INTERACTION OF INTERCROPS IN MAXIMISING UTILIZATION OF RESOURCES IN ARECANUT STANDS (*Areca catechu* L.) IN THE MAIDAN TRACTS OF KARNATAKA

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DEPARTMENT OF AGRONOMY
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CERTIFICATE

This is to certify that the thesis entitled "INTERACTION OF INTERCROPS IN MAXIMISING UTILIZATION OF RESOURCES IN ARECANUT STANDS(*Areca catechu* L.)IN THE MAIDAN TRACTS OF KARNATAKA" submitted by Mr. M. Sannamarappa for the degree of DOCTOR OF PHILOSOPHY IN AGRONOMY of the University of Agricultural Sciences, Bangalore, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I. INTRODUCTION

Plantation crops play a significant role in the agrarian economy in areas where they are intensively grown in commercialising agriculture on the one hand and in providing gainful employment to farming community for most part of the year on the other. They contribute to two per cent of the Gross National Product (GNP) accounting for about 10 per cent of foreign exchange earnings and over 80 per cent of these earnings from agricultural commodities. Plantation crops like tea and coffee, occupying about 5.51 lakh ha, earn nearly Rs.450 crores through export. They also provide employment to over 15 lakh people in farming enterprises. Arecanut plantations on the other hand occupying an area of 1.84 lakh ha with an annual production of 191 lakh tonnes of nuts valued at Rs.250 crores provide employment and livelihood to over four lakh people.

Arecanut plantations in India are mainly concentrated in the humid lateritic and red soil zones of Kerala, Karnataka, Assam and Meghalaya receiving heavy rainfall or under irrigated conditions at altitudes varying right from sea level to 1000 m. It is well recognised that although the production of arecanut is on a small scale and localised to small belts in a few states, the commercial product is very popular and is widely used all over the country and being consumed by all classes of people. Arecanut (Areca catechu L.) known as "Poogiphalam" in Sanskrit is being cultivated from very early times in India. The fruits of this palm form an important component of social and religious functions. The arecanut palm with its ringed erect, thin trunk reaches a height of 15 metres or more and has a closely packed crown of dark pinnate leaves allowing for partial trickling down of sunlight wherein lies the scope for agronomic manipulation of introducing some additional crops in the interspaces. Being a perennial crop, improvement in the productivity of the main crop is not an easy task through introduction of new varieties such as "Mangala" as in seasonal or annual field crops. With fluctuation in market prices from year to year added to severe damage to the crop due to drought, diseases and some pests, there is always a factor of great risk in this plantation crop and industry as a whole. Among the agronomic management practices, therefore, intercropping and mixed cropping systems seem to provide an answer in stabilizing the income of small arecanut farmers.

Intercropping in arecanut plantations is not new and farmers generally have their preferences in choosing seasonal crops in the interspaces especially when areca plantations are young. It is observed in one place or the other that crops such as turmeric, ginger, sweet potato, elephant foot yam, dioscorea, chicory, banana, betelvine, pineapple, tapioca, cacao, clove, cinnamon and a host several crops are raised in arecanut gardens. However, the reasons for choosing a particular crop for intercropping in areca would vary from location to location, the primary consideration being that of securing additional income, equitable distribution of labour forċe over a greater length of crop growth period and better utilization of inputs and resources such as fertilizers, land and solar energy. Even in Karnataka, with diversified conditions under which arecanut is cultivated in the heavy rainfall areas of hilly tracts of Shimoga and Chikmagalur and the coastal belts of Dakshina Kannada and Uttara Kannada in contrast to cultivation in scattered spots in semi arid belts under protective irrigation in other districts, there is no background information as to the most optimum combinations of intercropping or mixed cropping. This is especially so for small farms under tankbed situations too. The nature of the problem assumes added emphasis in the present day context of dwindling farm size, rising costs on inputs and increasing difficulties in managing labour forces in a just and profitable manner round the year.

A scientific approach to intercropping studies in arecanut plantation is ,therefore,warranted if resources such as light filtering through the canopy and moisture and nutrients untapped by the root system of the main crop are to be better utilized. Estimates indicate that under the recommended spacing of 2.7m x 2.7m nearly 40-50 per cent of incoming solar energy in pure arecanut plantations in coastal belts of Karnataka are not fully intercepted and about 60 per cent of land surface area in the interspaces of arecanut are either not foraged by the crop roots or underutilized both in depth and spread thus providing scope for intensification of cropping. Such a thinking also calls for new approaches such as; (1) changing plant densities of pure stands or altering planting geometry with or without changing palm density so as to accommodate intercrops or mixed crops thus allowing for maximum interception of light, (2) introducing multiple/multistorey cropping systems to increase cropping efficiency throughout the year facilitating proper distribution and utilization of solar energy in a vertical profile of the mixed canopies as well as to exploit different layers of soil for moisture and nutrients and (3) incidentally to reduce the cost on weeding, intercultivation and even on irrigation by providing a crop cover in the intercropping system instead of leaving the interspaces free as in pure stands.

Research needs with regard to intercropping in arecanut are thus required to be directed in locating optimum combinations of intercrops and their proportions coupled with bringing out suitable fertility and other agronomic management practices so as to maximise the utilization of all resources at hand and in bringing out findings of practical application even to small arecanut farmers of maidan tracts of Karnataka state. In the wake of such studies, where a possibility of enhancing the income of these farmers is upper most in thought, adverse effects, if any on the main crop of arecanut and on the soil on a long term basis because of introduction of certain intercrops coupled with their agronomic practices needs to be studied in greater depth. Such intercropping studies were wanting in the maidan tracts specially to meet the demands of small scattered arecanut gardens rather than big contiguous arecanut plantations of the hilly and coastal tracts. Therefore, the present investigations entitled " Interaction of intercrops in maximising utilization of resources in arecanut stands (Areca catechu L.) in the maidan tracts of Karnataka" were initiated with the following objectives:

1) to study the effect of planting densities and planting geometries of arecanut palms on light interception by the main crop and intercrops grown within it,

2) to identify optimum proportions of intercrops viz; turmeric, sweet potato and cowpea that could be raised under varying planting geometries of arecanut,

3) to locate optimum fertilizer combinations required for intercrops and their interaction on residual soil fertility,

4) to study the growth and development of intercrops and their interaction on the yield potential of arecanut, and

5) to estimate the efficiency of potential utilization of resources and economics of intercropping in arecanut stands.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

II.1. Intercropping and related cropping systems

Studies on intercropping with special reference to plantation crops have received scientific attention only in the recent years although intercropping has been a common practice in most plantations both in Malnad and Maidan areas for several decades. The relevant literature on intercropping studies, in general, including field crops is, therefore, presented in a brief review giving it as a back drop resource material in consonance with the objectives of the current investigations.

The concept of mixed cropping was defined by Aiyer (1949) as a system of growing two or more crops or varieties in the same field, garden or plantation, each carrying jointly the same ground and sharing in common the cultural operations of the field although the latter were intended for one single crop, and sown or planted either promiscuously in the midst of each other or systematically in alternating rows or otherwise. Gautam and Dastane (1970) refered to companion cropping as growing two crops together in the same field where they will be in harmony with each other. Hart (1974) introduced the term simultaneous polyculture for such combinations of different crops grown on the same field. Intercropping has also been frequently used to define situations where the crop combination is to produce a full yield of a main crop and some yield of a subsidiary crop.

Tarhalkar and Rao (1975) considered the term intercropping to refer to a situation where two or more species are grown together so that these different species jointly exploit the environment better. Andrews and Kassam (1976) refered to intercropping as growing two or more crops simultaneously on the same field where crop intensification is in both time and space dimensions with intercrop competition during all or part of crop growth. They distinguish four types of intercropping as mixed cropping, row intercropping, strip intercropping and relay intercropping.

Willey (1979) defined intercropping as the growing of two (or more) crops simultaneously on the same area of ground. The crops are not necessarily sown at exactly the same time and their harvest times may be quite different, but are usually simultaneous for a significant part of their growing periods. This distinguishes intercropping from relay cropping in which growing periods overlap only briefly.

The terms intercropping and mixed cropping, have often been used synonymously in the past. Recently, attempts have been made to distinguish between different forms of intercropping or intercropping from mixed cropping itself. Freyman and Venkateswaralu (1977) and Beets (1978) opined that intercropping should imply that the crops are grown in separate rows, and that any arrangement without a fixed pattern of spatial arrangement and without fixed plant populations and proportions of the components should be defined as mixed cropping.

