.60	0.92	0.62	1.45	0.16	3.76	5.92
Mean	5.65	5.13	1.33	0.83	1.38	0.21	2.09	4.06
R test	NS	S	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	1.78	2.05	0.61	0.90
treatments	-	4.59	1.09	1.57

S - Significant NS - Not Significant

the lowest level(F_5)at the second phase of growth it was maximum for the treatment F_3 at harvest stage though not significant. But in the second year the high fertilizer treatment recorded significantly superior bulking rate over others.

Lesser yam

The fertilizer levels had significant influence on the bulking rate of lesser yam only at first growth phase in the second year. It was maximum for the treatment F_2 and the values ranged from 0.92 g day^{-1} $plant^{-1}$ to 1.71 g day^{-1} $plant^{-1}$ during the first year and from 0.59 g day^{-1} $plant^{-1}$ to 1.27 g day^{-1} $plant^{-1}$ during the second year at later stage .

Tannia

The bulking rate of tannia was significantly influenced by fertilizer treatments at the first growth phase of the crop during the first year. During the second year a drastic decline in bulking rate was observed. The bulking rate ranged from 1.06 to 1.63 g day^{-1} $plant^{-1}$ and from 0.1 to 0.38 g day^{-1} $plant^{-1}$ in the first and second year respectively. There was a steady increase in bulking rate with advancing age of the crop during both the years.

Elephant footyam

The interaction effect of treatment was significant only at first and second growth phases during the two years of study. During both the years, the bulking rate was maximum for F_3 at later stage. The bulking rate ranged from 1.55 g day^{-1} $plant^{-1}$ to 3.76 g day^{-1} $plant^{-1}$ during the first year and from 2.92 g day^{-1} $plant^{-1}$ to 5.92 g day^{-1} $plant^{-1}$ during the second year at later growth phase.

Unlike other crops the bulking rate decreased steadily after second growth phase in all the treatments during the first year and for the treatment F_1 during the second year.

4.2.2. Dry matter production and distribution

4.2.2.1. Leaf dry matter

The data on leaf dry matter production at various growth stages are presented in Table 25.

There was significant variation among the tuber crops under study in leaf dry matter production. The highest value was recorded by greater yam and lowest by

Table 25. Effect of fertilizer levels on dry weight of leaves in kg ha^{-1} at 70 DAS

Treatment	Greater Yam 85-86	Greater Yam 86-87	Lesser Yam 85-86	Lesser Yam 86-87	Tannia 85-86	Tannia 86-87	Elephant footyam 85-86	Elephant footyam 86-87
F_1	320.84	285.05	82.60	238.95	47.96	57.59	125.00	107.50
F_2	283.62	277.65	107.68	433.65	47.30	92.55	163.33	120.00
F_3	251.12	360.95	121.54	389.40	39.49	28.79	189.17	220.00
Mean	285.26	307.68	103.94	354.00	44.92	59.64	159.17	149.17
F test	NS	NS	NS	S	NS	NS	NS	NS

	CD (0.05) 85-86	CD (0.05) 86-87	SE 85-86	SE 86-87
crops	72.04	69.65	24.56	23.75
treatments	-	120.64	42.58	41.13

S - Significant NS - Not Significant

Table 25 (b) Effect of fertilizer level on the dry weight of leaves in $kg ha^{-1}$ at 130 DAS

Treatment	Greater Yam 85-86	Greater Yam 86-87	Lesser Yam 85-86	Lesser Yam 86-87	Tannia 85-86	Tannia 86-87	Elephant footyam 85-86	Elephant footyam 86-87
F_1	1273.5	385.63	368.83	477.90	163.51	16.45	260.83	230.00
F_2	1204.85	596.49	292.05	929.25	194.36	55.53	250.22	262.50
F_3	1330.25	413.39	194.7	568.61	126.49	78.56	294.43	301.67
Mean	1289.53	465.64	285.19	658.59	161.45	50.18	268.49	262.31
F test	NS	S	NS	S	NS	NS	NS	NS

	CD (0.05) 85-86	CD (0.05) 86-87	SE 85-86	SE 86-87
crops	116.40	94.4	39.69	32.19
treatments	-	163.51	-	55.75

S - Significant NS - Not Significant

Table 25 (c) Effect of fertilizer level on the dry weight of leaves in $kgha^{-1}$ at 190 DAS

Treatment	Greater Yam 85-86	Greater Yam 86-87	Lesser Yam 85-86	Lesser Yam 86-87	Tannia 85-86	Tannia 86-87	Elephant footyam 85-86	Elephant footyam 86-87
F_1	851.46	753.36	380.55	227.33	234.46	24.68	365.00	378.00
F_2	1357.40	1551.14	539.85	669.65	339.35	30.85	540.00	223.00
F_3	999.54	407.22	376.13	311.52	401.05	94.61	302.50	298.50
Mean	1069.47	903.91	432.81	402.[illegible]3	324.95	50.04	402.50	299.63
F test	S	S	NS	S	NS	NS	S	NS

	CD (0.05) 85-86	CD (0.05) 86-87	SE 85-86	SE 86-87
crops	186.27	169.32	63.52	57.74
treatments	322.63	293.28	110.00	100.01

S- Significant NS - Not Significant

Table 25 (d) Effect of fertilizer level on the weight in kg ha^{-1} of leaves at harvest stage

Treatment	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	252.97	226.32	271.40	153.21	168.05	17.93	460.00	214.4
F_2	378.43	437.09	305.80	340.29	248.86	23.28	875.00	448.33
F_3	139.85	70.39	253.70	203.71	345.52	151.72	406.67	480.17
Mean	257.08	244.60	296.97	234.40	226.92	64.3	681.81	462.83
F test	NS	S	NS	NS	NS	NS	S	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	163.16	130.16	55.64	46.43
treatments	282.60	235.84	96.37	80.42

NS - Not Significant S - Significant

tannia during both the years. Interaction effect of fertilizer to different crops was also significant.

Greater yam

It is seen that the treatment F_2 recorded significantly higher leaf dry matter during both the years. It is also seen that the leaf dry matter production recorded a higher value at most of the growth stages in all the treatments during the first year than during second year.

Lesser yam

It is seen that the treatments differed significantly during the second year and maximum value was recorded by F_2 during both the years. Though there was a steady increase in the leaf dry weight upto 190 DAS in first year, this character showed a decline after 130 DAS during the second year.

The second year crop recorded higher leaf dry matter as compared to first year.

Tannia

The treatments did not show any significant variation at any of the growth stages.

The lowest fertilizer level recorded higher leaf dry matter during both the years. Tannia exhibited an increase in leaf dry weight upto 190 DAS during the first year though there was no general trend in the second year. The crop recorded very drastic reduction in leaf dry matter production during the second year.

Elephant footyam

The leaf dry matter production was not significantly influenced by different fertilizer levels at any of the growth stages during the first year excepting at harvest and F_2 recorded the highest value. The dry weight went on increasing upto the later stage of the crop during both the years.

During the later phase of growth, the first year crop recorded higher values than second year though there were not much differences during the early stages.

4.2.2.2. Stem dry matter production

The data on stem dry matter production are presented in Table 26.

Crops differed significantly in stem dry matter production. During both the years, greater yam recorded significantly higher stem dry matter at all stages of growth.

Greater yam

Although the treatments recorded significant influence at most of the growth stages this influence

Table 26 (a) Effect of fertilizer levels on dry weight of stem in kg ha^{-1} at 70 DAS

Treatment	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	575.79	561.47	135.70	216.82	178.27	102.83	279.00	75.00
F_2	444.24	376.37	129.80	265.50	209.78	89.47	203.33	67.50
F_3	459.46	604.66	128.33	283.20	183.87	92.55	335.00	177.50
Mean	493.19	514.17	131.28	255.17	190.64	94.95	272.94	106.67
F test	NS	S	NS	NS	NS	NS	NS	S

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	181.66	58.78	61.95	20.04
treatments	_	101.81	107.28	34.71

S - Significant NS - Not Significant

Table 26 (b) Effect of fertilizer levels on dry weight of stem in kg ha^{-1} at 130 DAS

Treatment	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	1456.12	940.93	398.33	331.88	169.68	32.91	510.00	244.00
F_2	1598.02	1184.64	204.14	709.95	230.35	55.53	345.00	282.50
F_3	1675.11	977.94	362.85	513.30	160.42	69.93	225.00	290.00
Mean	1576.47	1034.48	321.78	538.38	186.81	52.79	360.00	106.76
F test	S	S	S	S	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	179.01	173.27	61.25	42.03
treatments	311.09	213.51	106.08	72.81

S - Significant NS - Not Significant

Table 26 (c) Effect of fertilizer levels dry weight of stem in kg ha^{-1} at 190 DAS

Treatment	Greater yam		Lesser yam		Tannia		Elephant footyam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	1573.35	3186.93	269.92	261.08	348.61	14.41	427.50	685.00
F_2	1742.82	1977.49	411.53	384.98	561.47	46.11	635.00	367.50
F_3	1048.77	1030.39	316.48	227.45	635.51	22.65	372.00	331.50
Mean	1454.98	2504.35	332.64	291.17	515.64	27.72	478.33	599.30
F test	S	S	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	200.01	692.58	68.20	236.16
treatments	346.43	1199.59	118.13	409.05

S - Significant NS - Not Significant

Table 26 (d) Effect of fertilizer levels on dry weight of stem in kg ha^{-1} at harvest

Treatment	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	623.17	590.85	262.55	70.13	401.05	21.75	243.33	393.20
F_2	569.70	375.68	386.45	147.22	442.18	24.41	340.00	220.1
F_3	775.36	600.80	209.45	65.32	569.70	10.16	193.33	181.50
Mean	656.08	522.44	286.15	95.27	470.98	18.78	258.89	264.93
F test	NS	NS	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	183.16	187.25	62.46	63.85
treatments	-	-	108.16	110.63

S - Significant NS - Not Significant.

could not maintain any well defined pattern. The maximum dry weight of stem was recorded at 190 DAS for most of growth stages during both the years.

Lesser yam

Treatments differed significantly only at 130 DAS during second year recording maximum value for medium fertilizer level (F_2). In general, the stem dry matter went on increasing upto 130 DAS and thereafter a decline was observed during both the years.

The stem dry matter was comparatively higher during second year as compared to first year.

Tannia

The fertilizer levels did not influence the stem dry matter of tannia at any of the growth stages during both the years. The data revealed that the dry weight increased upto harvest stage in the first year. There occurred drastic reduction in dry matter production of stem during the second year as compared to the first year.

Elephant footyam

The stem dry matter production of elephant footyam was influenced significantly by the fertilizer levels only at 70 DAS of second year. The highest value was recorded by F_2 during the first year and F_1 during the second year at later stages of growth of the crop though not significant.

In general, the dry weight of stem increased with ageing of the crop upto 190 DAS after which there occurred a decline during both the years and for all the treatments.

4.2.2.3. Tuber dry matter

The data on tuber dry matter at various growth stages during the first and second years are presented in Table 27.

The crops differed significantly in tuber dry matter production and the maximum dry matter was recorded by greater yam followed by elephant footyam. The increase in dry matter yield of greater yam from 190 DAS to harvest was very significant during both the years. Elephant footyam out yielded all the other crops in tuber dry matter yield upto 190 DAS. But later, the increment in dry matter yield of greater yam at F_1 and F_2 levels was so high that it out yielded all the other crops including elephant footyam at harvest.

Greater yam

There was significant difference in dry weight of tuber at 190 DAS during first year and at 130 DAS

Table 27 (a) Effect of fertiliser levels on dry weight of tuber in kg ha^{-1} at 70 DAS

Treatment	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	92.22	120.32	29.50	39.83	37.84	49.36	211.67	220.00
F_2	70.10	148.08	29.50	61.95	32.91	148.08	265.00	288.00
F_3	103.66	170.29	33.60	30.98	26.74	135.74	278.33	267.50
Mean	90.66	146.09	30.88	43.66	32.49	111.06	251.67	258.39
F test	NS	NS	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	63.15	79.46	21.53	27.09
treatments	-	-	37.29	46.92

NS - Not Significant

Table 27 (b) Effect of fertilizer levels on dry weight of tuber in kg ha^{-1} at 130 DAS

Treatment	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	635.51	252.97	767.00	1010.67	336.47	131.63	500.00	395.00
F_2	832.95	505.94	501.50	1150.50	829.87	168.55	650.00	673.33
F_3	879.43	542.96	767.71	693.84	552.22	218.01	978.00	885.00
Mean	782.63	433.96	678.74	951.87	512.85	172.76	709.22	651.11
F test	NS	S	NS	S	S	NS	S	S

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	159.95	718.61	54.54	40.44
treatments	277.04	205.44	94.47	70.05

S - Significant NS - Not Singnificant

Table 27 (c) Effect of fertilizer levels on dry weight of tuber in kg ha^{-1} at 190 DAS

Treatment	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	4353.55	2129.27	802.40	1288.71	265.31	343.46	4247.00	2617.33
F_2	4642.93	1661.58	955.09	1520.69	765.08	197.44	5707.00	1708.00
F_3	1441.93	2628.42	801.22	1745.81	755.83	253.38	3673.00	2188.00
Mean	3483.58	2139.76	852.9	1518.41	595.43	264.76	6542.32	2171.11
F test	S	NS	NS	NS	NS	NS	S	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	468.61	572.23	159.79	195.13
treatments	811.00	996.39	276.77	339.76

S - Significant NS - Not Significant

Table 27 (d) Effect of fertilizer on dry weight of tuber in kg ha^{-1} at harvest

Treatment	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	8456.85	8786.20	2239.64	2267.96	1474.63	496.69	5175.57	4369.67
F_2	7986.03	5480.61	2770.64	3527.84	1554.84	271.48	6285.43	3721.00
F_3	6554.18	2698.88	1776.37	2405.13	1877.74	370.20	5930.03	5742.23
Mean	7065.69	5655.23	2262.22	2733.65	1635.74	369.32	5797.01	4584.33
F test	NS	S	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	1246.35	1966.40	425.00	670.53
treatments	-	3405.90	736.00	1161.39

S - Significant NS - Not Significant

and at harvest during the second year. The maximum dry weight was recorded by F_1 during both the years and with decrease in fertilizer level the dry weight of tuber also decreased though it was appreciable only during the second year.

It is seen that the dry weight of tuber increased upto harvest stage and the increase was significant between 190 DAS and harvest which contributed very high increase for most of the treatments from the previous stage.

The data also revealed that there was almost equal dry matter yield for the treatment F_1 during both the years. But for the lower fertilizer levels, second year crop recorded significant reduction with decrease in fertilizer level.

Lesser yam

The dry weight of tuber differed significantly only at 130 DAS during the second year. The tuber dry weight was maximum for medium fertilizer level (F_2) during both the years though not significant at most of the growth stages.

With ageing of the crop, the dry weight also increased and maximum was attained at harvest during both the years for all the treatments. The second year crop produced higher tuber dry matter than first year crop.

Tannia

The tuber dry weight was not significantly influenced by fertilizer levels at any of the growth stages excepting at 130 DAS during the first year.

The maximum tuber dry weight of 1877.74 kg ha^{-1} was recorded by F_3 at harvest during the first year. The second year crop yielded very poor dry matter at all growth stages for all the fertilizer treatments. The range in dry matter production was only 271.48 (F_2) to 496.69 kg ha^{-1} (F_1) at the harvest stage of the second year crop.

The tuber dry weight went on increasing with advancement in the age of the crop and maximum was attained at the harvest stage. The increase in dry weight of tuber was maximum between 190 DAS and harvest.

Elephant footyam

There were significant differences in tuber dry weight at 190 DAS and 130 DAS during the first year and at 190 DAS alone during second year. The maximum dry weights of 6285 kg ha^{-1} and 5742 kg ha^{-1} were recorded by treatment F_2 in first year and F_3 in the second year respectively.

The tuber dry weight went on increasing with ageing of the crop during both the years. Maximum dry weight increase was observed for this crop between 130 DAS and 190 DAS and there after the rate of accumulation decreased considerably.

4.2.2.4. Total dry matter production

The data on total phytomass production at different growth stages of greater yam, lesser yam, tannia and elephant footyam are presented in Table 28 and Fig. 13.

The crops differed significantly in total dry matter production at all growth stages during both the years. Greater yam recorded maximum dry matter accumulation in most of the growth stages and was significantly superior to other crops. Elephant footyam was the second best producer of dry matter and it maintained statistical parity with greater yam at the harvest stage during the second year.

Greater yam

Significant differences were observed only at 190 DAS during the first year. At the harvest stage, the dry weight ranged from 9121.3 kg ha^{-1} in F_1 to 7637.6 kg ha^{-1} in F_3 and an increase in dry weight with increasing fertilizer level was observed though the effect was not statistically significant.