Intercropping as applied to plantation crops refers to growing annuals or biennials in the interspaces of the main crop. No distinction regarding the arrangement of the intercrops is made. The desirability of raising annuals or perennials in the interspaces of coconut and the advantages arising out of such practices was earlier recognised by Nelliat (1973). He brought out the concept of multistoreyed cropping in plantation crops to maximise exploitation of all resources. The increased proximity of neighbours may lead in individual plants to express a lower growth rate and dry matter yield. Trenbath (1973) used the term neighbour effect to refer to morphological and physiological differences caused by the proximity of other plant species or genotypes.

The first and most important interaction in a plant community is competition for growth factors or environmental resources. Whittaker (1975) described competition as a situation in which there is not enough of an environmental resource for two individuals or two species populations. In a plant community, if the component plants are of similar nature as in a sole crop, and when the pool of resources from which they have to draw is of limited volume, then the successful competitor is the plant which draws most rapidly from the pool when it is at ebb. According to Boffoy and Veevers (1977), competition may be for light, space, moisture etc., the operative mechanisms in any particular instance being naturally complex.

The interaction effects in intercropping systems are more complex than monocultures or sequential systems since they vary as widely as overstorey crops with coffee and cacao or legume-grass pasture mixtures (Allen _et al._, 1976). Frequently, one crop that is taller will tend to dominate the photosynthetically active radiation environment. Some times the dominant (taller) species will be more or less permanent as in crop combinations with coconut or arecanut.

II.2. Intercropping and mixed cropping in plantation crops

The genesis of high intensity cropping concept in arecanut and other plantations especially of lesser rainfall area of maidan parts of Karnataka is only of a recent origin in terms of scientific research. Screening of mixed stands composed of different species for evolving an intensive cropping pattern for high yield, higher profit, better utilization of resources and to test the advantages of traditionally grown intercrops and to gain basic information on the process which lead to advantages and disadvantages of mixed crop communities in plantation crops has significance in the present day context of augmenting food production, with the existing land, labour and other resources.

Research work on mixed and intercropping in arecanut plantations was initiated some three decades ago (Sundarmurthy,1950 and Bavappa, 1951). Successful cultivation of intercrops in arecanut such as banana, betelvine, tapioca, black pepper, colocasia, yam, pineapple, jack and coconut (Bavappa, 1951) and ginger, turmeric, black pepper and cardamom (Abraham,1956) were reported.

Five year results from an experiment conducted at CPCRI Regional Station, Vittal indicated no significant differences in yield of arecanuts due to intercropping of banana under different intensities of planting (Sannamarappa and Muralidharan, 1982) confirming earlier reports (Bhat, 1974, Brahma,1974, Roy, 1974, Nagaraja, 1974 and Bhandary, 1974). Bhat and Khader (1970) reported that growing banana as an intercrop in young arecanut garden will protect the latter from sun-scorch. They also indicated that intercropping in young arecanut garden can derive the advantage of temporal complementarity while intercropping in mature arecanut gardens can be benefitted from spatial complementarity. Unlike in other crops where sole crops themselves, under optimum population, can achieve peak values of highest interception, leaving little scope for greater spatial interception of light by the intercrops (Willey and Roberts, 1976) the widely planted arecanut palms may not produce complete cover of the area to fully intercept the light.

However, yields of arecanut were reduced in experiments conducted at CPCRI, Hirehalli (1972-1980) and Kahikuchi (1973-1978) (Sannamarappa and Muralidharan, 1982), though there was economic advantage with banana fetching handsome additional income. Inspite of some of the early research reports on mixed and intercropping. Sadanandan (1974) considered that there was no authentic information available on the choice of intercrops in arecanut plantation for different localities. Velappan and Paulose (1974) stressed the importance for intensifying research to evolve suitable intercropping patterns in plantation crops. Bhandary (1974) reported that varying amounts of additional income can be obtained by intercropping. Roy (1974) and Bhandary (1974) opined that growing intercrops like banana, pineapple, pepper, ginger, betelvine etc., had no adverse effect on the yield of arecanut. Bhat (1978) found that cacao as a mixed crop with arecanut during the early ten years period of plantation did not show any adverse effect on the performance of arecanut.

Bhat and Leela (1968) suggested that on the West Coast of India, cacao is likely to go well with arecanut palm as a mixed crop. Bhat and Bavappa (1972) discussed the possibility of raising cacao in the normally spaced coconut and arecanut plantations. Menon and Nayar (1978) reported that the effects of intercropping with tubers in the coconut palms in the root(wilt) disease prevalent area, increased the yield of coconut.

In humid tropics, higher efficiency of utilization of the basic resources of crop production viz., land and solar radiation can be achieved by adopting intensive cropping systems like multistoreyed cropping (Nelliat, 1973). Problems and prospects associated with such an intensive system have been enumerated and discussed by Nelliat *et al.* (1974), Nair *et al.* (1975) and Nair and Verghese (1976). The garden lands of the humid tropics respond to intensive management but require location specific agro-techniques to achieve high and desirable production levels (Nelliat, 1976).

II.3. Competitive effects and resource utilization in an intercropping system

Competition for most of the environmental resources in a plant community is a natural phenomenon. This is particularly observed in such intercropping systems wherein there may be no yield advantages than in sole cropping. The hardships caused by the proximity of neighbours was regarded as "interference" by Harper (1961). When the neighbouring plants are of the same genotype as in monocultures, hardship are expressed as shortage of environmental resources such as light, water and nutrients (Donald, 1963). Willey (1979) presented the term "mutual inhibition" when the actual yield of each species in an intercropping system was less than expected.

II.3.1. Light interception and utilization

In any intercropping system light appears to be one of the most limiting factors in the productivity of crops. Donald (1963) observed that competition for light occurred when one plant casts shadow on another or within a plant when one leaf shades another leaf. Competition for light was absent among newly emerging crop seedlings while severe competition for light occurred at later stages of plant growth.

Interception and absorption of light by plant canopy diminishes as plants grow. In an intercropping system light penetration to the middle and lower leaves is inhibited by inter and intra-plant competition. Trenbath (1973) observed that even during grain filling in cereals a difference of height can profoundly affect the yield of grain of a shorter component. The reduction in light intensity due to interception within a leaf canopy is usually exponential (Trenbath, 1976). Consequently, in mixed intercrops where soil factors are not limiting and competition is only for light, slight differences in height, even early in growth, can lead to strong competition effects. Allen et al. (1976) reported that photosynthetic productivity of crops, which may not normally attain light saturation under ordinary sunlight, may be proportional to the radiation intercepted by their canopies when grown under other crops. Boardman (1977) considered that plants can be classified as sun and shade species depending on their light saturation curves, light compensation points and on their adaptability to varying light intensities.

Differences in growth rates and yield of component crops in mixtures have been explained in terms of competition for light (Black, 1958; Williams, 1963; Kumaraswamy and Hosmani, 1978), the more uniform the interception of light by the components, the lower the differences from their normal growth and yield. When competition for light is severe as in a dense population, reproduction is suppressed as in the amount of photosynthates available per plant becomes limiting even though primary productivity per unit ground is high which is not often the major objective in agricultural communities where economic yield is more valued than total biological production (Loomis et al., 1971).

Watson (1952) reported that density of leaf layers and leaf area density also play a major role in interception of light. Higher the vertical intervals of leaf layers, better will be the light penetration into deep layers. Kasanga and Monsi (1954) reported that high light intensities in tropics can be better utilized by a canopy with greater vertical distribution. Pendleton and Seif (1962) examined this possibility of different heights but could not observe any advantage on the yield. Combining crops with different inherent responses to light might help better utilization of light. Thus the top of the canopy could consist of a component with a high light requirement and the bottom component with a low light requirement, an obvious example would be a tall C_4 crop combined with a short C_3 one (Crookston and Kent, 1976).

The spectral qualities of radiation will change with depth of penetration into plant canopies because leaf pigments absorb more strongly in the PAR (Photosynthetically Active Radiation) spectrum than in the NIR (Near Infra-red Radiation). This may help in choosing components of the intercrops adopted to the qualitative changes in light which occur down through the canopy (Szeiz, 1975; Allen et al., 1976). This differential absorption causes shifts in the average spectral quality of radiation that reaches the lower canopy crops. The NIR/PAR ratios will also be affected by the time of day and solar elevation angles. If infra-red comprises 50 per cent of the solar radiation and if the leaves absorb 85 per cent of the near infra-red radiation, the total absorption by the upper canopy will be 55 per cent as assumed by Nichiporovich (1954).

Duncan *et al.* (1967) while presenting a mathematical model suggested that highest photosynthetic rate might be obtained from a canopy in which the steepness of inclination of the leaves decreases with depth. They also stated that over yielding of mixture has in some instances been attributed to a more efficient utilization of light. Trenbath (1974) reviewed the canopy structure of different crop mixtures in relation to light interception and concluded that a taller component with erect leaves will compete less strongly for light than the one with prostrate leaves with a shorter component of the mixture. Moss (1976) reported that yield of many crops was depressed in shaded environment. Maize yield was reduced to 29 per cent when one third light was cut. The primary effect was in reducing photosynthesis.

The importance of light and its interception has perhaps been overemphasized irrespective of whether intercrops have realy intercepted the light fully or not or whether the yield advantages are as a result of better utilization of light alone. This aspect needs further research as pointed out by Willey and

Roberts (1976) who stressed that given optimum plant populations, sole crops are themselves usually capable of achieving a peak value of light interception which leaves little scope for greater spatial interception by intercrops. Willey (1979) reported that although the intercrops sorghum and pigeon pea gave greater total dry matter yield and had a slightly greater leaf area index than peak light interception of about 90 per cent was virtually identical to the sole sorghum. Lakhani (1976) also found that peak light interception values were no higher than those of sole crops though yield advantages of more than 20 per cent were achieved.in the intercrops of sunflower and fodder raddish.

If shading is not too intense, the plants of the shaded canopy will continue to grow and will adopt to the low light levels, these adaptations will be competition effects (Trenbath, 1976). Adaptations to low light intensity include reduced rates of dark respiration, lowered root/shoot ratios and greater leaf area/leaf weight ratio. Increased stem extension usually occurs in shaded plants and can some times prevent a shorter component being overtopped.

In plantation crops too light interception pattern and utilization by the canopies of main crop as well as by the choice of intercrops needs a critical examination. The ecoclimate developed in such intercrops would be different from the ones of field crops largely because of the greater vertical distribution of light than in field crops.

Nair and Balakrishnan (1976) studied the intensity of light at the plantation floor of a pure stand of adult coconut palms planted at a spacing of 7.5m x 7.5m and reported that the growth and yield of intercrops was uneven depending on the proximity to the palm, the crop planted at the middle of four palms growing better due to the availability of more light. Nair (1978) reported that pulses did not grow successfully as intercrops in coconut plantations due to competition for light from the main crop.

II.3.2. Growth and development under restricted light

Growth and development of a pure stand is generally unhindered from the point of light interception and utilization of resources if optimum populations and planting patterns are adopted. But in an intercropping system light interception and utilization cannot be optimal for all the components of the system. Greater interception by one crop may lead to deficit situations for others resulting in lower growth and development. Lower photosynthetic rate is known to lower the LAI, crop growth rate and dry matter production. A crop with a low LAI had a photosynthetic response to increasing incident light flux and so also canopies respond to increasing light flux upto progressively higher levels as they grow(Trenbath, 1979). Thus, in an intercropping system, it is to be expected that greater proportions of incident light would be intercepted by the components put together if spatial arrangement is well manipulated. It is therefore pertinent to examine as to what happens to growth and development of component crops in an intercropping system under restricted light. Moss and Stinson (1961), Pepper and Prime (1972), Fischer and Wilson (1975), Moss (1976) and Evans (1978) observed reduction in yields of crops under shaded conditions. Shading can also reduce herbage (Blackmen and Black, 1959), [illegible]. Boardman (1977) observed that shaded plants often had thin leaves with a lower fresh weight per leaf area and a higher content of chlorophyll expressed on a dry weight basis than plants grown exposed to sun. Reduction in leaf number, leaf area index, leaf thickness has also been reported by Crookston et al. (1975) and Borhomme et al. (1977) and Oritani (1978) in shaded plants. Stomatal number also decreased with the extent of shade (Warmer, 1965; Moss, 1976 and Boardman, 1977). Restricted light not only affects the leaf development but also reduces the growth and development of the whole plant since photosynthesis is greatly affected under such limited resource. Crookston et al. (1975) reported that photosynthesis per unit area of shaded leaves was decreased by an average of 38 per cent when the light intensity was reduced from 22,000 lux to 3,200 lux. Singh (1973) reported a reduction in tiller number in cereals due to reduced light intensity causing reduction in leaf area, number of panicle and dry matter per plant. A lower tiller survival was observed by Urs (1977) under low light intensity.

Shading also affects the rate of translocation of assimilates. Geiger and Batey (1967) observed low rates of translocation of assimilates when dark treatments were imposed on sugarbeet. Wardlaw (1976) found high rates of translocation of metabolites to grain in sorghum under high light intensity but the rate dropped under low light intensity. The garden lands of the humid tropics respond to intensive management, but require location specific agrotechniques to achieve high and desirable production levels (Nelliat, 1976).

II.3.3. Utilization of interspaces in plantation crops

Plantation crops being perennial as well as having tall stature provide scope for greater penetration of light, and for greater utilization of floor space by way of taking mixed or intercrops. Even in pure stands research in the recent years has indicated that competition for resources like light, nutrients and floor space can be minimised by either altering plant population per unit area or by changing the planting geometry. Such changes are determined from the combined demand of the sources by the plants in relation to the supplies per unit area of plant. In mixed or intercropping systems in plantation crops, the competition between the crops may be regarded as negligible in the initial stages if plant populations, spacings and planting patterns are well adjusted in relation to growth, development and yield of crop mixtures.

Spatial arrangement decides the pattern of distribution of plants over the ground which determines the shape and the area available to the individual plant. For crops regularly arranged in rows spatial arrangements can be concisely defined by the rectangularity, which is the ratio of the inter row spacing to the intra-row spacing (Holliday, 1963). In arecanut plantations, the spacing adopted in different tracts varies from 1.25m x 1.25m to 3.6m x 3.6m (Nambiar, 1949). Spacing affects the growth and yield attributes of the crops. The percentage of fruitset and the number of female flowers generally increases with wider spacing. A spacing of 2.7m x 2.7m has been found to be optimum under pure stands in a number of instances (Anon; 1974, Bhat and Bavappa, 1972, Anon; 1976 (a) and Anon; 1977 (b)).

This spacing of 2.7m x 2.7m was found to be ideal for exploitation of soil resources fully, compared to other densities of planting. Bhat and Leela (1968), Bhat and Leela (1969) and Bhat (1978) also found that more than 79-80 per cent of the roots of the arecanut was within a radius of 60-75 cm from the base of the palms spaced at 2.7m x 2.7m. The normal cultural operations were also confined to this radius from the base. From these studies, Sannamarappa and Muralidharan (1982) infered that nearly 69% of the land was not effectively utilized by the root system of the arecanut palm, thus, providing scope for effective utilization of land resource through introduction of suitable intercrops. However, the yields obtained from other spacings of 1.8m x 3.6m and 2.7m x 3.6m in a few instances were also reported to be equally good (Muralidharan et al., 1976; Singh and Roy, 1977). These studies thus indicate that a change in planting geometry can make available more land and light resources for introduction of intercrops.

In any intercropping system the population of the component crop is thus determined on the plant population and planting geometry of the main crop. What is optimum for the sole crops may not necessarily be optimum for both main and intercrops when plant population is considered. Therefore, the combined optimum population may be higher than that of either sole crops when considering intercropping systems. The need for higher total populations has been emphasised for field crops by many workers (Willey and Osiru, 1972; Osiru and Willey, 1977, Shelke, 1977). In plantation crops, it is not clear, however, whether plant populations of the main crop could be enhanced. Thus, altering planting pattern or geometry and then accommodating suitable intercrops in varying proportions may provide an answer in optimising utilization of floor and light resources.

II.3.4. Utilization of land and soil resources in an intercropping system

According to Agarwal and Heady (1970) land must be put to a maximum use to obtain higher production and return as land being renewable resource. Recently a simpler procedure has become common practice in intercropping studies. This is the calculation of a land equivalent ratio (LER). This may be defined as the relative land area under sole crops that is required to produce the yields achieved in intercropping under the same level of management (Willey, 1979).

Soil resources play a key role in determining the feasibility and success of an intercropping system. Plant nutrients along with moisture availability are the most limiting factors in the production of crops. Competition for nutrients between adjoining plants occurs in three stages, which are called plant competition sequences (Bray, 1954). When plants are far enough apart so that neither of their root sorption zones overlap (interpenetrate), no competition for nutrients (or water) occurs. When the root system sorption zone of adjacent plants interpenetrate, competition for the relatively mobile nutrients occurs. Competition for the relatively immobile nutrients occurs only as the root surface sorption zones interpenetrates. Depending on the planting pattern and density of planting, plants can grow (a) without competing with each other for any of the nutrients (b) effectively competing for the relatively mobile nutrients only and (c) competing for both the relatively mobile and relatively immobile nutrients.