During the second year, the treatments differed significantly at all the growth stages. At initial growth

Table 28 (a) Effect of fertilizer level on total dry weight in kg ha^{-1} at 70 DAS

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	989.26	966.84	247.60	495.60	263.25	209.78	615.67	402.67
F_2	804.16	802.10	296.48	761.10	289.99	330.30	631.67	475.33
F_3	740.07	1139.39	400.31	703.28	250.09	257.08	802.50	665.00
Mean	844.50	969.44	314.86	653.33	267.78	265.72	683.28	514.33
F test	NS	S	NS	NS	NS	NS	NS	

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	297.63	159.14	101.57	54.27
treatments	-	278.91	175.90	95.11

S - Significant NS - Not Significant

Table 28 (b) Effect of fertilizer level on total dry weight in kg ha^{-1} at 130 DAS

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	3360.60	1579.52	1817.20	1820.45	669.70	181.40	1242.51	869.00
F_2	3689.70	2289.07	881.20	2855.60	1254.70	279.71	1245.00	1218.50
F_3	3880.80	1934.50	1339.30	1777.08	889.10	360.50	1498.33	1536.06
Mean	3643.70	1934.86	1382.60	2151.04	921.11	275.87	1338.10	1208.06
F test	NS	S	S	S	S	NS	NS	S

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	320.05	218.91	109.14	74.65
treatments	554.33	377.91	189.02	128.87

S. Significant NS Not Significant.

Table 28 (c) Effect of fertilizer level on total dry weight in kg ha^{-1} at 190 DAS

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	6778.66	6733.73	1385.03	2369.44	847.35	382.54	5040.00	3680.33
F_2	7743.80	6550.48	1906.88	3353.56	1665.90	288.35	6882.10	2298.50
F_3	3488.10	3822.64	1470.28	2284.78	1791.40	370.61	4347.70	2818.00
Mean	5003.30	5702.29	1567.40	2669.26	1434.90	347.17	5423.24	2932.28
F test	S	S	NS	NS	NS	NS	S	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	662.77	1309.97	226.00	446.69
treatments	1182.57	2268.94	403.25	773.70

S - Significant NS - Not Significant

Table 28 (d) Effect of fertilizer levels on total dry weight in kg ha^{-1} at harvest

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	9121.30	8787.85	2773.60	2475.05	1958.80	536.37	6148.70	5222.87
F_2	8932.10	5480.60	3522.90	3527.51	2245.90	319.17	8115.30	4389.43
F_3	7637.60	2698.88	2239.05	2404.84	2747.70	532.08	6600.00	6404.00
Mean	8563.70	5655.77	2345.20	2802.50	2317.50	462.54	6954.70	4611.00
F test	NS	S	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	1326.74	1976.61	452.41	674.01
treatments	-	3423.58	783.47	1167.42

S - Significant NS - Not Significant

stages, lower levels of fertilizer treatments recorded maximum dry weight. But at 190 DAS and at harvest stage the highest fertilizer treatment (F_1) gave maximum dry weight which was statistically on par with F_2 and significantly superior to F_3. With advancing age of the crop the dry weight increased considerably in both the years.

Lesser yam

The effect of different fertilizer levels on the dry matter production of lesser yam was significant only at 130 DAS during both the years.

The dry weight at harvest stage ranged from 2239.05 kg ha^{-1} to 3522.9 kg ha^{-1} during the first year and 2404.84 kg ha^{-1} to 3529.51 kg ha^{-1} during the second year and during both the years the dry weight was maximum for treatment F_2 though not significant. Over the stages there was increase in dry matter accumulation upto harvest.

Tannia

The dry matter production did not differ significantly between treatments at any of the growth stages except at 130 DAS and that too only during the first year.

Compared to first year, the dry matter production was considerably less during the second year. At harvest

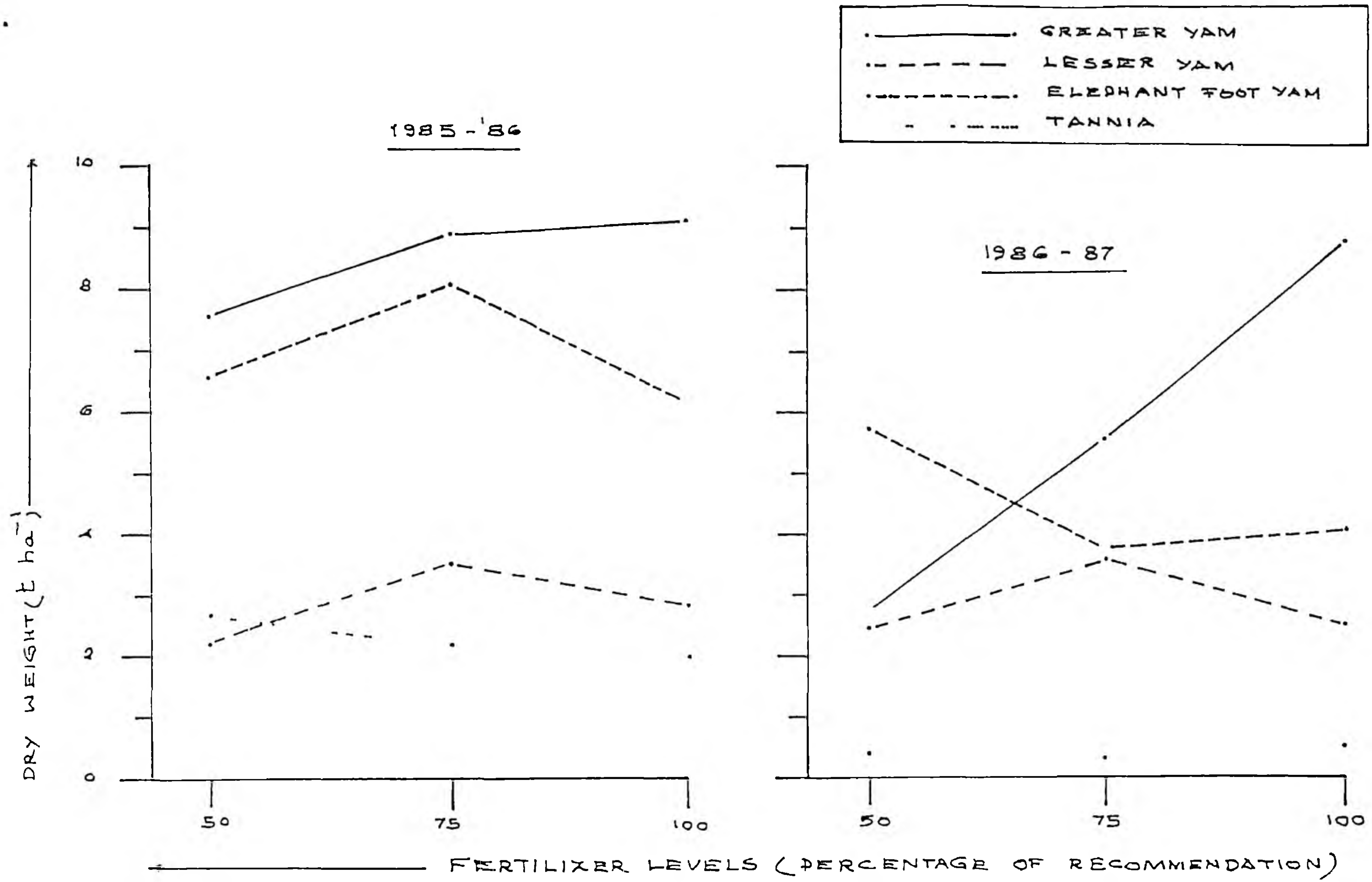


FIG 13 EFFECT OF FERTILIZER ON TOTAL DRY MATTER PRODUCTION ($t\ ha^{-1}$)

stage, the range in dry weight was from 1958.8 kg ha^{-1} to 2747.7 kg ha^{-1} and from 319.17 kg ha^{-1} to 536.37 kg ha^{-1} during the first and second years respectively.

Over the stages a steady increase in dry weight was observed during the first year. A reduction in dry weight was observed between the initial stages and further improvement was very slow during the second year.

Elephant footyam

Fertilizer levels recorded significant difference in total phytomass production of elephant footyam at 190 DAS and 130 DAS during the first and second years respectively. The dry weight was maximum for F_2 and F_3 during first and second year respectively. A reduction in dry matter production was observed in the second year as compared to the first year for all the treatments. But the dry weight increased steadily with ageing of the crop.

4.2.3. Yield and yield attributes

The data on yield attributes are presented in Table 29.

4.2.3.1. Length of tuber

This character was recorded only for greater yam and lesser yam.

Table 29 (a) Effect of fertilizer level on the length and girth of tuber of greater yam

Fertilizer levels	Length of tuber (cm)		Girth of tuber (cm)	
	1985-86	1986-87	1985-86	1986-87
F_1	25.33	24.15	40.67	39.25
F_2	22.83	21.15	43.17	31.35
F_3	20.05	21.15	43.33	33.70
F test	S	NS	NS	S
CD (0.05)	4.43	-	-	6.52
SE	1.51	1.36	1.53	2.22

Table 29 (b) Effect of fertilizer levels on the number, length and girth of tubers per plant of lesser yam

Fertilizer levels	No. of tubers $plant^{-1}$		Length of tuber (cm)		Girth of tuber (cm)	
	1985-86	1986-87	1985-86	1986-87	1985-86	1986-87
F_1	7.33	17.33	13.00	13.78	13.50	11.73
F_2	5.67	25.00	12.50	12.0	12.20	11.53
F_3	5.33	25.67	12.20	12.27	11.23	11.5
F test	NS	NS	NS	NS	NS	NS
CD (0.05)	-	-	-	-	-	-
SE	1.02	2.94	1.36	0.84	0.38	0.65

NS - Not Significant

Table 29 (c) Effect of fertilizer levels on the number and weight of cormels per plant of Tannia

Fertilizer levels	No. of cormels plant^{-1}		Weight of cormels g plant^{-1} (g)	
	1985-86	1986-87	1985-86	1986-87
F_1	9.0	3.98	73.5	32.50
F_2	7.0	3.27	117.0	54.67
F_3	6.67	2.65	108.17	66.87
F test	NS	NS	S	NS
CD (0.05)	-	-	69.80	-
SE	1.25	0.47	23.80	17.28

S- Significant NS - Not Singnificant

Greater yam

The length of tuber was significantly influenced by fertilizer treatments in the first years while it lacked statistical significance during the second year. The plants receiving full dose of fertilizer (F_1) recorded maximum length and was significantly superior to F_3 but was on par with F_2.

Lesser yam

The fertilizer levels did not significantly influence the length of the tuber in any of one year under study.

4.2.3.2. Girth of tuber

This attribute was recorded only for greater yam and lesser yam.

Greater yam

The girth of tuber was significantly influenced by the fertilizer treatments only during the second year. F_1 recorded the maximum girth which was significantly superior to F_2 but was on par with F_3.

Lesser yam

There was no significant influence on the girth of tuber of lesser yam during both the years.

4.2.3.3. Number of tubers per plant

This attribute was recorded only for lesser yam.

Lesser yam

The fertilizer treatments did not significantly influence the number of tubers per plant in any of the year under study. The number of tubers was considerably high during the second year. The values ranged from 5.33 to 7.33 and from 17.33 to 25.67 in the first and second years respectively.

4.2.3.4. Number and weight of cormels per plant of tannia

The treatments failed to show any significant influence on the number of cormels per plant during both the years while the weight of cormel per plant differed significantly during the first year and F_3 recorded highest values of 168.17 g $plant^{-1}$

4.2.3.5. Tuber yield

The data on the yield of tuber are presented in Table 30 and Fig 14

Crops differed significantly in tuber yield during both the years. Tuber yield was maximum for elephant footyam and was significantly superior to all the other crops. The crops in the decreasing order of mean tuber yield were elephant footyam, greater yam, lesser yam and tannia and the respective yields were 30.65, 24.71, 8.65 and 4.70 t ha^{-1} during first year. In the second year also the trend was the same, but an over all decline in the yield was observed for all crops except lesser yam which recorded conspicuous increase in yield during the second year.

Greater yam

The effect of fertilizer levels on the yield of the crop was significant only in the second year. The highest fertilizer level recorded maximum yield. The yield declined steadily with decrease in fertilizer level during both the years.

The range in tuber yield was from 21.18 t ha^{-1} to 27.35 t ha^{-1} and from 10.37 t ha^{-1} to 25.74 t ha^{-1} during the first and second years respectively.

Lesser yam

The maximum yield was recorded by F_2 during both the years. The yield ranged from 7.05 to 11.15 t ha^{-1} and from 10.96 to 15.20 t ha^{-1} during the first and second year respectively.

Table 30 Effect of fertilizer levels on tuber yield in t ha^{-1}

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87	'85-86	'86-87
F_1	27.35	25.74	7.76	10.96	3.45	1.68	27.50	22.09
F_2	25.58	16.86	11.15	15.20	4.89	2.03	33.15	17.69
F_3	21.18	10.37	7.05	14.79	5.76	0.88	31.30	23.45
Mean	24.71	17.66	8.05	13.65	4.70	1.53	30.65	22.18
F test	NS	S	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	4.50	6.38	1.53	2.17
treatments	-	12.76	2.66	4.35

S - Significant NS - Not Significant

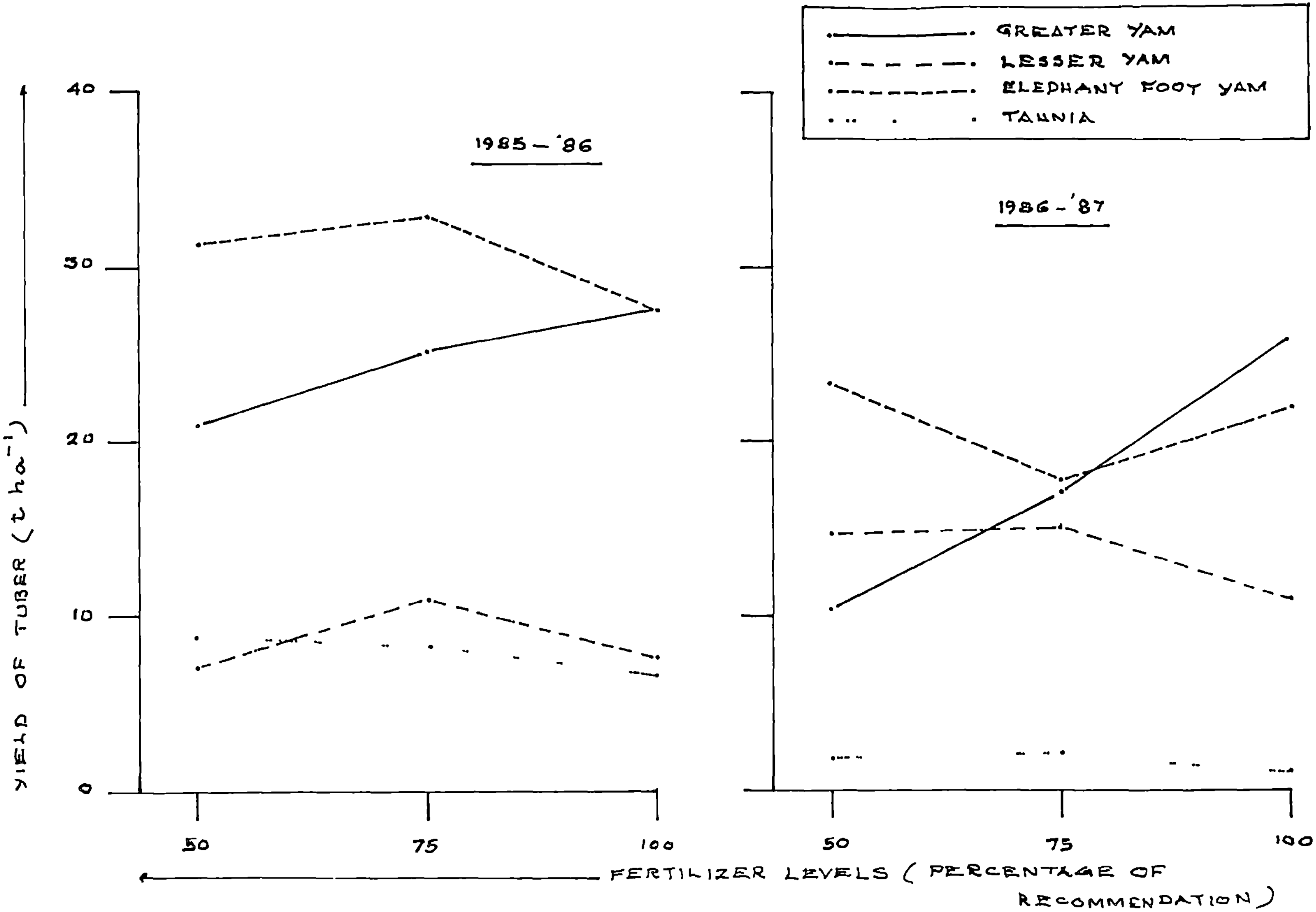


FIG 14 EFFECT OF FERTILIZER LEVELS ON TUBER YIELD

Tannia

The general yield level of the crop was comparatively low and the effect of treatment was also not significant. The lowest fertilizer level recorded the highest yield during the first year while medium fertilized crop gave the maximum yield in the second year. The yield ranged from 3.45 to 5.78 t ha^{-1} in the first year and from 0.88 to 2.03 t ha^{-1} in the second year.

Elephant footyam

The yield did not differ significantly due to fertilizer level. The maximum yield was for F_2 in the first year and for F_3 in the second year. The yield ranged from 27.5 to 33.15 t ha^{-1} in the first year and from 17.69 to 23.45 t ha^{-1} in the second year.

4.2.3.6. Top yield

The data on top yield are presented in Table 31.

There was significant difference between the crops in the top yield. As in the case of tuber yield mean top yield was also maximum for elephant foot yam. The crops in the descending order of mean top yield were elephant footyam, greater yam, tannia and lesser yam in the first year and elephant footyam, greater yam, lesser yam and tannia in the second year. During the second year as in the case of tuber yield, top yield was also very poor in tannia.

Greater yam

There was significant difference in the top yield of the crop due to fertilizer levels and F_2 recorded maximum value of 19.26 t ha^{-1} in the first year and 16.00 t ha^{-1} in the second year and was on par with F_1 and significantly superior to F_3.

Lesser yam

Top yield did not vary significantly due to fertilizer levels during the first year but there was significant difference in the second year. The value ranged from 2.60 to 4.42 t ha^{-1} in first year and from 2.01 to 6.81 in the second year. Comparison between years showed higher value during the second year.

Tannia

Top yield showed decreasing trend with increasing fertilizer levels and F_3 (lowest fertilizer level) was significantly superior to F_1 but was on par with F_2 in the first year.

The second year crop recorded very poor top yields.

Table 31 Effect of fertilizer levels on top yield in t ha^{-1}

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	'86-87	'85-86	'86-87	'86-86	'86-87	'85-86	'86-87
F_1	14.20	12.58	4.42	2.01	9.78	0.88	15.12	17.28
F_2	19.26	16.00	3.38	6.81	16.32	0.88	19.10	9.69
F_3	1043	5.85	2.60	3.01	17.46	2.50	11.63	9.50
Mean	14.63	11.47	3.47	3.94	14.52	1.42	15.28	12.16
F test	S	S	NS	S	S	NS	S	S

	CD (0.05)		SE	
	'85-86	'86-87	'85-86	'86-87
crops	3.16	2.41	1.08	0.82
treatments	5.48	4.17	1.89	1.42

S - Significant NS - Not Significant

Eleaphnt footyam

The variation in top yield between fertilizer levels was significant during both the years and treatment F_2 and F_1 recorded maximum yield during first and second years respectively.

4.2.3.7. Utilisation index

The data on the utilisation index are presented in Table 32.

Crops differed significantly in utilisation index during both the years. Lesser yam recorded maximum utilisation index which was significantly superior to all the other crops.

Utilisation index differed significantly due to fertilizer treatments during the second year of study.

The interaction effect was significant during both the years.

Greater yam

Fertilizer levels significantly influenced the utilisation index during the second year and the maximum was for F_3 (lower fertilizer dose). The utilisation index ranged from 1.44 to 2.03 in the first year and from 0.97 to 2.57 in the second year.

Table 32 Effect of fertilizer level on utilisation index

Fertilizer levels	Greater yam '85-86	Greater yam '86-87	Lesser yam '85-86	Lesser yam '86-87	Tannia '85-86	Tannia '86-87	Elephant foot yam '85-86	Elephant foot yam '86-87
F_1	1.66	1.84	2.05	5.13	0.28	1.80	2.33	1.[illegible]
F_2	1.44	0.97	3.28	1.89	0.37	1.20	2.86	1.36
F_3	2.03	2.57	2.71	2.19	0.37	1.87	2.54	1.72
Mean	1.71	1.79	2.68	3.07	0.34	1.61	2.45	1.[illegible]
F test	NS	S	NS	S	NS	NS	NS	NS

	CD (0.05) '85-86	CD (0.05) 86-87	SE '85-86	SE 86-87
crops	0.46	0.91	0.16	0.31
treatment	-	1.56	0.27	0.53

S - Significant NS - Not Significant

Lesser yam

Significant difference in utilisation index was observed only in the second year. The utilisation index was maximum for the highest fertiliser level (F_1) which was significantly superior to the other two treatments. The value ranged from 2.05 to 3.28 in the first year and from 1.89 to 5.13 in the second year.

Tannia

The fertilizer levels failed to show any significant influence on the utilisation index during both the years under study. The utilisation index ranged from 0.28 to 0.37 and from 1.20 to 1.84 during the first and second years respectively.

Elephant footyam

The influence of the treatments was similar to that of tannia where all the treatments were statistically on par. The values ranged from 2.33 to 2.86 and from 1.36 to 1.72 for the first and second years respectively.

4.2.4. Chemical analysis

4.2.4.1. Uptake of nitrogen

The data on total nitrogen uptake are presented in Table 33 and Fig.15.

The crops differed significantly in total nitrogen uptake. The mean uptake at harvest ranged from 27.11 kg ha^{-1} to 114.60 kg ha^{-1} by tannia and elephant footyam respectively in the first year. In the second year a general reduction in the total uptake was observed. The mean uptake of nitrogen ranged from 4.52 to 76.63 kg ha^{-1} by tannia and elephant footyam.

Greater yam

The effect of fertilizer levels on the total uptake of nitrogen was significant at 130 and 190 DAS during the first year whereas during the second year, all the treatments were on par. At harvest stage, the uptake was maximum for the highest fertilizer level during both the years and with decreasing fertilizer levels a steady decrease in uptake was observed though not significant.

The uptake went on increasing upto harvest in the first year while a reduction was observed after 190 DAS in the second year.

Lesser yam

The uptake of nitrogen was significantly influenced by fertilizer levels at 130 DAS during the second year.

Table 33 (a) Effect of fertilizer level on total nitrogen uptake in kg ha^{-1} at 70 DAS

Fertilizer levels	Greater yam '85-86	Greater yam 86-87	Lesser yam '85-86	Lesser yam 86-87	Tannia '85-86	Tannia 86-87	Elephant foot yam '85-86	Elephant foot yam 86-87
F_1	14.47	20.60	3.84	10.00	4.88	2.78	14.49	7.57
F_2	10.33	16.30	5.10	10.03	5.60	4.10	18.66	3.76
F_3	10.25	21.23	4.27	10.47	4.31	4.21	16.04	[illegible].37
Mean	11.68	19.38	4.40	10.14	4.93	3.70	16.40	10.88
F test	NS	NS	NS	NS	NS	NS	NS	NS

	CD (0.05) '85-86	CD (0.05) 86-87	SE '85-86	SE '86-87
crops	5.90	2.73	2.01	0.93
treatments	3 -	-	3.49	1.61

NS - Not Significant

Table 33 (b) Effect of fertilizer level on total nitrogen uptake in kg ha^{-1} at 130 DAS

Fertilizer level	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	57.15	23.20	20.97	31.67	15.93	3.20	21.93	23.01
F_2	66.30	22.33	14.90	31.50	32.73	4.49	24.83	23.40
F_3	78.23	25.50	17.80	22.78	20.07	7.32	36.93	24.47
Mean	67.23	27.08	17.89	28.65	22.91	5.00	27.90	23.63
F test	S	NS	NS	S	S	NS	S	NS

	CD (0.05)		SE	
	'85-86	86-87	'85-86	86-87
crops	6.17	5.11	2.10	1.74
treatments	10.69	8.85	3.65	3.02

S - Significant NS - Not Significant

Table 33 (c) Effect of fertilizer level on total nitrogen uptake in kg ha^{-1} at 190 DAS

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	78.00	79.46	17.10	35.50	20.03	12.90	91.03	47.40
F_2	114.10	97.20	23.37	44.00	26.60	8.80	159.73	29.40
F_3	53.53	81.47	20.53	23.20	29.17	14.80	81.07	30.30
Mean	81.88	86.04	20.33	34.40	25.27	12.17	110.61	37.70
F test	S	S	NS	NS	NS	NS	S	NS

	CD (0.05)		SE	
	'85-86	86-87	'85-86	86-87
crops	13.51	21.58	4.61	7.36
treatments	23.41	-	7.98	12.74

S - Significant NS - Not Significant

Table 33 (d) Effect of fertilizer level on total nitrogen uptake in kg ha^{-1} at harvest

Fertilizer level	Greater yam '85-86	Greater yam 86-87	Lesser yam '85-86	Lesser yam 86-87	Tannia 85-86	Tannia 86-87	Elephant root yam '85-86	Elephant root yam 86-87
F_1	101.43	79.20	35.27	30.23	22.30	5.63	101.50	68.03
F_2	94.17	61.13	28.37	39.37	31.65	4.15	135.57	72.30
F_3	83.77	30.40	22.40	24.00	27.40	3.77	106.73	89.55
Mean	63.12	50.91	28.68	31.20	27.11	4.52	114.60	70.63
F test	NS	NS	NS	NS	NS	NS	NS	NS

	CD (0.05) '85-86	CD (0.05) 86-87	SE '85-86	SE 86-87
crops	49.26	23.98	16.79	8.18
treatments	-	-	29.09	14.16

NS - Not Significant

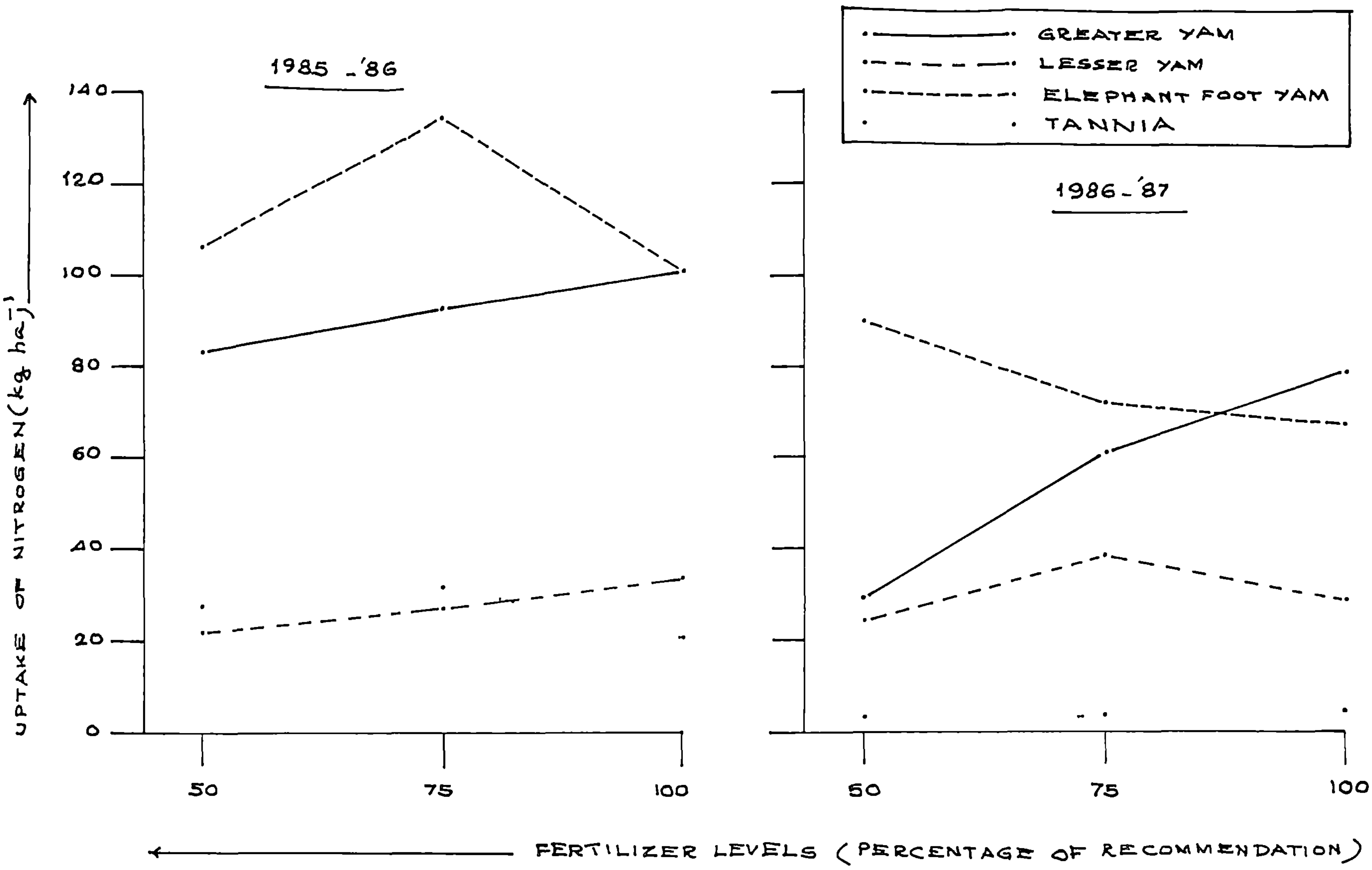


FIG 15 EFFECT OF FERTILIZER LEVELS ON UPTAKE OF NITROGEN ($kg\ ha^{-1}$) AT HARVEST

The maximum uptake of 35.27 kg ha^{-1} and 39.37 kg ha^{-1} were recorded by F_1 and F_2 in the first and second year respectively.

As in the case of greater yam, there was steady increase in the uptake upto harvest stage during the first year while a reduction was observed after 190 DAS in the second year.

Tannia

There was significant difference in the total nitrogen uptake between different fertilizer levels only at 130 DAS in the first year.

The uptake went on increasing with ageing of the crop in the first year. The general performance of the crop in the second year was very poor and the effect was reflected in the uptake pattern also, showing very low uptake for all the treatments at all the growth stages.

Elephant footyam

The fertilizer levels did not reveal any significant variation in the total nitrogen uptake at any of the growth stages in the second year and at harvest and early stage in the first year.

The maximum uptake though not significant was by F_2 in the first year and F_3 in the second year. It is also seen that uptake was lesser during the second year.

The general trend observed was that with ageing of the crop there was increase in the total uptake over the stages.

4.2.4.2. Total uptake of phosphorus

The data are presented in Table 34 and Fig. 16.

There was significant difference in the total phosphorus uptake between crops at all the growth stages in both the years under study. The uptake was maximum for elephant footyam which was closely followed by greater yam. These crops showed significant superiority over tannia and lesser yam in the two years of study.

Considerable reduction in the uptake was observed in the second year for all crops except lesser yam.

Greater yam

Total uptake of phosphorus by the crop varied significantly due to fertilizer levels at 130 and 190 DAS in the first year and at 130 DAS and at harvest in the second year. While the medium fertilizer level (F_2) recorded maximum phosphorus uptake in the first year, it was by high fertilizer level (F_1) which recorded maximum uptake of phosphorus in the second year. The

Table 34 (a) Effect of fertilizer level on total phosphorus uptake in kg ha^{-1} at 70 DAS

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	3.10	3.[illegible]5	0.58	1.51	1.25	0.88	2.74	2.28
F_2	2.46	3.79	0.74	2.25	1.28	1.56	2.53	2.22
F_3	2.14	4.80	1.10	1.77	1.12	0.87	3.05	3.69
Mean	2.57	4.[illegible]	0.81	1.84	1.22	1.11	2.78	2.73
F test	NS	NS	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	86-87	'85-86	86-87
crops	1.11	0.92	0.38	0.31
treatments	-	-	0.33	0.27

NS - Not Significant

Table 34 (b) Effect of fertilizer level on total phosphorus uptake in kg ha^{-1} at 130 DAS

Fertilizer levels	Greater yam '85-86	Greater yam '86-87	Lesser yam '85-86	Lesser yam '86-87	Taro '85-86	Taro '86-87	Elephant foot yam '85-86	Elephant foot yam '86-87
F	11.87	[illegible] 71	3.[illegible]	[illegible]	2.79	0.73	6.51	2.14
[illegible]	[illegible]	[illegible]	2.[illegible]	4.[illegible]	[illegible]	[illegible]	[illegible]	3.39
[illegible]	1[illegible]	[illegible]	3.5[illegible]	[illegible]77	[illegible]	0.[illegible]	[illegible]	2.[illegible]6
Mean	[illegible].50	[illegible].56	[illegible]	4.27	3.[illegible]	0.63	5.95	2.76
F test	[illegible]	S	NS	S	S	NS	NS	S

	CD (0.05) '85-86	CD (0.05) '86-87	SE '85-86	SE '86-87
crops	[illegible].17	0.50	0.40	0.17
treatments	2.0[illegible]	0.[illegible]	0.69	0.29

S - Significant NS - Not Significant

Table 34 (c) Effect of fertilizer level on total phosphorus uptake in kg ha^{-1} at 190 DAS

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	14.72	13.20	3.42	4.78	3.27	1.10	19.19	10.50
F_2	20.61	15.63	4.83	7.57	6.65	0.67	33.02	7.37
F_3	11.28	14.57	3.63	3.08	5.79	0.62	17.68	7.77
Mean	15.60	14.47	3.96	5.14	5.24	0.79	23.30	8.54
F test	S	NS	NS	NS	NS	NS	S	NS

	CD (0.05)		SE	
	'85-86	86-87	'85-86	86-87
crops	3.23	3.32	1.10	1.32
treatments	5.60	-	1.91	1.96

S - Significant NS - Not Significant

Table 34 (d) Effect of fertilizer level on total phosphorus uptake in kg ha^{-1} at harvest

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	25.84	18.85	6.01	4.84	6.51	1.89	24.31	16.64
F_2	28.69	15.67	9.07	9.18	8.02	0.91	29.10	14.19
F_3	21.50	7.25	7.02	7.41	11.08	1.46	26.15	23.35
Mean	25.34	13.92	7.37	7.14	8.54	1.42	26.52	18.13
F test	NS	S	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	86-87	'85-86	86-87
crops	5.26	4.85	1.79	1.65
treatments	-	8.41	3.11	2.87

S - Significant NS - Not Significant

uptake values ranged from 21.50 to 28.69 kg ha^{-1} and from 7.25 to 18.85 kg ha^{-1} during the first and second years respectively.