In closely planted agricultural crops individual plants compete strongly for the supplies of plant growth factors. Competition for nutrients among different components of intercropping system at any one time during their growth period exceeds the total supply of those nutrients in the soil in an available form (Nair, 1978). Depletion of mobile nutrients like nitrates will be faster and competition for such nutrients will arise immediately if the root system sorption zones of the component crops in the mixture overlap (Dunham and Nye, 1974). Since the degree of overlapping between root systems of the components determines the intensity of competition effects a knowledge of the distribution and density patterns of the roots of intercrop components becomes important (Trenbath, 1975).

Trenbath (1976) recognised a number of characteristics which contribute to success in competition for water and nutrients such as early and fast penetration of the soil, high root density, high root length/root weight, a high proportion of root system actively growing, long root hairs, and a high uptake potential for the nutrients. Luxury consumption may also confer a competitive advantage besides the agression of a genotype in a mixture in response to environmental conditions.

Roots grow more slowly in soil depleted of water or nutrients (Duncan and Ohlrogge, 1958). Competition for nutrients by the aggressive component can affect the less successful component of a mixture in different ways (Baldwin and Tinker, 1972). Competition for nutrients may lead to visible symtoms of mineral deficiency, reduced content of the element competed for (Donald, 1958) and physiological impairment (Murata, 1969). This physiological handicap usually leads to the worse affected component being yet further handicapped by a positive feed back process (Trenbath, 1976).

Stanford et al. (1973), reported depression in yield, especially to a greater extent in low fertile soils, when a second crop is also added to the normal crop under monoculture. Beets (1978) reported that individual plants of the same species are often highly competitive for certain resources when they are grown under high plant densities whereas inter-specific plant inter-relationships of certain crops combinations will be complementary and that crops will not compete for resources such as nutrients and water.

Since plant species foraging different soil layers may make use of the nutrients better. Aiyer (1949) suggested that mixtures should be compounded to exploit the whole depth of soil. Greater nutrient uptake by intercropping has been quoted by Willey (1979) in several cases, due to differences, in rooting pattern of the components.

The mechanisms by which nutrient uptake is increased are far from clear. If the components of a mixture differ in the times at which they make demands for soil nutrients, the mixture will make use of the resource better as evident from the yield advantages derived from mixtures of early and late season potatoes and mixtures of early maturing flax with late maturing linseed (Trenbath, 1975). Even when growing periods are similar, if component crops have their peak demands for nutrients at different stages of growth, a temporal effect would occur which may help to ensure that demand does not exceed the rate at which nutrients are supplied (Willey, 1979).

Khanna and Nair (1977) indicated the importance of crop combination in the context of nutrient economy in their system analysis studies. The presence of more plant cover as in a crop combination system increased the plant cycling fractions of nutrients and thereby reducing the direct loss of nutrients in percolating water. Martin (1977) revealed that the increased root volume of the crop combination can cause the formation of more organic matter during active root growth directly from the root tissue.

II.3.5. Nutrient requirements of plantation crops in an intercropping system

The removal of nutrients from the soil by any crop depends on the composition of the crop and the size of the crop harvested and removed out of the system (Bray, 1954). Though information on the nutrient removal of most of the cultivated crops is extensive, very little information is available on the nutrient cycling in multiple cropping systems with special reference to plantation crops.

A review on the nutrient studies carried out on arecanut was made by Mohopatra (1977). He reported that the annual removal of nutrients per hectare ranged from 67.2 to 89.6 kg N, 22.4 to 33.6 kg P2O5 and 67.2 to 89.6 kg K2O. However, these estimate were made for pure stands of arecanut. No quantification of nutrients removed by diffsent intercrops is made. Further no balance sheet has been worked out to verify the total input of nutrients into the system and also the total removal of nutrients out of the system. Steady release of carbohydrate-rich organic matter from actively growing roots represents energy input into the soil ecosystem and it can support a substantial microbial population. This phenomenon has been stressed as very important in nutrient cycling in perennial crop combinations (Nair, 1978).

In arecanut intercropping though yield reductions were observed (Bhandary, 1974; Roy, 1974) no information is available regarding any competitive interactions for nutrients between the components in any of the intercropping systems. Nair (1978) reported synergistic effects of a coconut-cacao crop mixture where both the crops complement each other. Cacao as an intercrop in this case, besides acting as a buffer against drastic changes in microclimate, enhances the availability of nutrients and water for the main crop through various interacting processes. Beneficial interaction in a similar mixture of arecanut and cacao has been suggested by Bhat (1978). An early grown crop of banana inx a young arecanut plantation is reported to protect the arecanut seedlings against sunscorch and provides them favourable environment for healthy establishment (Bhat and Khader, 1970). Beneficial effects of intercropping banana, betelvine, ginger and guinea grass in arecanut gardens have also been reported by Roy (1974) and Nagaraja and Bhat (1977). However, none of these studies provide any indication as to whether the intercrops were also beneficial by such an association.

Nambiar (1949) reported that manuring arecanut palm was practised only in parts of Karnataka, South Malabar of Kerala and to some extent in Coimbatore District of Tamil Nadu. In these parts green leaves and cattle manure were being applied either annually or once in two or three years. The growers of Mettupalayam area are applying farm yard manure, groundnut cake and fertilizers. Coleman and Rao (1918) revealed the

the system of manuring with cattle manure and green leaves in Malnad and use of silt or earth from paddy fields together with cattle manure in maidan tracts of Karnataka.

Iyengar (1954) presenting the results of manurial experiments of Marthur Farm stated that an yield of over 876 kg/ha can be obtained by an application of 560 kg N, 84 kg P_2O_5 and 112 kg K_2O /ha using groundnut cake as a source of N.

Nitrogen at 50 and 100 g, green leaf at 7 and 14 kg/palm increased the yield of nuts significantly over no fertilizer at Vittal, Hirehalli and Kahikuchi (Anon; 1976).

Nitrogen at 100 g and K_2O at 140 g/palm increased the production of spadices, nut production and its relative weight significantly. The influence of P was not significant on any of the characters studied except on an initial increase of height and percentage of spadices to leaf fall. At Hirehalli, the main effects of N and green manure were significant with respect to number of nuts produced and their wet weight. Among N and P interactions * N_2P_1 produced significantly more number of nuts. ** P_0K_1 interaction produced significantly more number of nuts and their wet weight over any other PK interaction (Anon; 1979).

The fertilizer recommendation for arecanut is 100:40:140 g of NPK/palm (Anon; 1978).

II.3.6. Fertilizer requirements of intercrops in plantations

* N_2P_1 = 100g N 40g P

** P_0K_1 = 70g K without P

Varghese *et al.* (1978) revealed that raising tuber crops had no adverse effect on the main crop of coconut, provided these intercrops were grown in rotation and both the intercrops and the main crop were adequately and separately manured. Nelliat *et al.* (1974) observed that against popular belief intercropping in coconut gardens had no adverse effect on the yield of palms, when both the main and intercrops were adequately manured.

Turmeric responds to heavy manuring. The curing percentage of turmeric was found to be influenced by fertilizer application (Rao, 1965). According to Rao *et al.* (1975) 25 tonnes of cattle manure or compost and 63 kg N/ha as oil cake was found to be optimum. Aiyadurai (1966) found that 100 kg/ha of ammonium sulphate doubled the yield over that of unmanured crop. Nair (1964) reported significant effect of nitrogen and potash on plant height, tiller production and yield, while the response to phosphate was rather negligible. A fertilizer dose of 189:63:126 kg of NPK/ha was recommended for the best yield in Andhra Pradesh (Rao *et al.*, 1975). Rajput *et al.* (1980) revealed that 100 kg N/ha is the optimum requirement of nitrogen. The fertilizer recommendation for Kerala as per the package of practices was 30:30:60 kg NPK/ha, full dose of P_2O_5 and half K_2O to be applied as basal, two third of nitrogen to be applied 30 days after planting and the rest 60 days after planting (Anon, 1976(b)). The fertilizer recommendation for Karnataka as per the package of practices was 70:60:120 kg NPK/ha (Anon, 1977(a)).