The total uptake of the nutrient recorded a steady increase upto harvest for all the treatments in the first year and only for the full dose treatment (F_1) in the second year. For the medium fertilizer level, the uptake remained more or less stable between 190 DAS and harvest while a slight reduction was observed at the low fertilizer level (F_3) of the second year crop.

Lesser yam

The variation in the total phosphorus uptake was significant only at 130 DAS in the second year.

The uptake pattern was more or less the same during both the years with medium fertilizer level recording maximum uptake which was not significantly superior to the other treatments.

With advancing age, the uptake also steadily increased, thus recording the maximum uptake at harvest.

Tannia

There was no significant difference due to treatments in the total phosphorus uptake of tannia at any of the growth stages during both the years excepting 130 DAS during first year.

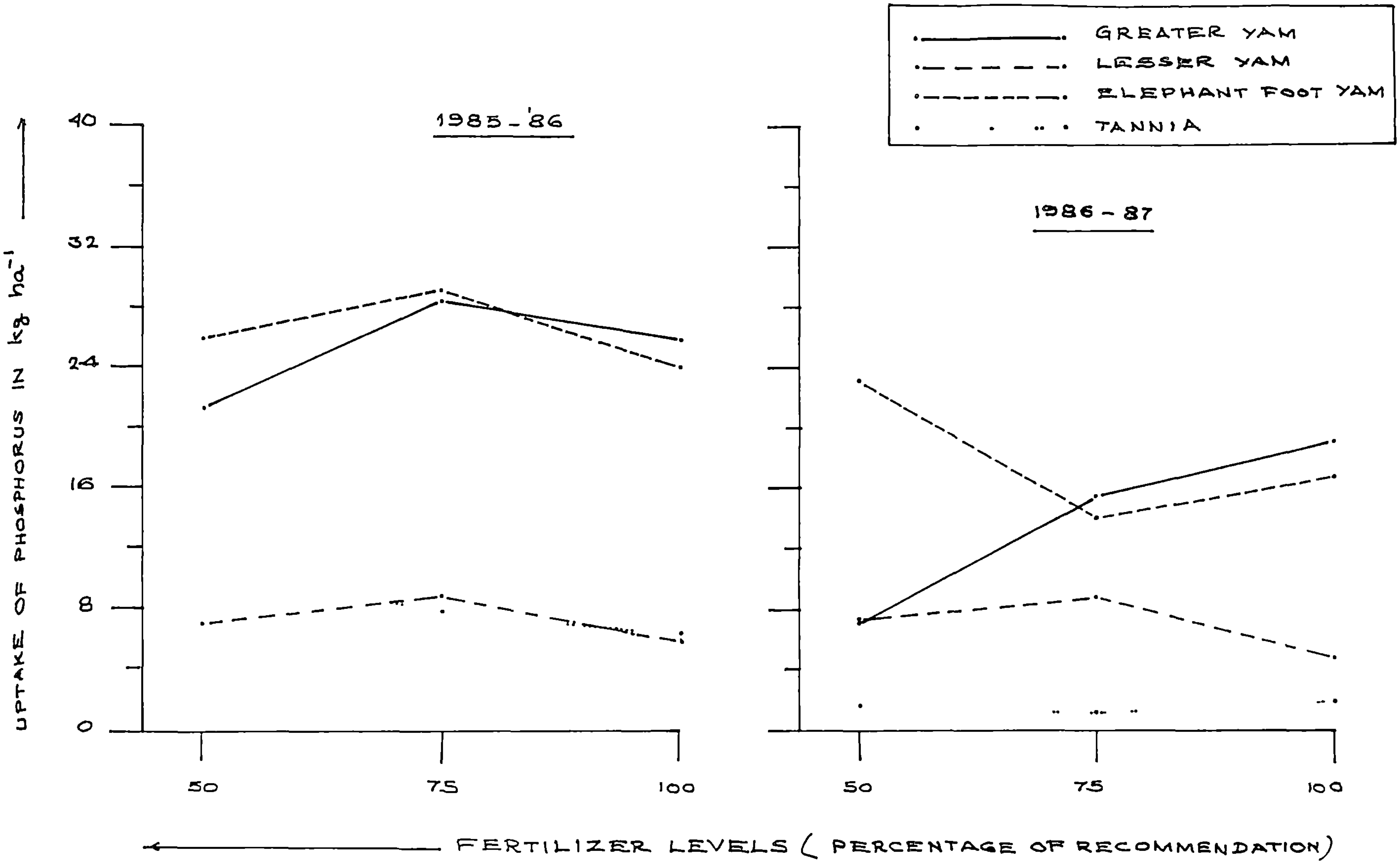


FIG 16 EFFECT OF FERTILIZER LEVELS ON UPTAKE OF PHOSPHORUS (kg ha^{-1}) AT HARVEST

A drastic decline in the phosphorus uptake was observed during the second year and the value ranged from 6.51 to 11.08 kg ha^{-1} and from 0.91 to 1.89 kg ha^{-1} in the first and second years respectively.

A steady increase in the uptake was observed with ageing of the crop.

Elephant footyam

The treatments did not differ significantly at all of the growth stages [illegible] except at 190 DAS in the first year and 130 DAS in the second year. The medium fertilizer level was significantly superior to the other treatments at 190 DAS and this treatment continued to be superior till harvest stage also, although not significant, in the first year. The uptake was maximum for F_3 in the second year.

As in the case of other crops the second year crop recorded reduced uptake of phosphorus.

The uptake went on increasing upto harvest.

4.2.4.5. Total uptake of potassium

The data are presented in Table 35 and Fig. 17.

The crops differed significantly in total uptake of potassium at all the growth stages during both the

Table 35a Effect of fertilizer level on the total uptake of potassium in kg ha^{-1} At 70 D A S

Fertilizer levels	Greater yam '85-86	Greater yam 86-87	Lesser yam '85-86	Lesser yam 86-87	Tannia '85-86	Tannia 86-87	Elephant footyam '85-86	Elephant footyam 86-87
F_1	33.60	48.83	7.91	22.53	15.42	15.08	35.08	30.77
F_2	25.07	40.70	8.95	33.23	18.27	19.53	35.54	26.83
F_3	25.21	52.97	11.86	31.17	14.12	24.63	39.96	44.37
Mean	27.96	47.50	9.41	26.98	15.93	19.81	36.86	33.99
F test	NS	NS	NS	NS	NS	NS	NS	NS

	CD (0.05) '85-86	CD (0.05) 86-87	SE '85-86	SE 86-87
crops	13.01	10.45	4.44	3.56
treatments	-	-	7.68	6.1

S - Significant NS - Not Significant

Table 35 (b) Effect of fertilizer leve_ - the total uptake of potassium in kg ha^{-1} at 130 D - S

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	104.13	43.90	31.87	38.30	32.17	8.30	57.33	40.70
F_2	114.13	68.70	21.87	67.50	54.43	12.00	52.70	51.90
F_3	10[illegible].[illegible]7	46.30	42.90	45.50	38.20	16.53	66 .00	70.[illegible]0
Mean	108.11	53.[illegible]	32.21	50.40	41.80	12.30	58.88	[illegible]4.40
F test	NS	[illegible]S	S	NS	S	S	NS	NS

	CD (0.05)		SE	
	'[illegible]-86	86-87	'85-86	86-87
crops	[illegible]	8.50	3.04	[illegible].90
treatments	1[illegible].-3	-	5.26	5.02

S - Significant S - Not significant

Table 35 (c) Effect of fertilizer level on the total uptake of potassium in kg ha^{-1} at 190 D A S

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	135.00	141.00	40.57	82.60	52.44	15.40	259.20	181.90
F_2	188.67	110.70	53.37	86.00	95.33	13.80	487.57	1[illegible]7.90
F_3	103.67	126.90	50.06	66.30	107.83	11.10	236.93	1[illegible]3.90
Mean	142.44	126.90	48.00	98.30	85.[illegible]0	13.40	328.56	164.60
F test	S	NS	NS	NS	S	NS	S	NS

	CD (0.05)		SE	
	'85-86	86-87	'85-86	86-87
crops	18.53	38.42	6.32	13.10
treatments	32.10	-	10.95	22.69

S - Significant N S - Not Significant

Table 35 (d) Effect of fertilizer level on the total uptake of potassium in kg ha^{-1} at harvest

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	273.13	242.65	79.73	65.53	76.70	19.37	254.87	189.30
F_2	255.57	174.66	90.43	105.42	101.17	10.43	370.73	185.34
F_3	210.60	81.65	78.73	71.30	123.73	[illegible].33	373.53	2[illegible]0.27
Mean	246.43	166.33	82.97	80.75	100.53	[illegible].70	333.04	218.30
F test	NS	NS	NS	NS	NS	NS	NS	NS

	CD (0.05)		SE	
	'85-86	86-87	'85-86	86-87
crops	64.22	77.66	21.89	26.48
treatments	-	-	37.92	45.86

S - Significant NS - Not Significant

years and the maximum and minimum values were recorded by elephant footyam and lesser yam respectively in the first year while in the second year the minimum uptake was recorded by tannia.

Greater yam

The variation due to fertilizer levels was significant only at 190 DAS and F_2 was significantly superior during the first year. But at the harvest stage, an increase in the uptake with increase in fertilizer level was observed during both the years though not significant.

Compared to first year, a reduction in the uptake of potassium was observed during the second year. The quantity ranged from 210.60 to 273.13 kg ha^{-1} and from 81.65 to 242.65 kg ha^{-1} in the first and second years respectively.

A steady increase in potassium uptake was observed with ageing of the crop during both the years.

Lesser yam

The uptake differed significantly due to fertilizer treatments only at 130 DAS in the first year and all the treatments were on par during other stages of the crop. The uptake was maximum for F_2 during both the years though not significant.

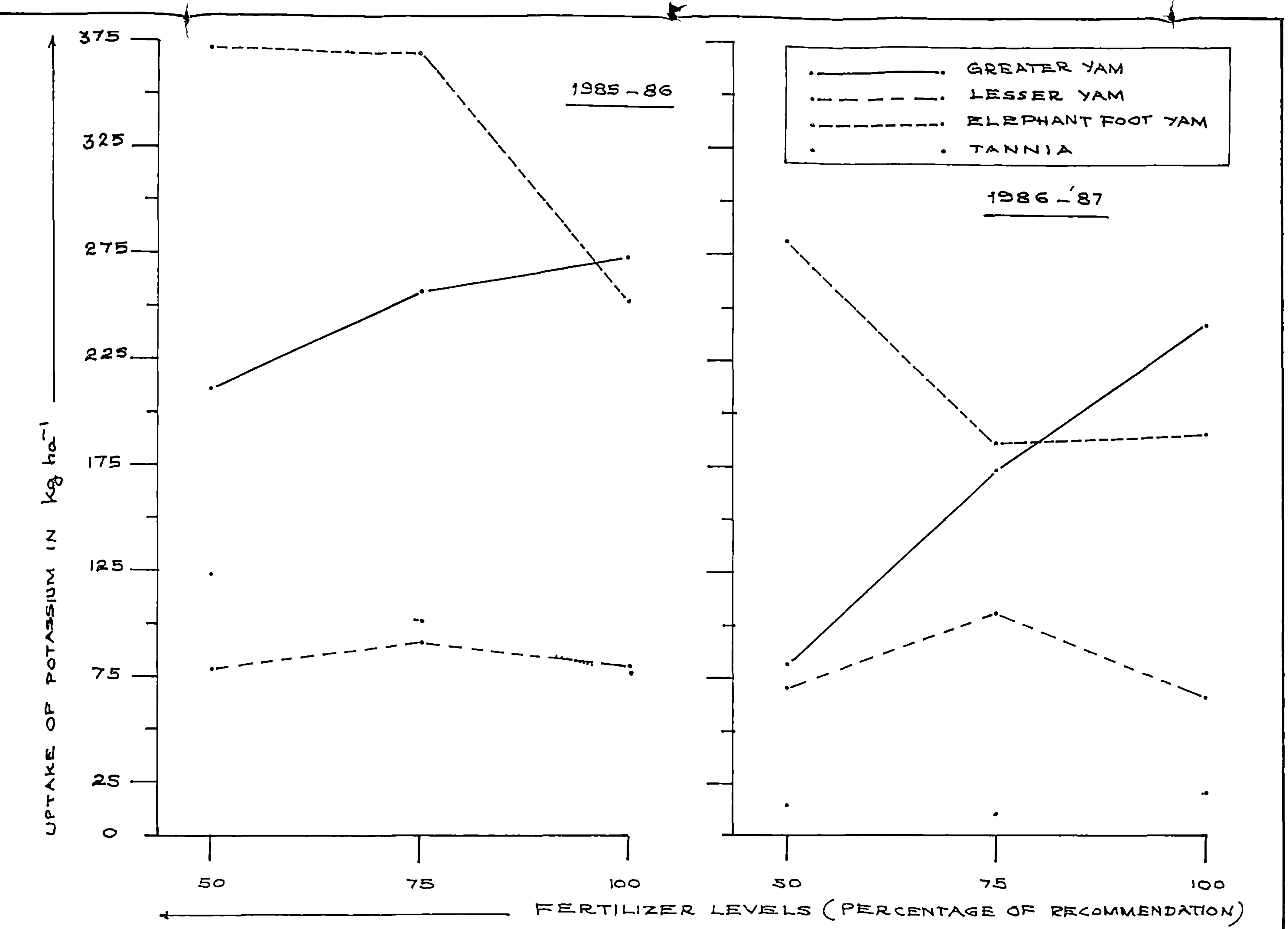


FIG 17 EFFECT OF FERTILIZER LEVELS ON THE UPTAKE OF POTASSIUM ($kg\ ha^{-1}$) AT HARVEST

Comparison between stages indicated an increase in the potassium uptake upto harvest stage of the crop during both the years.

Tannia

The potassium uptake by tannia differed significantly at 130 and 190 DAS in the first year only and the uptake increased with decrease in the fertilizer levels.

There was considerable reduction in the total potassium uptake during the second year. With ageing of the crop, the uptake also increased during the first year.

Elephant footyam

The uptake differed significantly only at 190 DAS during the first year. At this stage, F_2 recorded maximum uptake which was significantly superior to the other treatments. But at harvest stage, F_3 and F_2 recorded almost equal amounts of uptake.

In the second year, the uptake of potassium was reduced considerably as in the case of nitrogen and phosphorus. The uptake was maximum for F_3 but was statistically on par with other treatments.

With advancement in age, the uptake also increased upto 190 days in the first year and upto harvest in the second year. A reduction in the uptake was observed after 190 DAS for F_1 and F_2 during the first year.

4.2.5. Soil nutrient status after the crop

NPK status of the soil after each crop are presented in Table 36.

Significant difference was observed only in the case of available nitrogen and available phosphorus due to different fertilizer treatments during both the years. Appreciable reduction in the available NPK status of the soil was observed at low fertilized plot (F_3).

The available nutrient status of the soil differed significantly due to the growth of different tuber crops.

4.2.5.1. Available nitrogen

The available nitrogen status of the soil differed significantly due to fertilizer treatments and significantly lower values were recorded by F_3 during both the years.

The effect of different crops on the available nitrogen status of soil was significant only in the first year. Significantly high value was recorded after elephant foot yam while there was statistical parity between lesser yam and greater yam in the first year.

Table 36 (a) Effect of fertilizer level on the available nitrogen status of soil in kg ha^{-1}

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	250.71	252.76	301.68	234.41	275.17	273.14	315.94	271.24
F_2	280.36	244.60	275.17	248.70	285.37	262.94	283.33	242.56
F_3	236.61	240.54	232.37	232.37	248.68	242.57	267.02	230.33
Mean	257.56	245.97	269.74	238.49	269.74	259.55	288.76	248.04
F test	S	NS	S	NS	S	S	S	NS

	CD (0.05)		SE	
	'85-86	86-87	'85-86	86-87
crops	15.32	19.69	5.22	6.71
treatments	26.54	34.10	9.05	11.63

S - Significant NS - Not Significant

Table 36 (b) Effect of fertilizer levels on the available phosphonus status of soil in kg ha^{-1}

Fertilizer levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	85-86	86-87	85-86	86-87	85-86	86-87	85-86	86-87
F_1	28.37	27.13	24.92	23.76	22.61	26.72	22.17	27.87
F_2	29.17	26.11	28.20	26.11	22.17	25.81	23.05	26.40
F_3	21.72	24.93	19.68	24.93	22.79	23.91	17.29	21.56
Mean	26.42	26.06	24.27	24.93	22.52	25.48	20.84	25.28
F test	S	NS	S	NS	NS	NS	NS	S

	CD (0.05)		SE	
	85-86	86-87	85-86	86-87
crops	3.30	4.47	1.25	1.52
treatments	6.72	7.74	1.95	2.64

S - Significant NS - Not Significant

Table 36 (c) Effect of fertilizer on available potassium status of soil in kg ha^{-1}

Fertiliser levels	Greater yam		Lesser yam		Tannia		Elephant foot yam	
	'85-86	86-87	'85-86	86-87	'85-86	86-87	'85-86	86-87
F_1	111.06	100.00	93.35	75.00	105.00	106.65	123.38	103.38
F_2	103.32	95.00	110.00	75.00	103.05	116.07	136.67	118.34
F_3	110.00	75.00	95.00	66.05	121.05	78.35	103.38	90.00
Mean	108.00	90.00	99.45	75.50	110.00	100.50	121.11	103.69
F test	NS	NS	NS	S	NS	NS	NS	NS

	CD (0.05)		SE	
	85-86	86-87	85-86	86-87
crops	-	-	16.39	18.53
treatments	-	-	29.25	32.09

S - Significant NS - Not Significant

During second year the plot after the growth tannia recorded significantly high value.