In sweet potato, Togari (1950) observed that the tuber yield was low without N, but little difference in yield was observed between the low N plot and the control. Heavy N, however, decreased yield. He further found that the yield of sweet potato was not affected by 'P' application. Stino and Lashin (1953) observed a yield response of P treatment. He also observed that when P fertilizer was applied, sweet potatoes became long in shape, increased in sweetness and storage properties improved. Miller and Covington (1962) observed that there was no advantages in applying more than 100 kg N/ha and 83 kg K_2O/ha to sweet potato. Tsuno and Fugise (1965) revealed that the response to heavy N application differed according to variety. In some varieties a high yield was obtained with high N application without causing over growth of the aerial parts (Var: Okinawa No.100) while in others the yield of tubers decreased drastically with a slight increase in N application due to too much of top growth (Var: Kanto No.48). Tsuno and Fujise (1968) noticed that K alone was not so effective but the combined application of N and K showed a remarkable yield increasing effect. They further observed that N and K together kept the roots healthy for a longer period than K alone. Li (1971) found that sweet potato tuber yields were increased from 21.71 t/ha with no fertilizer to 44.58 t/ha with 80 kg N + 200 kg K_2O/ha but with no effect observed from P_2O_5 when the crop was given all combinations of 0, 40, 80 kg N, 0, 20, 40 kg P_2O_5 and 0, 100, 200 kg K_2O/ha.

Uriyo and Kesseba (1973) applied all combinations of 0, 25, 50 kg P and 0, 50, 100 or 150 kg K_2O/ha in red oxisol soil in

Tanzania and found that highest yield of 42.7 t/ha was obtained with application of 150 kg K20/ha alone and tuber yields decreased with combined applications of 25 or 50 kg P205/ha and 150 kg K20/ha. Similarly, Wang (1975) revealed that sweet potato is particularly responsive to application of K fertilizer and it is usual to apply both N and K in split dressings. However, in field trials in Alberta, Dubetz (1975) reported that tuber yield increased by 27 per cent when fertilizer was applied either by broadcasting before ploughing or banded at planting at the rate of 200 kg N, 229 kg P205 and 120 kg K20 per hectare.

In sweet potato, a sizable yield can be obtained without fertilizer (Tsuno, 1975). According to him, the yield indices for the no fertilizer, no N, no P and no K treatments were 60, 84, 90 and 74 respectively, against 100 for the NPK treatment showing that among the three major fertilizer nutrients K exerts the greatest influence on yield. Sugawara (1938) pointed out that tubers swell and large sweet potatoes are obtained when K application is increased. The most important manurial effect of K20 on sweet potato is that the enlargement of root tubers is expedited and even with heavy N application the over growth of the aerial part is lessened and high root tuber yield is secured if K dosage increased. Ho et al. (1967) observed a high correlation (r = +0.878) between the yield index and K content in the blade 40 days after planting and r = +979 between the yield index and the K content 100 days after planting. Scott and Bouwkamp (1974) in their study on seasonal mineral accumulation by the sweet potato in USA reported that the concentration of N, P, K, Mn and Mg in the vines and N, P and K in the roots of four sweet potato cultivars decreased slightly in the 14 weeks starting two months after planting. Whereas other elements like Ca, Fe and B showed no definite seasonal trends. Total uptake by the vines showed little change after the second sampling except for Ca and Fe which continued to increase. The N and Mn content of the vines decreased towards the lateral part of the season. Roots showed increasing total accumulation of all elements as the crop developed.

Tyagi *et al.* (1982) recommended a fertilizer dose of 20 kg N and 50 kg P_2O_5 to obtain a good yield of cowpea. Mann (1968) said that the growth and yield of cowpea depend upon the nodulation and rhizobial (bacterial) activity which is influenced by soil pH and nutrients like phosphate, calcium and molybdenum. For optimum growth of cowpea and its response to applied fertilizers, the soil pH should be 6.0 to 6.5. From the experimental results he revealed that phosphate application to cowpea not only benefitted the particular crop and increased its yield but also favourably affected the soil nitrogen content for the succeeding non-legume crop.

II.4. Associated growth, development and complimentarity advantages in intercropping systems

Donald (1963) reported that two species of contrasting habits with respect to branching, leaf distribution, height, root distribution, mineral uptake or other morphological and physiological characters will be able to complement each other in a common environment more effectively than plants of similar habits as in monocultures. Whittaker (1975) suggested that the components of a mixture may be complementary in a spatial sense exploiting different layers of the soil with their root system. Components of mixture may complement each other nutritionally. One component may require much of an element while the needs of other component for this element may be little. Biological complementarity between species in a stable community due to niche differentiation has been brought out by Trenbath (1978).

There can be situations where a given crop will actually grow better in the presence of another crop than as a sole crop (Willey, 1979). Erect growing species may provide support for intercropped climbing species (Aiyer, 1949). Taller, robest components may provide a wind break for more delicate components (Brown and Rosenberg, 1970).

The leaf canopies of intercrop components may occupy different vertical layers with the tallest component having foliage tolerant of strong light and high evaporative demand and the shorter components having foliage requiring shade and or relatively high humidity. Such advantageous combination is used in North African Desert Oases where three layers are often planted with date palm, citrus and vegetables (Trenbath, 1976). Nambiar (1970) reported that arecanut can protect pepper trailed to it by giving shade during hot summer months. Instances of rhizosphere microflora of component crops solubilizing insoluble forms of nutrients in the soil and benefitting the nutrient uptake of the main crop have been reported by Shantaram and Rangaswami (1967).

Information on legumes benefitting the arecanut directly is not available, though Bhat and Mahopatra (1973) recommended growing of leguminous cover crops like Pueraria javanica, Mimosa invisa and Calopogonium mucunoides for enriching the soil of young arecanut plantations through fixation of atmospheric nitrogen. Nair and Rao (1977) reported on intense microbial activity in the rhizosphere of coconut with which cacao was interplanted. They explained that this phenomena might have been made possible due to the energy-rich substracts for the multiplication and activity of the microorganisms provided through the increased volume of dead roots, formatiòn of carbonaceous substances during the active root growth and the fallen leaves of cacao. They also found increased activity of phosphate solublizing bacteria in the coconut rhizosphere interplanted with cacao than in the rhizosphere of a pure stand of coconut. From the intercrop studies at Hirehalli, it is revealed that highest fungal and bacterial population was noticed in dioscorea plots and actinomycetes in controlled plots (Anon; 1982(a)).

Menogy et al. (1978) suggested another measure called the crop intensity index (CII) for measuring land use in multiple cropping. It is a measure of time weighted land use index to compare the actual area time devoted to crop production with total area-time available to a farmer or group of farmers during a specified time period, usually one year. Crop Intensity

Index values below 1.0 indicate incomplete utilization of land and time and value 1.0 will indicate very high intensity of land and resource use.

Muralidharan (1980) obtained LER values of 1.80 and 1.61 in the intercropping systems of turmeric and cowpea in arecanut and fodder sorghum and sweet potato in arecanut respectively. For these intercropping systems, the values of CII were 1.56 and 1.41 compared 0.84 and 0.71 under sole cropping systems respectively.

II. 5. Income and its stability in intercropping systems

Scope for increased additional income from unit area of land has been developed by growing intercrops. Bains (1968) reported a net profit of Rs 11,500/- per ha per year from a 400 per cent cropping intensity like mung-maize-potato-wheat relay cropping system. Beets (1978) has also reported that multiple cropping system can provide substantial benefits in increased food production and higher income. Economic gains of intercropping in coconut gardens were reported by Nair et al. (1974). In arecanut, intercropping with banana or cacao was found to be beneficial in providing additional income (Muralidharan and Nayar, 1979 and Bhat, 1979). In the latter combination of arecanut and cacao, it was found that the gross annual income between 1973 and 1975 was Rs 18,949 per ha as compared to Rs 13,083 per ha from pure plantation of arecanut. Muralidharan (1980) obtained the highest net income of over Rs 17,700 per ha when arecanut was intercropped with either ginger and chilli combination or with banana. Intercropping in arecanut thus seems to enhance not only the income but also provides a stability factor in raising crops.

MATERIAL AND METHODS

III MATERIALS AND METHODS

Studies on the "Interaction of intercrops in maximising utilization of resources in arecanut (*Areca catechu* L.) in the Maidan tracts of Karnataka" were conducted in two separate experiments during 1978-79 and 1979-80 at the Central Plantation Crops Research Institute, Hirehalli in Tumkur District of Karnataka State. These experiments were supported by the data on yield and yield attributes of the main crop arecanut from pre and post experimental periods of two years each.

III.1. Location of the experimental site

The Research Centre at Hirehalli lies about 58 km west of Bangalore on Bangalore-Tumkur National Highway (NH-4). The experimental farm of the Centre is situated at 845 M above MSL, on 77.12° E longitude and 13.08° N latitude.

III.2. Soil

The soil of the experimental farm is predominantly clayey loam. The physical and chemical properties of the soil are given in Table III.1.

III.3. Climate and weather

Rainfall was almost of the same magnitude in both the years of field experimentation and was higher by 110.05 mm over the average rainfall (880.7 mm) for the last five years. A dry spell of about a month during January, 1979 and about three months prevailed from December, 1979 to February, 1980.