Greater yam

Nitrogen status of soil after greater yam differed significantly only in the first year with F_2 recording the highest value. In the second year F_1 recorded highest value though not significant.

Lesser yam

The influence of fertilizer treatment on the available status of the soil was significant only in the first year recording maximum value for F_1. With decrease in fertilizer level there was reduction in the soil nitrogen status also.

Tannia

Soil nitrogen status after tannia was significantly influenced by fertiliser levels during both the years. The lowest value in both the years were recorded by F_3 and highest value was recorded by F_2 during the first year and F_1 during second year.

Elephant footyam

The available nitrogen status of the soil was significant only in the first year and F_1 recorded significantly high value.

During both the years there was a general reduction in the soil nitrogen status with decrease in fertilizer level.

4.2.5.2. Available phosphorus

The phosphorus status of the soil differed significantly due to fertilizer treatments recording significantly lower value for F_3 though F_2 and F_1 were statistically on par.

Crops influenced the available phosphorus status of soil only during the first year, the maximum being recorded after greater yam followed by lesser yam. Lowest value was recorded in the plots where elephant footyam was grown.

Greater yam

There was significant difference in the soil available phosphorus status after greater yam during the first year. Maximum phosphorus content was recorded at F_2 which was statistically on par with F_1 and significantly superior to F_3. In the second year the fertilizer treatments did not influence the soil available phosphorus status.

Lesser yam

Significantly lower phosphorus content of soil was recorded by F_3 in the first year. There was no significant variation due to fertilizer treatments in the second year.

Tannia

Soil phosphorus status was not influenced by fertilizer treatments in the two years of study.

Elephant footyam

The fertilizer levels did not influence the soil available phosphorus status during both the years. The general trend was a decrease in the available phosphorus content of soil with reduction in the fertilizer dose.

4.2.5.3. Available potassium

The fertilizer treatments and crops could not influence the available potassium status of the soil. The interaction effect was also not significant.

4.2.6. Correlation studies

Correlation between uptake of nitrogen, phosphorus, potassium and yield.

Simple correlations worked out between plant uptake of nitrogen, phosphorus and potassium (at harvest) and tuber yield are presented in Table 37.

Greater yam

It is observed that there was significant positive correlation between uptake of the above nutrients and tuber yield during both the years for greater yam.

Table 37 Simple correlation between yield and uptake of nutrients

	Greater yam	Lesser yam	Tannia	Elephant foot yam
		1985 - '86		
N - uptake	0.8440**	0.6504	0.5655	0.8344**
P uptake	0.8023**	0.8164**	0.8947**	0.8991**
K uptake	0.8797**	0.6880*	0.8195**	0.7638*
		1986 - '87		
N uptake	0.9797**	0.1714	0.4475	0.4996
P uptake	0.9897**	0.6635	0.0548	0.8871**
K - uptake	0.9950**	0.5284	0.1527	0.7271*

* Significant at 5 percent level ** Significant at 1 percent level

Lesser yam

In lesser yam, the correlation was significant only for phosphorus and potassium uptake during 1985-86. The uptake of the nutrients failed to show any positive correlation in 1986-87.

Tannia

As in the case of lesser yam, tannia also recorded significant positive correlation with yield, only for phosphorus and potassium uptake during first year.

Elephant footyam

There was significant positive correlation between yield of elephant footyam and nitrogen, phosphorus and potassium uptake during 1985-86 and only between phosphorus and potassium uptake in 1986-87.

4.2.7. Economics

The data on economics of growing minor tuber crops as inter crop in coconut garden using different levels of fertilizer are presented in Table 38.

From the data it is observed that maximum benefit - cost ratio was obtained by growing elephant footyam followed by greater yam and lesser yam. Growing of tannia resulted in a loss. Greater yam gave highest benefit - cost ratio of 2.44 with full dose of fertilizer as per

Table 38 Economics of fertilizer application to minor tuber crops when grown as intercrops in cocunut garden

Sl. No	Fertilizer levels	cost of cultivation ha^{-1} $year^{-1}$	Mean yeild t ha^{-1}	Value of tuber	Profit ha^{-1} $year^{-1}$	Benefit-cost ratio
Greater yam						
F_1	80:60:80	10,930.00	26.63	26,630.00	15,700.00	2.44
F_2	60:45:60	10,698.00	21.22	21,220.00	10,522.00	1.98
F_3	40:30:40	10,465.00	15.78	15,780.00	5,315.00	1.51
Lesser yam						
F_1	80:60:80	9,630.00	9.35	9,350.00	280.00	0.97
F_2	60.45:60	9,398.00	13.20	13,200.00	3,802.00	1.40
F_3	40:30:40	9,165.00	10.92	10,920.00	1,750.00	1.19
Tannia						
F_1	80.50:100	7,925.00	3.82	5,730.00	-2,195.00	0.72
F_2	60:37.5:75	7,693.75	4.98	7,470.00	- 223.75	0.97
F_3	40.25:50	7,462.50	4.00	6,000.00	-1,462.50	0.80
Elephant foot yam						
F_1	80:60:100	12,980.00	24.80	31,000.00	18,020.00	2.39
F_2	60:45:75	12,735.00	25.40	31,750.00	19,015.00	2.49
F_3	40:30:50	12,490.00	27.40	34,250.00	21,760.00	2.74

package of practices recommendation. There was a steady increase in profit with increase in the fertilizer levels.

Lesser yam registered the maximum benefit - cost ratio of 1.40 with medium level fertilizer and elephant footyam gave maximum benefit - cost ratio 2.74 with lowest fertilizer dose.

Discussion

5. DISCUSSION

5.1. Experiment I

The results of the experiment, 'screening of minor tuber crops under varying intensities of shade' are discussed here under.

Greater yam

It is seen that the length of the vine was significantly influenced by different shade intensities. The data indicated that the length was maximum under medium shade (50 per cent shade) which was statistically on par with that at low shade (25 per cent shade). But at intense shade (75 per cent shade) a drastic reduction was observed. While an increase of 183 cm and 137 cm were obtained for low and medium shade levels respectively, a decrease of154 cm was observed at intense shade level when compared to open ('0' per cent shade) which recorded a length of vine of 825 cm.

Reports of increased plant height under shade are available for different crops. In ginger, Aclan and Quisumbing (1976) observed an increase in plant height due to shade. Lalithabai (1981) observed an increase in plant height with increase in shade intensity upto 50 per cent shade level in coleus and ginger and upto

75 per cent shade in turmeric and sweet potato. Reduction in plant height with increase in shade intensity was observed in sorghum crop by Palis and Bustrillos (1976). As reported by Kulasegaram and Kathiravetpillai (1976), this reduction in height may be due to reduced terminal bud activity induced by intense shade.

An evaluation of the effect of shade on LAI of greater yam revealed that maximum LAI was at medium shade followed by open and minimum for intensely shaded crop. This clearly indicates the fact that the photosynthetic area of the plant was not affected by shade upto 50 per cent shade and thereafter there occurred drastic reduction in LAI at intense shade ie the LAI was reduced from 9.25 to 5.48.

After about 130 DAS the density of canopy steadily increased and the LAI value remained above 5 at all shade levels. Though the optimum LAI of greater yam is not available from literature, the observed value of more than five at all shade levels would indicate that LAI of greater yam may perhaps be super optimal at all shade levels. Though the yam petiole is also reported to be capable of growing or twisting in such a way as to expose the lamina to maximal amount of sunlight (Onwueme, 1978), this may not lead to complete avoidance of leaf parasitism. This leaf parasitism would have substantially increased as the intensity of shade increased. Thus at intense shade level probably the parasitic effect would be maximum as the photosynthetically active radiation falling on the leaf surface was only 25 per cent of that at open. But from the data it could be observed that the LAI was significantly reduced at intense shade level thus avoiding such excessive parasitism. This may be a plant adaptation when grown under shade as reported by Lalithabai (1981).

The photosynthetic efficiency of the crop could be obtained from the data on net assimilation rate (NAR). There was no significant difference in NAR due to shade. Gopinathan (1981) reported lack of statistical significance in NAR of cocoa due to shade. At the early stage of the crop, the NAR was minimum in the open but this went upto the maximum at later stage. This may be due to the suboptimal LAI values at initial stage which would have caused a reduction in the photosynthetic efficiency. This result is in conformity with the finding of Lalithabai (1981) who reported lowest LAI values in the open upto 120 days of growth of colocasia and after that maximum and minimum values were reported by open and intense shade levels respectively. Thus at initial stages both the photosynthetic area and efficiency would have been depressed considerably by the intense sunlight, for treatment at full illumination. This can be further substantiated from the LAI and NAR values obtained for other shade treatments where both photosynthetic area and efficiency were high at initial stages.

At the later stage the canopy density increased appreciably for all treatments. Maximum LAI after 190 DAS was recorded by medium shade (9.25) and all the other treatments recorded LAI values below 7. At this stage the photosynthetic efficiency measured as NAR was maximum for the open and minimum for medium shade. This may be because that, the high LAI values observed under 25, 50 and 75 per cent shade intensities along with the shade provided by treatments might have caused excessive parasitism thus reducing the photosynthetic efficiency considerably.

The influence of the above characters on the general growth and dry weight accumulation has been reflected in the data on total dry matter production per hectare. During the initial growth stage of the crop the total dry weight was maximum at 25 per cent shade while at later stages, the maximum dry weight accumulation was for 'open' treatment. Though at the initial stages the dry weight seemed to be influenced by LAI which was less than 5, at later stages when LAI increased to more than 9, there was mutual shading and parasitism which were reflected in NAR and in turn in the total dry matter production. When the dry weight obtained in the open was considered as 100 the percentage values at 25, 50 and 75 per cent shade levels were 73.6, 88.3 and 31.83 respectively. At intense shade level the availability of light for photosynthesis was the decisive limiting factor and hence dry weight was markedly reduced. General decline in total dry matter production when shade was increased from '0' to 73 per cent and a drastic low shade. Substantial yield decline occurred at intense shade of 75 per cent. When expressed as percentage of yield in the open the corresponding figures at 25, 50 and 75 per cent shade levels were 87.95, 68.65 and 43.51 respectively. Based on these data it could be assumed that the tuber yield of greater yam was greatly influenced by shade and each lower shade level was significantly superior to the next higher level. At intense shade level of 75 per cent, light may become the decisive factor that limits the crop yield. The yield reduction due to shade had been reported by Togari (1950), Wilson (1967), Martin (1985), Lalithabai (1981) and Asandhi and Suryadi (1982) in sweet potato; Matusiewicz (1967) in sugar beet; Caesar (1980) in Xanthosoma and Colocasia and Ramanujam et al. (1984) in cassava.

The influence of shade on the tuber yield of greater yam was explained by the linear regression given by Y = 38.235 - 0.279x with a coefficient of determination (R^2) 98.09%.

This reveals that 98.09 per cent of the total variation in tuber yield is attributed to the shade intensity (Fig. 8a). For a given shade intensity the yield can be predicted using this regression relationship of yield on shade.

Though not significant, there was marked decrease in the utilisation index at intense shade level. This would reveal that upto 50 per cent shade intensity, the partitioning of assimilate was not affected where as at intense shade level assimilate translocation was adversely affected which resulted in lesser tuber production compared to top vegetative parts. Thus at intense shade level along with reduced photosynthetic area and efficiency which resulted in lesser photosynthetic accumulation, the partitioning and poor translocation of assimilates were also responsible for the reduced yield. This is in conformity with the findings of Ramanujam et al. (1984) who observed that most of the photosynthates of shade grown cassava plants were utilised for shoot growth at the expense of tuber growth.

The chlorophyll content of the crop was significantly influenced by shade and an increase in chlorophyll content with increase in shade was observed. This is in agreement with the report of Clark (1905) in straw berry; Evans and Murray (1953) and Guers (1971) in cocoa; Radha (1979) in pineapple and Lalithabai (1981) in coleus, ginger and turmeric.

The starch content of the plant recorded significant difference due to different shade levels and maximum value for intense shade. Hozyo and Kato (1976) observed that roots of sweet potato when exposed to sunlight resulted in reduced starch content. Similarly An (1982) observed increased starch and reducing sugar content of groundnut seeds due to shade.

Significant difference in protein content was also observed due to shade and the maximum was for intense shade. Similar results of increased protein content in grain sorghum due to increase in shade was reported by Palis and Bustrillos (1976).

No definite trend could be seen in the uptake of nutrients upto medium shade while a drastic decline was observed at intense shade level. This may probably be a reflection of the influence of total dry matter production on the uptake of nutrients (Table 7).

From the data on soil nutrient status after the cropping it was observed that the available phosphorus content alone was significantly influenced by the shade. There was significant increase in the phosphorus status of soil at intensely shaded plot. This probably may be due to the very low phosphorus uptake of the crop at this shade level (5.96 kg ha^{-1}) as compared to other shade levels (Table 15).

Lesser yam

Contrary to greater yam the vine length increased with increase in shade intensity, the maximum being recorded at intense shade level. Ramanujam *et al*. (1984) reported that increased height of plant under coconut shade was due to internodal elongation and this in turn was attributed to cell elongation as the plants have to compete with coconut palms for light energy. Here also there was great demand for light energ , which would tempt the plants to elongate in search of light and hence an increased length of vine was observed under shade. Similar results were reported by Lalithabai (1981) for crops like sweet potato, coleus, ginger and turmeric.

Leaf area index of lesser yam differed significantly with different shade treatments. At 130 DAS, LAI was significantly lower in the open while at later stages the lowest LAI was for intense shade which was on par with that of open. Higher LAI values were maintained at 25 and 50 per cent shade levels through out the growth stages. 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. Ramanujam *et al*. (1984) observed increased LAI in cassava varieties when grown under shade and they suggested the reason being the longer leaf life under shade resulting in the retention of more number of leaves at any stage of the crop.

The effect of shade on the net assimilation rate and crop growth rate was almost the same as that of greater yam. Here, although the photosynthetic area was maximum at low and medium shade levels, the NAR and CGR went upto the maximum under open. Similar reduction in CGR and NAR of cassava grown under shade as compared to those grown under normal light was reported by Ramanujam et al. (1984).

The influence of photosynthetic area and photosynthetic efficiency on the performance of the crop can be seen from the data on total dry matter yield. The maximum dry weight was obtained for the low shade intensity. The percentage of dry weight obtained for 25, 50 and 75 per cent shade level were 117.8, [illegible].86 and 16.54 of that of open. The above data revealed that a shade level of 25 per cent was very much advantageous to the crop in terms of photosynthetic accumulation and an increase of shade resulted in a sudden decline in dry matter. A higher dry matter production under shade was recorded by Aclan and Quisumbing (1976) and Lalithabai (1981) in ginger.

Although the dry weight was increased at the low shade intensity by 17.8 per cent of that of open the yield was found to be decreased by 12.75 per cent. This mean that the dry weight increase may be due to the increased top vegetative yield of the crop at 25 per cent shade level. The yield obtained for 25, 50 and 75 per cent shade levels were 77.25, 32.59 and 6.22 per cent of that at open. From the above data it could be seen that the higher LAI values along with increased dry weight could not contribute to higher yield. Most of the photosynthates of shade grown plants would have been utilised for shoot growth affecting tuber growth significantly (Ramanujam et al., 1984). They had also observed poor starch deposition in the vascular region of leaves grown under shade demonstrating lower rate of photosynthesis. The lower photosynthetic rate in shade grown plants may be due to less number of stomata in the leaves of shade grown plants which resulted in a decrease in CO_2 diffusion as reported by Crockson et al. (1975) in bean leaves.

The influence of shade on the tuber yield of lesser yam was explained by the linear regression $Y = 20.09 - 0.2446x$ with a coefficient of determination R^2 97.87%. This means that 97.87 per cent of the total variation in yield due to shade was explained by the linear regression (Fig. 8b).

The ratio of tuber to shoot weight as seen from the data on utilisation index revealed the same trend as as that of yield and the values ranged from 1.16 to 5.89. The highest utilisation index was at full illumination supporting the result of Ramanujam et al. (1984).

The chlorophyll content of this crop showed great variability due to shade. Starch content of lesser yam did not differ significantly due to shade. This is in agreement with the results of Tamaki and Naka (1972) who reported that the seed carbohydrate of broad bean was not affected by shade.

Unlike starch content , protein content of tuber differed significantly and there was an increasing trend with increase in shade. Wahua and Miller (1978) reported that the protein content of soybean was highest at 93 per cent shade.

The uptake of the nutrients followed the same trend as that of dry matter accumulation and maximum uptake of nitrogen, phosphorus and potassium was observed at 25 per cent shade. Since the yield was not at all correlated with the uptake of nutrients it could be presumed that the extra nutrient obtained at low shade intensity might have been utilised for the shoot growth. The fact that the uptake was also reduced with reduction in yield at medium and intense shade levels would also indicate the possibility of reducing the fertiliser level when this crop is grown under shade.