Table III.1. Soil properties of the experimental site

(a) Mechanical composition

Constituent	Depth (cm)	
	0 - 25	25 - 50
Coarse sand (%)	17.00	9.5
Fine sand (%)	21.00	14.5
Silt (%)	11.00	18.00
Clay (%)	51.00	58.00

(b) Chemical properties of the soil of experimental site

Constituent	Depth (cm)	
	0 - 25	25 - 50
1. pH	6.35	6.53
2. Electrical conductivity at 25°C	0.25	0.25 Mhos/cm
3. Organic matter	0.95%	0.85%
4. Total nitrogen	2.06%	1.41%
5. Available nitrogen	250 ppm	200 ppm
6. Total P2O5	0.34%	0.25%
7. Total potassium	0.62%	0.65%
8. Available P2O5	25 ppm	22 ppm
9. Available K2O	95 ppm	78 ppm
10. Cation exchange capacity	7.5	7.0 m.e/100 g soil
11. Exchangeable calcium	1.8	1.5 "
12. Exchangeable magnesium	0.90	0.75 "

The deviation from the normal weather of five years data in maximum temperature during 1978-79 were considerable, ranging from +0.5°C to -3.2°C and during 1979-80 it ranged from +2.9°C to 1.2°C. The deviation in minimum temperature during 1978-79 ranged from -3.4°C to +4.5°C and during 1979-80 it ranged from -1.0°C to +6.5°C.

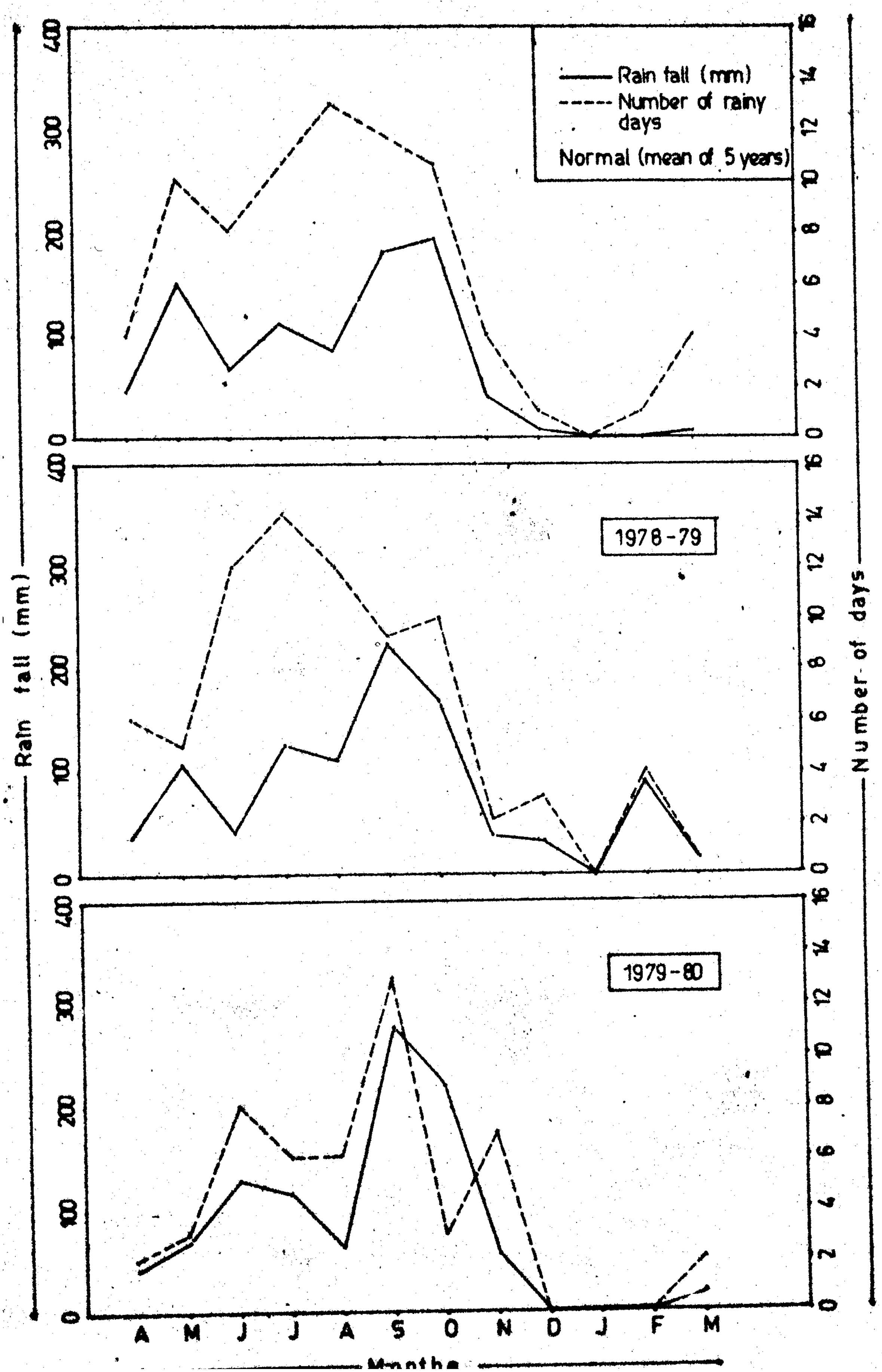
The meteorological observations recorded at CPCRI, Research Centre, Hirehalli during 1978-80 are presented in Fig. 1.

III.4. Previous history of the garden selected

The first experiment on the effect of spacing, planting geometry and cropping intensities of intercrops in arecanut was laid out in block number D and plot number 1 of the experimental centre in an existing 17 year old areca plantation, planted at four different spacings (1.8m x 3.6m, 2.7m x 2.7m, 2.7m x 3.6m and 3.6m x 3.6m). The experimental palms have been receiving 100 g N, 40 g P_2O_5 and 140 g K_2O per palm per year regularly since planting.

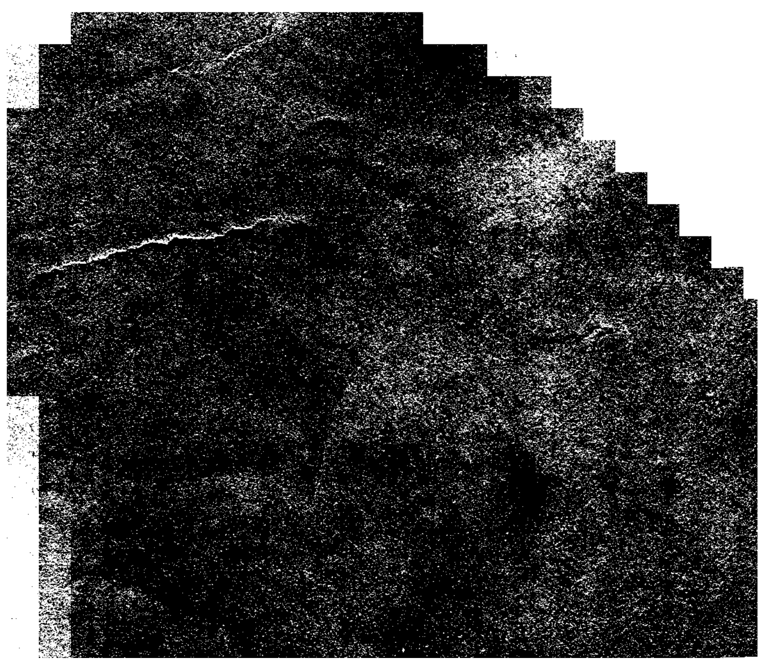
The second experiment on the effect of intercrops in arecanut under varying fertilizer levels was laid out in block number A and plot number 1 in an existing 15 year old areca garden having a uniform stand of areca palms spaced at 2.7m x 2.7m. The palms have been regularly manured every year since planting as per the recommended schedule.

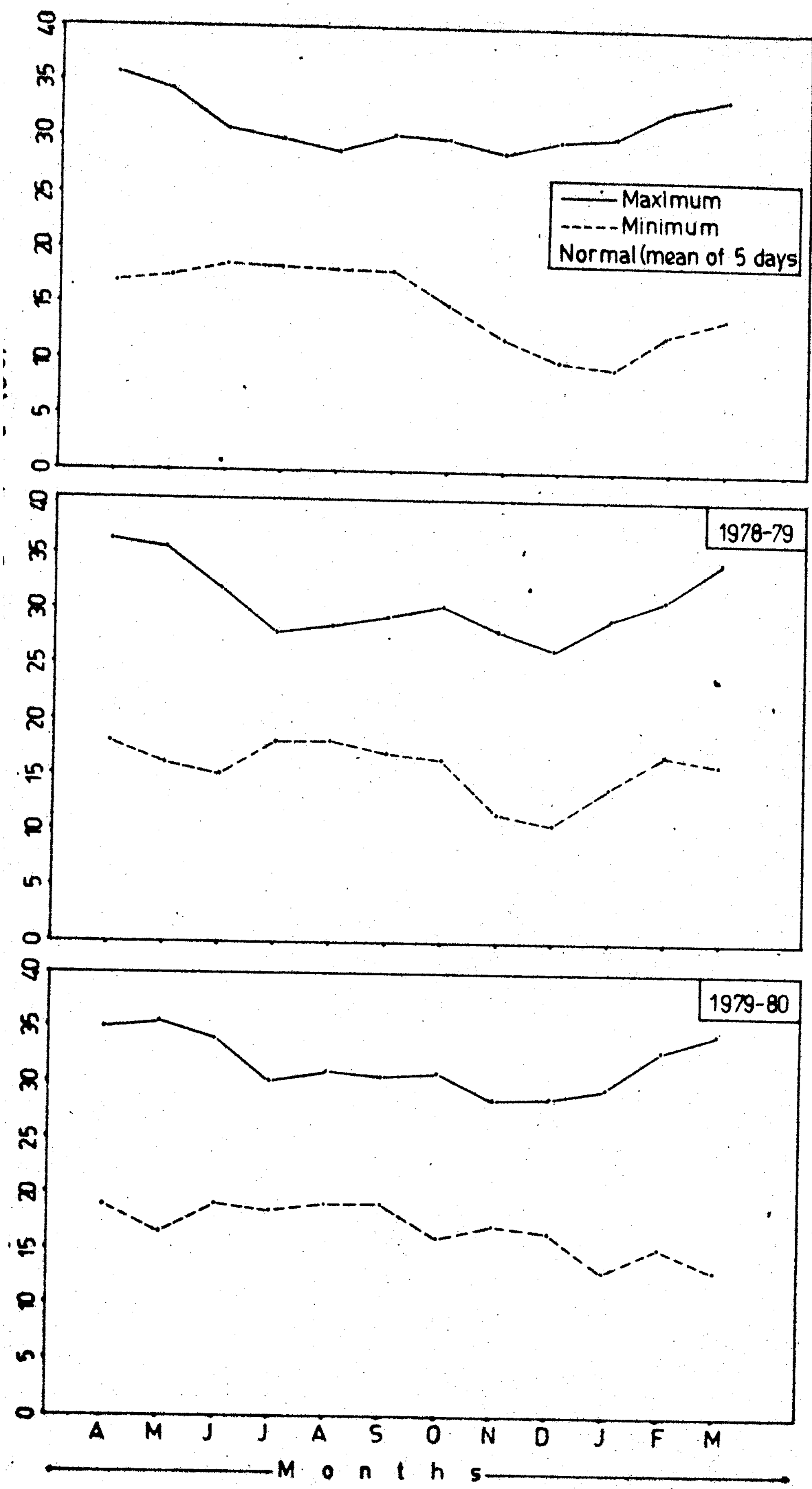
Fig.1a. RAINFALL DATA AT CPCRI, HIRЕHALLI FOR 1978-79, 1979-80 AND MEAN OF FIVE YEARS.



Rain fall (mm)
Number of rainy days
Normal (mean of 5 years)
1978-79
1979-80
Rain fall (mm)
Number of days
A M J J A S O N D J F M
Months

FIG.1b. MAXIMUM AND MINIMUM TEMPERATURE AT CPCRI, HIREHALLI FOR THE YEAR 1978-79, 1979-80 AND MEAN OF FIVE YEARS.





Maximum
Minimum
Normal (mean of 5 days
1978-79
1979-80
A M J J A S O N D J F M
Months

FIG. 1b.

FIG.1c. BRIGHT SUNSHINE HOURS AT CPCRI, HIREHALLI FOR THE YEAR 1978-79, 1979-80 AND MEAN OF FIVE YEARS.

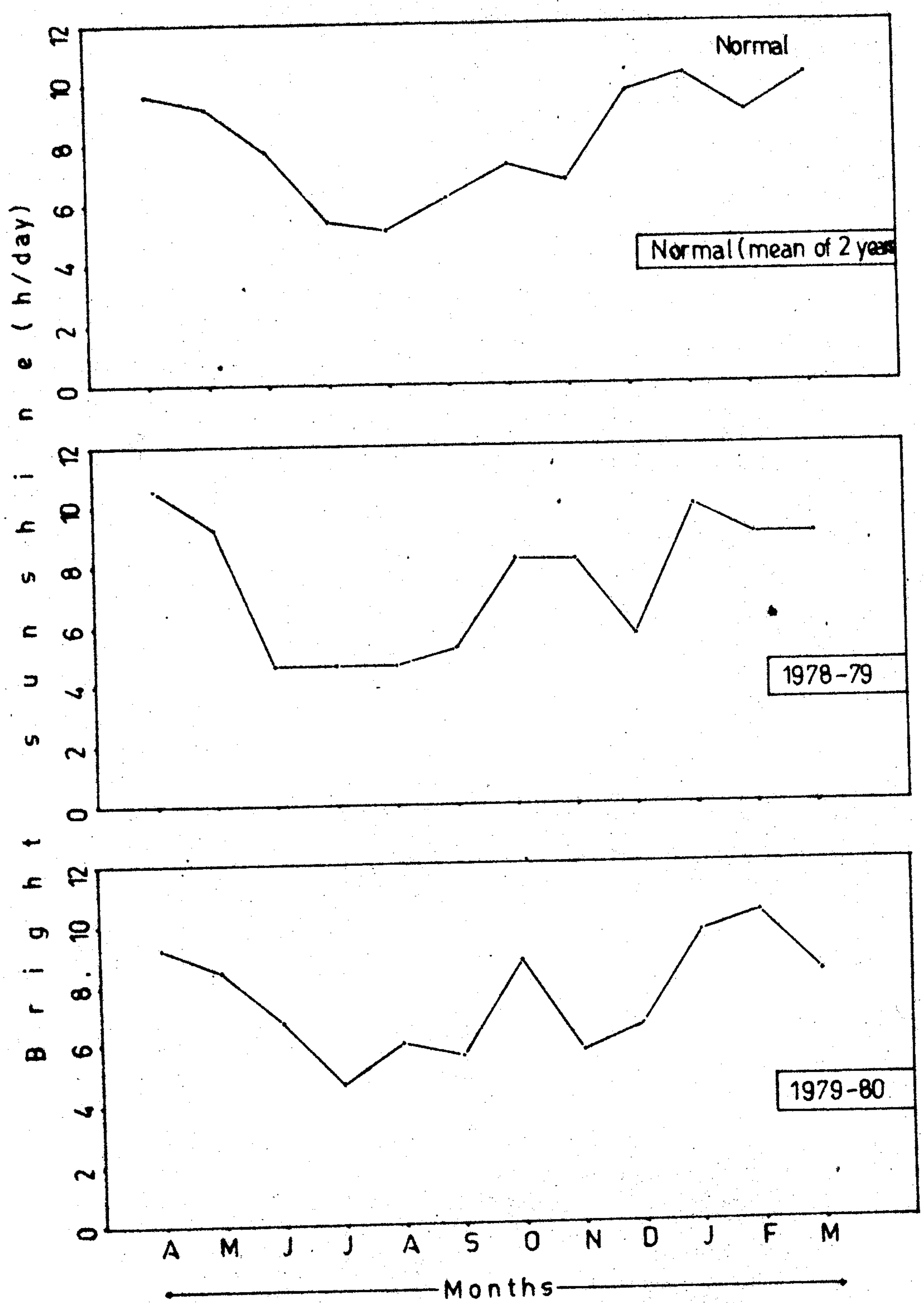

Normal
Normal (mean of 2 years
1978-79
1979-80
Bright sunshine (h/day)
0
2
4
6
8
10
12
A
M
J
J
A
S
O
N
D
J
F
M
Months

FIG. 1c.

An open field lying adjacent to this experiment site (Block No.B, Plot No.1) was selected for growing the same crops as sole crops under open conditions.

III.5. Details of crop varieties

Local varieties of turmeric with a duration of eight months and sweet potato with a duration of about five months and a high yielding variety of cowpea (C-152) with a duration of 90-100 days were used for raising intercrops and sole crops during the period of study. The main crop of arecanut was a high yielder planted at the time of establishment of the gardens.