The data on soil nutrient status showed significant influence of shade on the available nitrogen, available phosphorus and available potassium status after the crop. However the variation was not following any definite trend.

Tannia

The height of tannia was significantly influenced by shade and crops grown in the open recorded the lowest height. Such a reduction in plant height at full illumination was reported by Aclan and Quisumbing (1976) in ginger and Tarila et al. (1977) in cowpea. Plants under varying shade levels recorded more or less the same plant height which was greater than that of open. Ramanujam et al. (1984) reported increased plant height in cassava grown as intercrop under partial shade of coconut and the reason being internodal elongation of inter crop for competing with coconut for light.

The LAI of tannia was below 2, at almost all stages and at all shade levels which revealed that there was no mutual shading or overlapping of leaves in this crop. Among the different shade levels the lowest LAI was recorded at full illumination. Higher LAI under shade may be due to longer leaf life under shade as reported by Ramanujam *et al*. (1984) in cassava. Lalithabai (1981) also reported lower LAI values for colocasia.

Net assimilation rate was maximum at open which was statistically on par with treatments upto 50 per cent shade at the second growth phase. Only at intense shade there was significant reduction in NAR. This would mean that upto 50 per cent shade there was no mutual shading and hence no reduction in photosynthetic efficiency. This probably may be due to the lower photosynthetic area exhibited by the crop.

The dry weight was maximum at low shade followed by medium shade. Higher LAI with moderate NAR made the low and medium shade levels to accumulate more photosynthate and thus maximum dry weight. Such higher dry matter accumulation under shade had been reported in crops like ginger (Aclan and Quimbing, 1976; Lalithabai, 1981), tomato (Ahmed *et al*., (1964) and tea (Joseph, 1979). The reason attributed to such performance was that shade loving plants had a threshold illumination beyond which the stomata of such shade loving plants tend to close (Hardy, 1958) which would result in reduction in CO_2 diffusion and photosynthesis as reported by Crockson *et al*. (1975). However, in the present study it could be assumed that the lowest LAI maintained by the crop through out the growth period under full illumination could not have been compensated by the highest NAR and this resulted in very low dry matter accumulation. But beyond this level the availability of light became the decisive limiting factor for photosynthesis and thus intense shade recorded lowest dry matter. Very low light intensities was reported to reduce the rate of photosynthesis resulting in the closing of stomata (Morachan, 1984).

The tuber yield of the crop exhibited the very same trend as that of total dry weight accumulation which reveals the influence of photosynthesis on the yield of crop as reported by Gupta (1984). More or less equal yields were obtained at 25 and 50 per cent shade levels and were significantly superior to open and intense shade. As such the explanation given for plant dry weight is applicable here also. The lowest yield at intense shade might be due to an increased stomatal resistance and intracellular resistance (Wilson and Ludlow, 1970). The number and weight of cormels plant^{-1} were also maximum for low and medium shade. Expressed as percentage of the yield in open, the yield at 25, 50 and 75 per cent shade levels were 202.67, 207.00 and 77.60 respectively. The influence of shade on yield of tuber was explained by the following equation (Fig. 8c).

$Y = 7.721 + 0.52799x - 0.0073x^2$ with a coefficient of determination R^2 99.53%

The optimum was found to be 30 per cent. This means that 99.53 per cent of the total variation in tuber yields was explained by the equation.

The utilisation index though not significant was maximum for low and medium shades and minimum at intense. This would indicate that not only the production of assimilate, but the translocation of these synthesized material to the economic part also is influenced by shade.

Chlorophyll content was significantly influenced by shade levels recording an increase in the content with increasing shade levels. This is in agreement with the findings of Radha (1979) in pineapple; Lalithabai (1981) in coleus, ginger and turmeric; Ramanujam and Jose (1984) in cassava and Vijayakumar et al. (1985) in pepper.

The starch content of tuber was influenced by shade recording significantly lower content at intense shade level. Similar results of reduction in starch percentage due to shade was reported by Aclan and Quisumbing (1976) in ginger rhizomes and Palis and Bustrillos (1976) in grain sorghum. Though there was significant variation in the protein content of tuber due to shade no definite trend could be observed for the character. This is in accordance with the result obtained by Sansamma George (1982) in groundnut, blackgram and cowpea.

The uptake of nutrients was significantly influenced by shade and followed the same trend as that of dry matter accumulation. The highest uptake of nitrogen, phosphorus and potassium were 61.83, 16.29 and 143.80 kg per hectare respectively for low shade. Lalithabai (1981) reported more or less same uptake values. At medium shade levels, the uptake was slightly reduced and this would indicate the scope of reducing the fertiliser quantity. At intense shade and in the open the uptake of nutrients was significantly reduced. This would indicate that if the crop is to be cultivated under intense shade the fertiliser levels could be brought down to a great extent. The reduced uptake at full illumination was due to the reduced total dry matter which could be improved by enhancing the plant population per unit area.

The data on the soil nutrient status revealed that there was significant difference only in the available phosphorus status of the soil which was high at medium shade level.

Elephant footyam

There was significant difference in the plant height due to shade at the initial growth stages of the crop upto 130 DAS after which it lacked statistical significance. The height of the plant recorded appreciable increase under intense shade level which decreased with increase in light intensity. Asokan (1986) reported increased plant height in elephant footyam under intercropped situation and the reason attributed was competition for light. An increase in plant height due to shade was observed in tannia also in the present experiment. Based on these results it could be concluded that where ever photosynthetically active radiation is insufficient for the crop the cells elongate to the extent possible and necessary for the plants to harvest more light.

The LAI increased upto 25 per cent shade level and there after it decreased considerably. This is in accordance with the result obtained by Asokan (1986) in elephant footyam where their occurred reduction in leaf area under intercropped situations than under sole crop situation. The explanation given for this kind of response was the competition for light and nutrients. Here also the induced restriction for light under the different shade treatments could have caused this variation in the response.

At the initial stage of the crop, the NAR and CGR were lowest in open which increased appreciably with the advancement in the growth of the crop. Thus at later stages, maximum NAR was in open and this maintained statistical parity with all other treatments excepting that at intense shade. As in the case of LAI, NAR and CGR were also minimum under intense shade level.

Though the photosynthetic area and efficiency were not affected significantly due to shade upto medium shade level, the total dry matter accumulation was steadily decreased with increase in shade intensity. Calculated as percentage of open, the dry weight of low, medium and intense shade levels were 86.62, 29.75 and 27.30 respectively. This is supported by the result of Wilson and Ludlow (1970) where a reduction in light intensity from 100 per cent to 11 per cent during growth resulted in a decline of the maximum photosynthetic rate from 72 to 22 mg dm^{-2} h^{-1} in Panicum maximum.

The result on the tuber yield indicated that the yield decreased considerably due to shade. The decrease was not so drastic at low shade level. But at medium and intense shade levels, the tuber yields were only 48.87 and 33.85 per cent of that in the open thus substantiating the influence of photosynthesis on the yield of crop as already reported by Gupta (1984). The reason for such a behaviour may be due to the peculiar nature of this crop where the canopy coverage is only in a single layer. According to Loomis and Williams (19 3) a single horizontal canopy can utilise only about 25 per cent of the total photosynthetically active radiation received on the canopy surface and the rest go unutilised. If this is the case the crop under 25, 50 and 75 percent shade levels could utilise only 18.75, 12.50 and 6.25 per cent of the total photosynthetically active radiation. Many investigators indicated the dependence of crop yield on intercepted radiation (Wong and Wilson, 1967; Monteith, 1969; Biscoe and Gallagher, 1977).

Asokan (1986) reported reduced dry weight and yield of elephant footyam when the crop was grown in the shades of cassava crop and the result in the present study is in agreement with this. Lalithabai (1981) obtained the very same yield response in coleus and she classified that crop as shade intolerant. Yield as a function of shade was explained by the linear regression

$Y = 27.89 - 0.255x$ with a coefficient of determination R^2 98.34%

This suggests that 98.34 per cent of the total variation in tuber yield due to shade was explained by the linear regression (Fig. 8d).

The utilisation index was not influenced by shade. This is in accordance with the result obtained by Asokan (1986) where the harvest index was not markedly different in intercrop and sole crop of elephant footyam. The lack of influence of shade on utilisation index would lead to the conclusion that the partitioning of assimilate was not influenced by shade.

The chlorophyll content was significantly influenced by shade levels recording maximum value at intense shade level and minimum at open. This is in accordance with the findings of Evans and Murray (1953), Ramaswami (1960), Venkatamani (1961), Ramanujam and Jose (1984) and Vijayakumar et al. (1985).

The percentage of starch in tuber was significantly influenced by shade showing a decreasing trend with increase in shade intensity. As in the case of other crop, the protein content was also significantly influenced by shade.

The uptake of all the three nutrients viz nitrogen, phosphorus and potassium was maximum by plants in the open and a decrease was observed with increasing shade levels. At full illumination, the uptake of nitrogen, phosphorus and potassium was 90, 16.17 and 143.35 kg ha^{-1} respectively while that at 25 per cent shade level were only 50, 11.62 and 131.38 kg per hectare. This would indicate that even by a 25 per cent reduction in light intensity the yield reduction was to the tune of about 25 per cent Where in the fertiliser uptake was reduced roughly by 50, 30 and 10 per cent of nitrogen, phosphorus and potassium respectively as that of open. Thus, if the crop is to be grown under shade situation the fertiliser dose could be reduced accordingly.

It was observed from the data on soil nutrient status that there was significant increase in the soil available nitrogen status at intense shade which was on par with low shade and superior to open and medium shade. Recalling the data of uptake of the nitrogen (Table 14) will reveal the fact that there was an increased uptake at open and medium shade which might have resulted in the low nitrogen status in these treatments. Phosphorus and potassium content of soil did not differ significantly due to the influence of shade.

5.2. Experiment II

The results of the experiment 'Fertilizer management of minor tuber crops in coconut based cropping system' are discussed here under. Individual crops are discussed separately.

Greater yam

The general trend in the length of vine was an increase with incremental doses of fertilizers. Almost the same trend was observed during both the years eventhough during the second year the crop registered lower values.

Similar increased vine length in sweet potato due to increased levels of nitrogen was reported by Purewal and Dargan (1959). The influence of nitrogen, phosphorus and potassium in improving the plant height was documented by several workers (Ngongi (1976) and Nair (1986) in cassava, Dubey and Bharadwaj (1971) and Krishnappa and Shivasankara (1981) in potato and Hossain and Rashid (1982) in colocasia.

The number of leaves per plant was not significantly influenced by fertilizer levels during both the years. From the data it is observed that the maximum number of leaves of 846 was recorded by medium fertilizer level (75 per cent of recommended dose) at 130 DAS during the first year, while the maximum of 722 number of leaves was recorded by low fertilizer level (50 per cent of recommended dose) at 190 DAS during the second year. In first year there occurred a reduction in the number of leaves at later stages. As pointed out by Onwueme (1978) the crop might have entered the third phase of growth at this stage and hence started senescence of leaves and photosynthate might have been translocated to tuber for development.

As in the case of leaf number the highest LAI values were also recorded at 130 DAS during the first year and the maximum value of 5.4 was recorded by high fertilizer level (full dose) and the effect was significant. Similar positive effect of nitrogen on leaf area development of <u>Dioscorea</u> <u>esculenta</u> was reported by Enyi (1970). Increases in LAI due to nitrogen (Ngongi, 1976 and Nair, 1986), phosphorus (CIAT, 1977 and Nair 1986) and potassium (Ngongi, 1976 and Nair,1986) application to cassava crop were reported earlier. Though the photosynthetic area exhibited by the crop was greater at high fertilizer level at the initial stages, after 190 DAS there was a reduction in the leaf area. This may be due to the drastic reduction in rate of the production of new leaves together with continuing senescence and abscission of some older leaves at the base of the plant. Haynes <u>et</u> <u>al</u>. (1967) pointed out that for greater yam crop, leaf area declines as tuberisation begins.

The reduction in LAI was conspicuous in high fertilizer level as compared to medium and low levels where there occurred only slight decrease. This may naturally lead to the conclusion that there occurred few newer leaves also at the expense of tuber development at lower fertilizer levels during later phases.

During the second year the LAI values were below three at all stages for all treatments and even at 190 DAS there was an increase in LAI. Such an increase of LAI at the later growth phases could happen only at the expense of tuber production and development.

The photosynthetic efficiency was obtained from the data on net assimilation rate (NAR). But this could be worked out only between 70 and 130 DAS as there was leaf shedding, after this stage. At this stage the maximum NAR was found to below fertilizer treatment during the first year and medium fertilizer level in the second year though not significant. This is in accordance with the report that cassava when grown under lower fertility conditions restricted its leaf area but maintained leaf photosynthetic efficiency (CIAT, 1979).

The rate of growth of crop (CGR) varied significantly due to fertilizer levels and the treatment receiving full dose of recommended fertilizer had lower CGR during both the years. As these observations were obtained only during the early growth phase on account of the leaf shedding of the crop during the later stages there might have been some other factors responsible for determining the total dry matter yield and this may probably be the rate of increase in tuber weight as is revealed from the data on bulking rate. From the data, it is observed that the overall effect of bulking rate was an increase with increase in fertilizer levels. Shukla and Singh (1975) in potato and Geetha (1983) in coleus observed an increase in bulking rate due to increased potassium application under open conditions. USDA (1974) pointedout that potassium is particularly needed during tuberisation. These results are in conformity with the findings of the present experiment and the reason of increased tuber bulking rate can be attributed to increased nutrient availability at higher doses of fertilizer given.

The maximum leaf dry weight of 1357.40 kg ha^{-1} and 1551.40 kg ha^{-1} were recorded by medium fertilizer at 190 DAS during first and second year.

The effect of fertilizer on the stem dry matter production was significant at most of the growth stages and maximum was recorded by medium fertilizer level in the first year and high fertilizer level in the second year. Increase in shoot dry weight due to higher rates of nitrogen to cassava grown under shade was reported by Kasele _et al_. (1984) and Nair (1986). The decline in dry weight of stem observed at later growth phase may be due to the die back of shoot tips at later phase.

Root dry matter production exhibited drastic increase after 130 DAS in both the years for all the treatments. At initial stages, the root dry matter was maximum for lowest fertilizer level. But as the crop advanced growth, the increment in root and tuber dry weight went on increasing registering maximum value for high fertilizer level at harvest stage and the effect was significant only during second year. This is in agreement with the report of Nair (1986), where he observed an increased root dry weight with enhanced rate of potassium.

The total dry matter yield of the crop increased with increase in the fertilizer levels. The highest value of 9121.3 kg ha^{-1} and 8787.85 kg ha^{-1} were recorded by full recommended dose during first and second year respectively. Increased fertilizer levels were reported to increase the dry matter production of cassava in partial shade (Nair, 1986) and this is in conformity with the present result. The percentage of total dry weight at low and medium fertilizer levels were 83.73 and 97.92 and 30.71 and 62.35 of that of highest fertilizer level during the first and second years respectively. Recalling the data on LAI, NAR and CGR would reveal that the initial crop growth rate or photosynthetic efficiency was not contributing to the total dry matter production of the crops as these values were lowest for the high fertilizer level. The highest LAI (Table 21) maintained by the medium fertilizer treatment at 190 DAS was also not reflected in the total dry matter production. At this juncture it might be quite logical to think that the increased total dry matter production at higher levels of fertilizer may be due to the increased bulking rate exhibited by the crop for this treatment.

The influence of fertilizer levels on the length and girth of tuber indicated that there was significant effect on the length of the tuber in the first year and on the girth of tuber in the second year. In both cases, the full recommended dose recorded high values. This would indicate that in the first year the length of tuber was more responsible for the highest tuber yield while in the second year it was the girth.

Improvement in the girth of tuber due to nitrogen and potassium at higher rates was reported in cassava by Nair (1986). Kasele _et al_. (1983) demonstrated the beneficial effect of higher level of potassium in increasing the number and size of storage cells in shade grown cassava. Similar effect might have contributed to higher length and girth of tuber at higher fertilizer level in the present experiment also.

The top yield was found to be maximum for medium fertilizer level which was statistically on par with high fertilizer level. Increased leaf+stem weight, leaf number and leaf area at 190 DAS (Table 24, 25 and 21) might have contributed to the increased top yield. Moreover an adequate supply of nitrogen is related to carbohydrate utilisation and protein synthesis there by enhancing the vegetative growth of the crop. Krishnappa and Shivasankara (1981) obtained increased fresh weight of haulm with increased nitrogen application in potato. At the highest fertilizer level of this experiment, there was no corresponding increase in the vegetative growth but a slight decrease was observed. This probably may be due to the combined enhancement of all the three nutrients which can be substantiated by the statement that potassium being involved in the carbohydrate metabolism and translocation of starch (Samuel Tisdale and Werner Nelson, 1978) acts as a corrective to the harmful effects of nitrogen (Russel, 1973) could restrict the extra vegetative growth when supplied along with higher levels of nitrogen.

The results of the study for the two years indicated that the tuber yield of greater yam was proportionate to the fertilizer doses given which is a reflection of total dry matter production. The maximum yield was obtained with highest fertilizer level, viz. full dose as recommended in the package. The yields obtained with 50 and 75 per cent of the recommended fertilizer levels were 77.43 and 93.52 per cent and 40.29 and 65.50 per cent of that of full recommended dose in the package in the first and second year respectively.

The fresh weight of tuber ranged from 21.18 t ha^{-1} to 27.35 t ha^{-1} in the first year and 10.37 t ha^{-1} to 25.74 t ha^{-1} in the second year. Though the treatment effect was significant only during second year same trend was noticed in both the years.

Such a positive and linear response with fertilizer levels would indicate that the crop has almost the same fertilizer requirement under intercropped and sole crop situation.

In this context it may be noted that for securing higher tuber yield, Nair and Mohankumar (1976) reported NPK @ 120:80:80 kg ha^{-1} under open condition for greater yam.

The efficiency of translocation of assimilate to the economic part can be had from the data on utilisation index. The utilisation index was maximum at lowest fertilizer level during both the years. This probably may be due to the increased top growth at higher fertilizer levels. Nair (1986) reported significantly reduced utilisation index at increased rates of nitrogen application in cassava. It was reported that cassava, when grown under low fertility, the distribution index was higher indicating that most of the carbohydrates produced were transported to the roots (CIAT, 1980).

This can be the reason in greater yam also for recording a higher U.I. at low fertilizer level.

While discussing about the LAI of the crop, it was explained that the increment in LAI at later phases of the crop would have occurred at the expense of tuber production. But the fact that there was higher utilisation index for lowest fertilizer level during both the years would lead to believe that the increase in leaf area was not at the expense of tuber production and development. The sub-optimal LAI value registered by the crop at almost all growth stages may be the reason for such a behaviour of the crop.

The total uptake of nitrogen, phosphorus and potassium followed almost the same trend as that of dry matter accumulation. Increase in the uptake of nutrients with increased rates of application is quite natural. The total uptake of nitrogen at harvest ranged from 83.77 kg ha^{-1} to 101.43 kg ha^{-1} and 30.41 kg ha^{-1} to 79.20 kg ha^{-1} in the first and second years respectively. This result would indicate that with increase in the uptake of nitrogen the yield also was increased. Uptake of nitrogen upto 163 kg ha^{-1} had been reported earlier (CTCRI, 1983). Nitrogen uptake at 75 and 50 per cent of recommended levels were 92.8 and 82.6 per cent of that at full dose in the first year and 77.18 and 38.38 per cent in the second year.

The uptake of phosphorus ranged from 21.50 kg ha^{-1} to 25.84 kg ha^{-1} and from 7.25 kg ha^{-1} to 18.85 kg ha^{-1} during the first and second years respectively. Uptake of phosphorus was not significant in the first year although significant reduction in the uptake was observed at the lowest fertilizer level during the second year. Coursey (1967); Lyonga et al. (1973) and Umanah (1973) reported lesser response to phosphorus by yam crop.

The potassium uptake ranged from 210.60 kg ha^{-1} to 273.13 kg ha^{-1} and 81.65 kg ha^{-1} to 242.65 kg ha^{-1} during the first and second years respectively. The increase in potassium uptake at harvest was very high during both the years. This may be due to its special need during tuberisation (USDA, 1974). The amount of nutrients removed per ton of tuber ranged from 3.39 to 3.65 kg nitrogen, 0.77 to 0.92 kg phosphorus and 9.26 to 10.14 kg potassium. When calculated as removal per ton of dry matter yield it was 10.10 kg nitrogen 2.50 kg phosphorus and 28.80 kg potassium. Obigbesan and Agboola (1978) reported that greater yam removed 14.2 kg nitrogen and 17.9 kg potassium per ton of dry matter produced.

Correlation studies showed significant positive correlation between uptake of nitrogen, phosphorus and potassium with yield.

In general there was an increase in the available nitrogen and phosphorus status of soil with increase in the fertilizer levels. Such an increase in available nutrient status consequent to their application was reported by Rajendran *et al*. (1971), and Nair (1986). Potassium content of soil was not influenced by the fertilizer application as there occurred higher uptake of potassium by the crop at higher level of application.

Lesser yam

The length of vine was not significantly influenced by fertilizer levels in either of the two years. The crop recorded maximum length of vine at medium fertilizer level during both the years though the effect was not significant. The second year crop registered higher value. Sasidharan (1985) reported non significant influence of fertilizer treatments on the length of vine of lesser yam.

The number of leaves plant^{-1} was also not significantly influenced by the fertilizer levels. Medium level fertiliser recorded maximum number of leaves during both the years.

Further analysis of the data revealed that after 130 DAS there was reduction in leaf number in the second year while the number of leaves went on increasing upto 190 DAS for treatments with medium and low fertilizer in the first year. The reduction in leaf number at later stages may be due to abscission of existing leaves and reduction in new leaf formation.

In the first year the increase in leaf number after 130 DAS might have occurred by formation of new leaves even at the tuber development phase.

Fertilizer levels had significant influence on the LAI of the crop only at 130 DAS during the first year and 130 and 190 DAS during the second year. Medium fertilizer level recorded highest LAI in most of the growth stages. The LAI values ranged from 0.68 to 1.80 and from 0.56 to 2.97 in the first and second years respectively. As could be seen from the data, the LAI was suboptimal at all growth stages, though there occurred a general increase in LAI in the second year. Leaf area index being the most variable character of the crop (Gupta, 1984) can be improved either by an enhancement of fertilizer application or by increasing plant population per unit land area. As evidenced from the data, in a partially shaded condition the enhancement of fertilizer is of only little value. But there is scope for increasing plant population by way of reducing the spacing.

The photosynthetic efficiency of the crop can be assessed from the data on net assimilation rate. Here again the observation was taken only between 70 and 130 DAS as the plant started defoliation after this stage. The NAR was not significantly influenced by fertilizer levels during both the years. The rate of growth of a crop (CGR) is determined by the unit leaf photosynthetic rate and by the leaf area and its rate of development. The variability in NAR is reflected in this character also. It was significantly high at medium fertilizer level in the second year.

The bulking rate of the crop was not significantly influenced by the fertilizer level and this is in agreement with the reported result of Sasidharan (1985). As in the case of most of the other characters, the bulking rate was also high under medium level fertilizer. The positive effect of medium level of fertilizer on the bulking rate may be due to its influence on photosynthetic area as evidenced from the data on LAI. In coleus, Geetha (1983) reported similar influence of LAI on bulking rate.

The treatments differed significantly on leaf dry matter production and maximum production was recorded by medium fertilizer level in both the years. As in the case of leaf area, leaf dry matter also went upto the maximum at 190 DAS of the crop in the first year and

130 DAS in the second year registering higher value by the second year crop. The number of functional leaves and leaf area were also higher in the second year. More or less similar effects were observed in the case of stem dry matter also. The tuber dry matter followed a similar pattern. Thus it is seen that the crop registered maximum total dry matter production at 75 per cent of the recommended dose although the effect was not significant in most of the growth stages. This is in agreement with the reported result of Mandal et al. (1969) and Sasidharan (1985).

Top yield was not significantly influenced by the fertilizer levels during the first year of study. It may be remembered in this connection that during this year the fertilizer levels could not influence the length of vine and the number of leaves $plant^{-1}$ which are the major contributors to top yield and as such the lack of influence of fertilizer levels on the top yield is quite natural. On the contrary, the second year crop registered significant difference on the number of leaves $plant^{-1}$ which along with a higher length of vine for medium level fertilizer though not significant might have made this treatment significantly superior.

The top yield ranged from 2.6 t ha^{-1} to 4.42 t ha^{-1} in the first year and from 2.01 t ha^{-1} to 6.81 t ha^{-1} in the second year. The utilisation index was not significant in the first year, while significantly very high utilisation index was observed for high fertilizer level in the second year, which may probably be due to the very low top yield obtained by the treatment. Considerable increase in utilisation index due to application of phosphorus and potassium (Nair, 1986) and decrease due to higher levels of nitrogen (Nair, 1986; CIAT, 1977) were already reported. Reduction in vegetative growth at enhanced rates of potassium was also reported by Nair, 1986 which is in confirmity with the present result.

The yield contributing characters like number and weight of tubers per plant and length and girth of tuber were found to be not influenced by the fertilizer levels. As in the case of vegetative characters the number and weight of tuber per plant were also very less in the first year.

The tuber yield of the crop followed almost the same trend as that of total dry matter yield recording maximum at 75 per cent fertilizer level in the first year. In the second year the yield was more or less equal for medium and low fertilized plots. The mean yield for both the years would indicate that the medium level of fertilizer was good for getting good yield in lesser yam.

Contrary to the dry matter production the tuber yield was minimum at the highest fertilizer level. This means that even at low fertility condition the photosynthate accumulated by a plant might be translocated to the economic parts more efficiently. This view is in agreement with the report of CIAT (1980) where when cassava was grown under low fertility the distribution index was higher and most of the carbohydrate produced were transported to the roots. When calculated as percentage of the full recommended dose, the mean yield of low and medium fertilizer levels were 116.79 and 141.18 per cent respectively. Thus a reduction of the fertilizer level from 80:60:80 kg NPK ha^{-1} to 60:45:60 kg NPK ha^{-1} was found to be advantageous to lesser yam when grown under partial shade. Sasidharan (1985) reported that when lesser yam was grown with different fertilizer treatments viz. 60:60:90; 80:80:120 and 100:100:150 kg NPK ha^{-1}, there was no significant difference in yield and hence considered 60:60:90 kg ha^{-1} as sufficient under open conditions in Trivandrum District. Mandal <u>et al</u>. (1969) found that in <u>Dioscorea esculenta</u>, the yield increased progressively with the increase in nitrogen application upto 80 kg nitrogen and 120 kg K_2O ha^{-1}, but decreased with further increase of nitrogen or potassium.

Recalling on a perusal of the data on LAI it may be seen that this crop registered suboptimal LAI values in most of the growth stages. The influence of photosynthetic area is very well reflected on the tuber yield as could be seen from the low LAI values and low tuber yield in the first year and higher LAI and high tuber yield in the second year.

The total uptake of nutrients followed almost identical trend as that of dry matter production. The effect of fertilizer levels on the uptake of nitrogen was not significant. In the first year there was a gradual increase in the uptake of nitrogen with increase in fertilizer level, while in the second year the medium level of fertilizer recorded maximum uptake. The quantity ranged from 22.40 kg ha^{-1} to 35.27 kg ha^{-1} in the first year and 24.0 kg ha^{-1} to 39.37 kg ha^{-1} in the second year.

Uptake of phosphorus ranged from 6.01 kg ha^{-1} to 7.02 kg ha^{-1} and 4.84 kg ha^{-1} to 9.18 kg ha^{-1} in the first and second years respectively. The maximum uptake was with medium fertilizer level which was on par with other treatments. An uptake of below 10 kg P_2O_5 ha^{-1} would indicate the very little response of lesser yam to phosphorus as reported by Coursey (1967). Varis (1973) revealed that the uptake of phosphorus was reduced by a heavy nitrogen and potassium application confirming the present result.

Potassium uptake ranged from 78.73 kg ha^{-1} to 90.43 kg ha^{-1} and from 65.53 kg ha^{-1} to 105.42 kg ha^{-1} during the first and second years respectively.

Villanueva (1986) reported that during tuber formation potassium is the limiting element. This may be the reason for the higher uptake of this nutrient compared to nitrogen and phosphorus. But there was no significant difference in the uptake due to fertilizer levels. As in the case of phosphorus there was a reduction in the potassium uptake also at higher fertilizer level. This may be due to the inability of the crop when grown under partial shade to exhibit its full potential as evidenced from the reduced tuber and dry matter yield at higher fertilizer levels.

As reported by Onwueme (1978) nitrogen and potassium constitute the major plant nutrients removed by yams which is evident from the quantity of major nutrients removed per ton of tuber yield in this experiment which accounted for 3.5 kg nitrogen, 0.58 kg phosphorus and 7.78 kg potassium. According to Obigbesan and Agboola (1978) the mean nutrient removed per ton of dry matter produced by Dioscorea alata were 14.2 kg nitrogen and 17.9 kg potassium and by D. cayanensus was 9.0 kg nitrogen and 11.9 kg potassium where as Dioscorea rotundata removed 11.8 to 12.8 kg nitrogen and 12.7 to 14.7 kg potassium.

The quantity of nutrient removed per ton of dry matter of *Dioscorea esculenta* in the present experiment was 10.60 kg nitrogen, 2.57 kg phosphorus and 29 kg potassium.

Correlation with yield was significant only for phosphorus and potassium uptake during first year while uptake of nutrients failed to show any positive correlation in the second year.

As observed in the case of greater yam, there was an increase in soil nutrient status with increased fertilizer application, but the effect was significant only during the first year.

Tannia

The levels of fertilizers could not influence the growth parameters as evidenced from the data on height of the plant, girth at the base of the plant and number of leaves plant^{-1}. Plant height ranged from 77.00 cm to 94.50 cm in the first year and from 57.7 cm to 77.3 cm in the second year. The plant height was maximum for low fertilizer level in the first year and medium level in the second year though not significant. The girth at the base of the pseudostem was also not significantly influenced by the fertilizer levels and it was maximum for the lowest fertilizer level. The number of leaves plant^{-1} was very low during the second year.

The LAI values were below 1.5 at all growth stages during both the years and the maximum value was only 1.23. Lalithabai (1981) reported very low LAI for colocasia crop. As the photosynthetic area was very much limited the photosynthetic efficiency would have also been reduced recording very poor dry matter yield. Thus the very low LAI values have been reflected in the dry matter production of the crop also. The crop growth rate was also poor especially during the second year.

Though not significant the data on bulking rate showed a maximum value with full dose of fertilizer. This is in accordance with the result of greater yam in the present experiment.

There was no significant variation in the utilisation index. Thus indicating the fact that fertilizers did not influence the ability of the plant in the translocation of photosynthates to the economic parts. This is in accordance with the report of Sasidharan (1985) in lesser yam.

As in the case of dry weight the uptake of nutrients was also very low and that too in the second year. The uptake of nitrogen was not significantly influenced by the treatments and it ranged from 22 kg ha^{-1} to 31.65 kg ha^{-1} in the first year and from 3.77 kg ha^{-1} to 5.63 kg ha^{-1} in the second year. The highest uptake of 31.65 kg ha^{-1} of nitrogen was recorded by medium fertilizer level and was statistically on par with other treatments. Phosphorus uptake also did not vary significantly due to fertilizer levels. The range in uptake was 6.51 kg ha^{-1} to 11.08 kg ha^{-1} and from 0.91 kg ha^{-1} to 1.89 kg ha^{-1} in first and second years respectively and the highest uptake of 11.08 kg ha^{-1} was recorded by the lowest fertilizer level. The uptake of potassium varied significantly at 130 and 190 DAS during the first year only. As in the case of phosphorus the maximum uptake of potassium was by the treatment with 50 per cent of fertilizer level. The uptake value ranged from 76.60 kg ha^{-1} to 123.73 kg ha^{-1} and from 10.43 kg ha^{-1} to 19.37 kg ha^{-1} in the first and second years respectively. In the screening experiment discussed earlier in this thesis the crop recorded an uptake value from 92.92 to 143.80 kg ha^{-1} of potassium when grown under different intensities of shade. These quantities were comparable with potassium uptake value of this experiment also. The quantity of dry matter produced per kg of nutrients removed under high, medium and low fertilizer levels were 82.83 kg, 70.96 kg, 100.28 kg for nitrogen; 300.89 kg, 280.04 kg, 247.96 kg for phosphorus and 25.53 kg, 22.08 kg, and 22.20 kg for potassium respectively. This would indicate that the utilisation efficiency of phosphorus and potassium was maximum at high fertilizer levels while that for nitrogen was at low fertilizer level.

On account of the general poor performance of the crop which was reflected in most of the growth and yield attributes it is rather difficult to reach at conclusion with regard to the fertilizer requirement of this crop. However, as there was no statistical significance between different treatments, the lowest fertilizer level might be sufficient for this crop. At the same time the lower LAI values recorded through out the growth stage of the crop in both the experiments clearly indicate the scope of increasing the plant population per unit area to increase the yield.

Soil nitrogen status was significantly high in the plots receiving full recommended dose as reported by earlier workers. But there was no significant difference in the phosphorus and potassium status.

Elephant footyam

It is seen from the data that the height of the plant did not vary significantly due to different fertilizer levels. The values ranged from 40.80 cm to 69.50 cm at different growth stages. Lack of significant influence of nitrogen and potash treatments on the length of vine was reported by Hafizuddin and Haque (1979) in sweet potato and Sasidharan (1985) in lesser yam.

The girth at the base of plant was significant only at 130 DAS and the highest value was recorded at lowest fertilizer level. The value ranged from 18.17 cm to 19.53 cm during first year and from 14.33 cm to 17.90 cm during second year.

LAI values varied significantly due to different levels of fertilizer only at 1[illegible]0 DAS of first year. However, for the rest of the stages during both the years there was no significant difference in the LAI of the crop. This is in accordance with the report of Sasidharan (1985) in Dioscorea esculenta.

As could be seen from the data the photosynthetic rate (NAR) of the crop was not significantly influenced by the fertilizer levels. But crop growth rate was significantly high at lowest fertilizer levels. But these observations were taken only during the first growth phase.

The leaf and stem dry matter was maximum for the medium fertilizer treatment in the first year and high fertilizer treatment in the second year. But the total dry matter yield followed an identical trend with tuber yield recording maximum quantity for medium fertilizer level and low fertilizer levels during the first and second year respectively. The mean total dry matter yields calculated as percentage of full recommended dose were 117.34 and 112.53 respectively for treatment 50 per cent and 75 per cent of the recommended dose.

In elephant footyam as there is not much difference in the vegetative growth of the crop due to ageing, the photosynthetic efficiency can be evaluated from the data on bulking rate. Bulking rate was significantly influenced by fertilizer levels at the initial growth phases during both the years. This was maximum at lowest fertilizer level at the later growth phase of the crop in both the years though the effect was not significant.

The above results would indicate that the tuber efficiency was in some way affected negatively by higher quantity of fertilizer at later stages. But further analysis of the data revealed that the bulking rate at the initial stage was maximum at higher level of fertilizer in both the years which was compensated by higher bulking rate for low levels of fertilizer at later stage. This would lead to the conclusion that the tuber development process may be slow at low fertilizer levels under partially shaded conditions as compared to the highest fertilizer level. But the over all effect of these treatments on bulking rate substantiates that under shaded situation the fertilizer need of the crop was only 50 per cent of the recommendation for the open.

Utilisation index being the ratio of fresh weight of tuber to vegetative part would indicate how much of the food material synthesized is being effectively utilised for tuber production. As this was also not influenced by fertilizer levels it could be concluded that the efficiency of production of assimilates as well as its translocation to the economic part also did not vary by fertilizer treatments. This is in accordance with the result of Sasidharan (1985) in *Dioscorea esculenta*.

The tuber yield of elephant foot yam was not significantly influenced by the fertilizer levels. The mean yield over the two years of study revealed that the crop exhibited more or less equal yields under different fertilizer levels. It can thus be concluded that elephant footyam when grown as an intercrop in coconut garden the fertilizer level can be reduced to 50 per cent of the recommended dose. The data even revealed a reduction in mean tuber yield with increase in fertilizer levels.

Mandal and Saraswat (1968) reported that a fertilizer dose of 25 t farm yard manure + 80 kg nitrogen + 80 kg P_2O_5 + 120 kg K_2O ha^{-1} gave the highest yield while the most economical fertilizer usage was found to be 25 t farm yard manure + 40 kg nitrogen + 40 kg P_2O_5 + 80 kg K_2O ha^{-1} for elephant footyam. This would mean that even under open conditions the crop is not able to effectively utilize the fertilizer nitrogen and phosphorus above 40 kg ha^{-1} each and potassium above 80 kg ha^{-1}. Wormer (1934) pointed out that abundant supply of nitrogen will favour top growth and impair the process of tuberisation.

In general, the uptake of nutrients followed the same trend as that of dry matter. The uptake value of nitrogen lacked statistical significance at the initial and harvest stage of the crop in the first year and at all stages in the second year. The per hectare removal of nitrogen at the harvest stage ranged from 101.5 kg ha^{-1} to 135.57 kg ha^{-1} and from 68 kg ha^{-1} to 89.55 kg ha^{-1} during the first and second year respectively.

The quantity of nitrogen removed per ton of dry matter for the treatments high, medium and low levels of fertilizer was 16.50, 16.70 and 16.17 and 15.59, 19.43 and 15.59 kg for the first and second year respectively. This would indicate that the utilisation efficiency of nitrogen was more or less similar in all the treatments.

Phosphorus uptake by plants was significant only at 190 DAS in the first year and 130 DAS in the second year. Phosphorus removal ranged from 24 to 29 and 14 to 23 kg ha^{-1} in the first and second years respectively. The quantities of phosphorus removed per ton of dry matter produced with treatments high, medium and low fertilizer levels were 3.95, 3.58 and 3.96 during the first year and 3.85, 3.81 and 4.67 in the second year respectively. As evidenced from these data the utilisation efficiency of phosphorus was also similar for all the treatments.

The uptake of potassium ranged from 254 kg ha^{-1} to 373.53 kg ha^{-1} in the first year and from 185 kg ha^{-1} to 280.27 kg ha^{-1} in the second year. The rate of removal of this nutrient per ton of dry matter were 42.45, 45.68 and 56.59 kg with high, medium and low levels of fertilizer in the first year and 43.33, 49.81 and 48.81 kg for the above treatments in the second year. The utilisation efficiency of potassium was also low at higher fertilizer levels. This may probably be due to the continuous uptake of the nutrients in excess of their need.

There was significant positive correlation between yield of elephant footyam and nitrogen, phosphorus and potassium uptake during first year of study and only between phosphorus and potassium uptake in second year.

The general trend in soil nutrient status after the crop was an increase in the nutrient status with increase in fertilizer levels and the effect was significant only in the case of nitrogen.

5.3. Economics

The gross and net return were maximum by growing elephant foot yam as intercrop in coconut garden. The crops in the decreasing order of benefit-cost ratio were elephant footyam, greater yam and lesser yam. Tannia could not earn any profit due to its very poor yield. Asokan (1986) reported elephant footyam as the most profitable floor crop in cassava + banana intercropping system.

Among the fertilizer levels tried, greater yam gave maximum benefit-cost ratio with higher level of fertilizer, lesser yam with medium level and elephant footyam with low level. Therefore, it could be concluded that under partial shaded condition, greater yam can be grown economically with full dose as recommended in the package of practices for open condition, lesser yam need only 75 per cent of the recommended dose and elephant footyam can be grown profitably with 50 per cent of the recommended fertilizer.

Bavappa *et al*. (1986) obtained substantial saving by reducing the fertilizer level to 1/3 of the dose for both main crop of coconut and intercrops viz. tannia, tapioca and elephant footyam without substantial reduction in yield.

Summary

SUMMARY

An investigation was carried out to evolve the fertilizer management practices of minor tuber crops in coconut based cropping system during the years 1985-86 and 1986-87. This investigation was carried out as two experiments. In experiment I, screening of minor tuber crops under varying intensities of shade was done adopting a split plot design with 4 replications. In experiment II, the fertilizer management of minor tuber crops in coconut based cropping system was studied. The experiment II was conducted adopting randomised block design with 3 replications. While experiment I was taken up at the Instructional Farm, College of Agriculture, Vellayani, experiment II was conducted at Coconut Research Station, Balaramapuram. The salient findings of the above studies are summarised below.

Shade had significant influence on the length of vine/height of plant of greater yam, lesser yam, tannia and elephant footyam recording significantly lower vine length/height of plant in the open. At intense shade level a reduction in vine length was observed for greater yam.

Girth at collar was significantly influenced by shade in tannia only recording highest value under

25 per cent shade. However this character was not significant in elephant footyam.

Shade significantly influenced LAI of all crops and maximum value was recorded at 50 per cent shade in greater yam and at 25 per cent shade in lesser yam, tannia and elephant footyam.

The over all effect of shade on net assimilation rate of the crops was a decrease in NAR with increase in shade intensity. But significant variation could be observed only in lesser yam and elephant footyam recording highest values at open. Though not significant, other crops also recorded higher NAR values at open.

Shade significantly influenced the crop growth rate. Although greater yam and lesser yam recorded lowest CGR values under open condition at the initial growth phase it was maximum at later growth phase for the same treatment. Tannia and elephant footyam recorded highest values by medium and low shade in the first and second growth phases respectively.

Dry matter production was significantly influenced by shade. At harvest stage highest dry weight accumulation was observed under open condition for greater yam and elephant footyam, while tannia and lesser yam recorded highest value at 25 per cent shade. All the four crops recorded significantly lower dry matter production at intense shade.

Shade had a dominant role in modifying the tuber yield of the crops under study. All the four crops registered significantly lower yields under intense shade of 75 per cent intensity.

With increase in shade intensity the yield declined proportionately in greater yam and elephant footyam recording highest yields under open condition. The tuber yields of lesser yam at open and at 25 per cent shade were statistically on par and after that a drastic reduction in yield was observed with increase in shade intensity. Tannia recorded highest yield under 25 per cent shade with an almost equal yield under 50 per cent shade.

Lesser yam, tannia and elephant footyam recorded maximum top yield under 25 per cent shade while greater yam had maximum value at open. All the four crops recorded significantly lower top yields at intense shade.

The overall effect of shade on utilisation index was not significant. Lesser yam alone recorded significant difference due to shade.

The effect of shade on the content of chlorophyll 'a', 'b' and total chlorophyll in leaves was significant for all the crops recording a general increase in the content with increasing shade intensities.

Although shade significantly influenced the starch content of tubers the crop performed differently.

Excepting tannia the protein content of tuber in all the crops was highest at intense shade level. Tannia recorded maximum protein content at 50 per cent shade.

Open treatment recorded maximum uptake of nitrogen and phosphorus by greater yam and nitrogen, phosphorus and potassium by elephant footyam. Lesser yam and tannia had higher uptake values of nitrogen, phosphorus and potassium at 25 per cent shade level. But all these four crops recorded very poor uptake values at intense shade.

The over all effect of shade on soil nutrient status was significant only in available phosphorus content which was found to increase with increasing shade levels.

From this study it was concluded that greater yam can be grown under partial shaded situation upto 50 per cent shade with an yield reduction of only 30 per cent.

Lesser yam can be grown only upto 25 per cent shade level and that also with an yield reduction of 23 per cent.

Tannia recorded highest tuber yield at 25 per cent shade with an almost equal yield under 50 per cent shade.

Elephant footyam can also be grown under partial shade situation upto 25 per cent shade level with an yield reduction of 28 per cent.

Plant height/length of vine of lesser yam, tannia and elephant footyam was not significantly influenced by the fertilizer levels. But for greater yam, there was significant increase in the plant height with increasing fertilizer levels.

Girth at the base of the stem of tannia and elephant footyam was not influenced by fertilizer levels.

The fertilizer treatments did not significantly influence the number of leaves plant^{-1}.

Net assimilation rate did not vary significantly due to fertilizer levels.

Bulking rate at later growth phase was not significantly influenced by fertilizer levels for any of the crops excepting greater yam which recorded significantly high bulking rate at full recommended dose.

Total dry weight at harvest stage also did not vary significantly due to fertilizer levels for any of the crop excepting greater yam in the second year, which recorded maximum value with full recommended dose of fertilizer.

The crops in the decreasing order of mean tuber yield were elephant footyam, greater yam, lesser yam and tannia.

Greater yam responded linearly to fertilizer levels recording maximum yield with full dose as recommended in the package although the variation was significant only in the second year. Lesser yam had maximum yield at medium fertilizer level and elephant footyam at lowest level though not significant. The general performance of tannia was very poor.

Among the four tuber crops under study, elephant footyam recorded maximum top yield followed by greater yam, lesser yam and tannia in the descending order.

Greater yam and elephant footyam recorded significantly lower top yields at lowest fertilizer level during both the years of study. But tannia had maximum top yield at lowest fertilizer level. However, there was no significant difference in lesser yam with regard to this character.

Crops differed significantly in the uptake of nutrients. Greater yam and elephant foot yam recorded higher uptake values of nutrients which were superior to lesser yam and tannia.

The economics worked out for the fertilizer management practices of greater yam, lesser yam, tannia and elephant footyam revealed that among the four crops, elephant footyam gave the maximum net profit followed by greater yam and lesser yam. However, tannia resulted in a loss.

Greater yam crop gave maximum benefit - cost ratio of 2.44 with the full dose of fertilizer (80:60:80 kg NPK ha^{-1}). 75 per cent of the recommended dose (60:45:60 kg NPK ha) resulted in maximum benefit - cost ratio of 1.40 with lesser yam. But with 50 per cent of the recommended fertilizer dose (40:30:50 kg NPK ha^{-1}) elephant footyam could give the maximum benefit - cost ratio of 2.74

Tannia could give only a maximum benefit - cost ratio of 0.97 which means a loss and this too is with 75 per cent of recommended dose.

CONCLUSIONS AND FUTURE LINE OF WORK

It may be concluded that the crops performed differently under varying shade intensities. Tannia alone could give an enhanced yield under partial shade situation. The yield reduction pattern of greater yam, lesser yam and elephant footyam were also different recording 30 per cent yield reduction at 50 per cent shade level for greater yam, 23 and 28 per cent yield reduction at 25 per cent shade levels and after that a drastic decline in yield with increase in shade levels for lesser yam and elephant footyam. Thus it is seen that the possibilities of introducing lesser yam and elephant footyam exist only upto 25 per cent shade where as greater yam could be introduced even upto 50 per cent shade, although there was a reduction in yield to the tune of 30 per cent. However, there exist a possibility of introducing a shade tolerant crop like tannia to compensate a part of the reduction in yield with greater yam. But this requires further thorough investigation on the geometry of planting and other management practices.

Lesser yam crop also exhibit very low LAI values which is an indication that the plant population was not optimum. Detailed studies are required to make changes in the spatial arrangement of this crop along with studies on nutritional requirements. At intercropped situations, it may be worth while to include some other shade tolerant crop of lower canopy level rather than increasing the plant population but this also need thorough investigations.

In the fertilizer management studies, greater yam alone could respond economically to full dose of fertilizer recommendation. Even here, to arrive at the optimum dose one more higher level may be included in the treatment for future studies.

On account of the very poor performance of tannia, the fertilizer influence could not be revealed full and as such this crop is to be studied in another location suited to the crop.

The increase in yield observed at lower fertilizer levels for elephant footyam, would lead to a further reduction in fertilizer dose for this crop under partial shade situations. But this requires further detailed investigation on the influence of fertilizer treatments both on the intercrop and main crop.

The major constraint in the production of tuber crops is that approximately one fourth of the tuber produced is utilized as planting material. Therefore some bio-techniques need to be evolved for reducing the quantity of planting material.

Since the influence of intercrops on the yield of main crop was not studied in this investigation, it is quite appropriate to initiate programmes for assessing the effect of intercropping on the main crop of coconut.

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* Originals not seen

Appendix

APPENDIX I

Weather data during the crop period

Month	Temperature °c Max	Temperature °c Min	Humidity (percent)	Total rainfall (mm)	No of rainy days
1	2	3	4	5	6
Feb '85	31.8	23.8	82.0	26.0	4
Mar "	32.4	25.6	82.5	8.1	4
Apr "	33.5	22.3	77.5	38.4	5
May "	33.7	23.1	75.0	100.0	4
Jun "	28.5	23.1	79.0	322.1	20
Jul "	28.2	22.4	71.5	71.0	7
Aug "	28.6	23.6	83.0	21.7	3
Sep "	30.3	23.6	81.0	0.0	0
Oct "	30.6	22.8	85.0	594.0	13
Nov "	29.8	23.0	79.0	240.0	12
Dec "	30.9	23.0	72.4	104.8	10.0
Jan '86	31.9	21.8	75.0	21.6	2
Feb "	31.9	20.8	76.0	86.0	3
Mar "	31.6	20.8	59.0	8.6	2
Apr "	33.9	23.6	73.6	125.5	9
May "	33.7	22.7	73.8	132.1	5
Jun "	31.2	22.6	76.0	224.3	15
Jul "	30.5	22.9	79.0	94.4	13
Aug "	30.3	22.4	74.0	419.3	13
Sep "	30.3	23.4	74.0	102.4	11
Oct "	30.8	22.6	74.0	80.2	8
Nov "	30.6	21.4	74.0	183.4	13
Dec "	31.5	21.9	68.5	25.4	3
Jan '87	30.7	20.3	72.7	0.0	0

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FERTILIZER MANAGEMENT OF MINOR TUBER CROPS IN COCONUT BASED CROPPING SYSTEM

By

R. PUSHPAKUMARI

ABSTRACT OF A THESIS

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Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF AGRICULTURE
Vellayani - Trivandrum
Kerala India

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ABSTRACT

An investigation was carried out to evolve the fertilizer management practices of minor tuber crops in coconut based cropping systems during the years 1985-86 and 1986-87. This investigation was carried out as two experiments. In experiment I, screening of minor tuber crops under varying intensities of shade was done adopting a split plot design with 4 replications. In experiment II the fertilizer management of minor tuber crops in coconut based cropping system was studied. The experiment II was conducted in randomised block design with 3 replications. While experiment I was taken up at the Instructional Farm, College of Agriculture, Vellayani, experiment II was conducted at Coconut Research Station, Balaramapuram.

Shade had significant influence on the length of vine/height of plant, LAI, NAR, CGR, dry matter production chlorophyll content of leaves, starch and protein content of tubers and yield of tuber of greater yam, lesser yam, tannia and elephant footyam.

With increase in shade intensity, the yield decline proportionately in greater yam and elephant footyam recording highest yield under open condition. The tuber yield of lesser yam under open and 25 per cent shade levels were

statistically on par, beyond which a drastic reduction in yield was observed with increase in shade intensity. Tannia recorded highest yields under 25 per cent shade, with an almost equal yield under 50 per cent shade.

Fertilizer levels did not significantly influence the growth and yield characters of lesser yam, elephant footyam and tannia. But for greater yam there was significant increase in plant height in the first year and tuber yield in the second year with increase in fertilizer level.

Greater yam responded linearly to fertilizer levels recording maximum yield with full recommended dose of fertilizer, although the variation was significant only in the second year. Lesser yam had maximum yield at medium fertilizer level and elephant footyam at lowest level, though not significant. The general performance of tannia was very poor.

The economics worked out for the fertilizer management practices of greater yam, lesser yam, tannia and elephant footyam revealed that among the four crops tried, elephant footyam gave the maximum net profit followed by greater yam and lesser yam. However, tannia resulted in a loss.