III.6. Details of manures and fertilizers

The package of practices for turmeric and sweet potato recommended by the University of Agricultural Sciences, Bangalore wasz adapted (Anon; 1978). Ten tonnes of compost and 70 N, 60 P_2O_5, 120 K_2O kg/ha for turmeric and 70 N, 50 P_2O_5, 70 K_2O kg/ha for sweet potato were applied (N as ammonium sulphate, P as single super phosphate and K as muriate of potash) in split doses. Areca palms received 100 N, 40 P_2O_5, 140 K_2O g/palm/year during the period of experimentation as per the ràcommendation of CPCRI, Kasaragod (Anon; 1978). Fertilizers were applied as suphala (15 N, 15 P_2O_5, 15 K_2O), calcium ammonium nitrate and muriate of potash in two split doses. In addition to chemical fertilizers, 10 kg each of compost and green leaf manure per palm were applied.

The split schedule of fertilizer application adapted is mentioned hereunder:

a) Areca palms

1) August - September : ½ N + Full P_2O_5 + ½ K_2O
10 kg each of compost
and green leaf

2) February - March : ½ N + ½ K_2O

b) Turmeric

1) Full dose of compost at planting

2) Full dose of P_2O_5 and half dose of K_2O at planting

3) 2/3 of N application at 45 days after planting and

4) 1/3 N and half K_2O application at 90 days after planting

c) Sweet potato

1) Full dose of compost at planting

2) Half N and full dose of P_2O_5 and K_2O application at planting and

3) Half N application at 45 days after planting

d) Cowpea

In this experiment, in order to equate the total duration of about eight months occupied by turmeric, a short duration of cowpea of about 90-100 days were raised in succession after the sweet potato crop which had a duration of about five months. No separate fertilizer application was made for cowpea, which was raised only with the residual effect of fertilizer applied to sweet potato.

The chemical composition of manures and fertilizers used in the experiments are presented in Table III.2.

Table III.2

Manures/Fertilizers	N%	P2O5%	K2O%
1) Cattle manure	0.65	0.40	0.88
2) Green leaf	2.90	0.50	2.80
3) Suphala	15	15	15
4) Ammonium sulphate	20-21	-	-
5) Single super phosphate	-	16	-
6) Muriate of potash	-	-	58.60

III.7. Methods

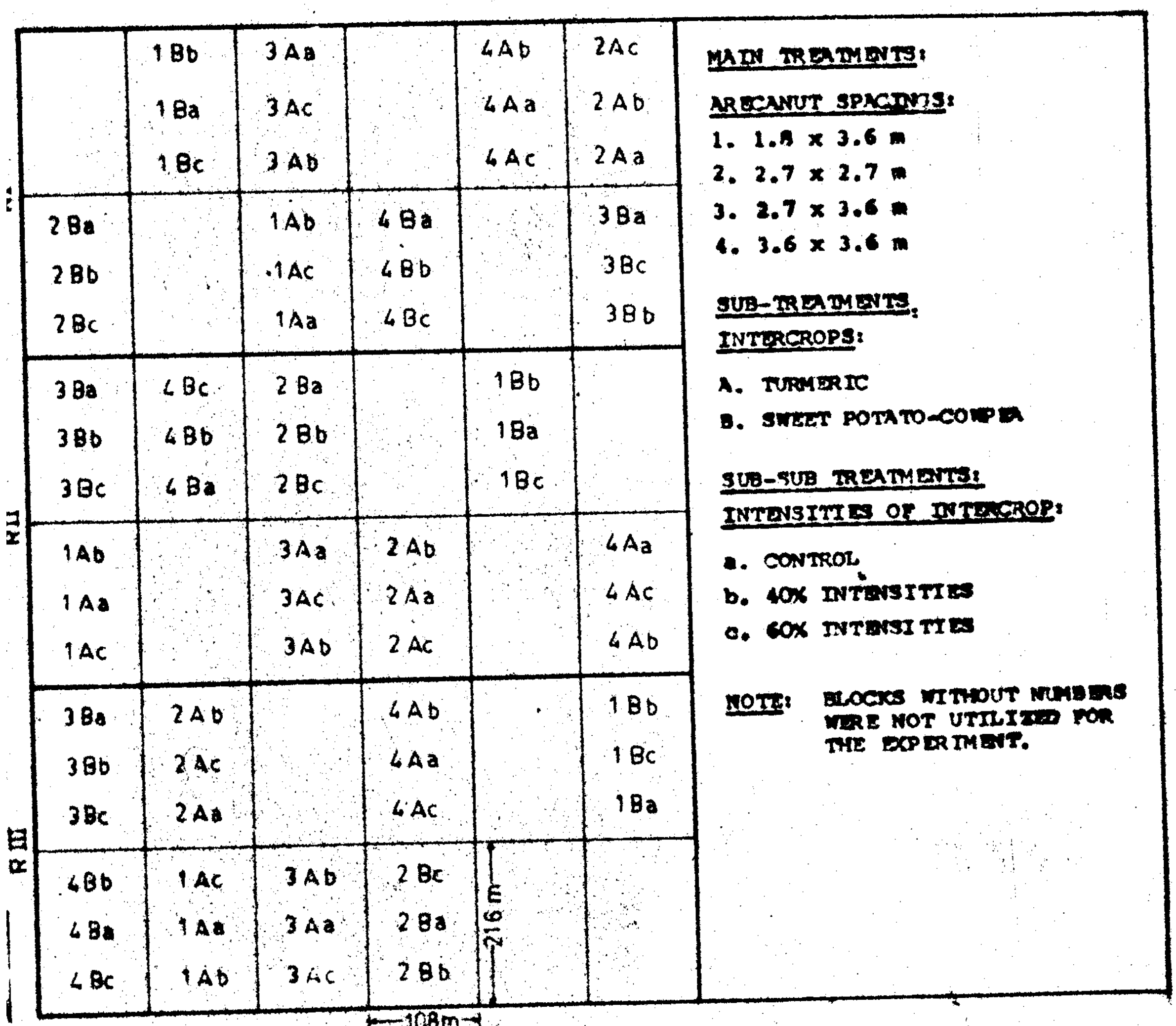
III.7.1. Experimental design

The first experiment on "Interaction of plant densities and planting geometries of arecanut with intercropping intensities of turmeric, sweet potato-cowpea on the growth and yield attributes of arecanut and intercrops and in maximising utilization resources" was laid out in split-split plot design with spacings as main plot treatments, two intercrops as sub-plot treatments and three intercropping intensities as split-split plots and replicated thrice. (Fig. 2)

Treatments

A. Details of treatments are given below:

a) Main plot treatments (4)



LAYOUT PLAN OF EXPERIMENT NUMBER 1

FIG. 2. INTERCROPPING INTENSITIES UNDER FOUR PLANTING DENSITIES OF ARECANUT.

	Arecanut spacing
1	1.8m x 3.6m
2	2.7m x 2.7m
3	2.7m x 3.6m
4	3.6m x 3.6m

b) Sub-plot treatments (2)

	Intercrops
1	Turmeric
2.	Sweet potato-cowpea

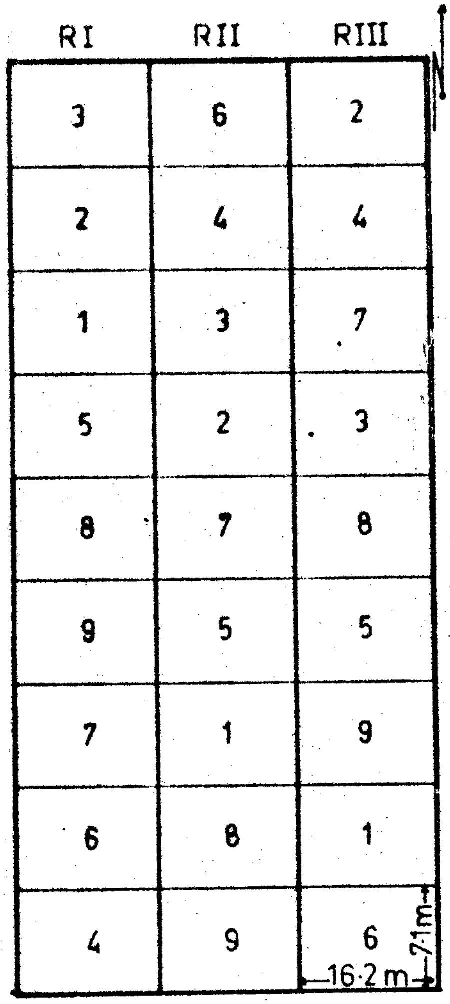
c) Sub-sub plot treatments (3)

	Intensity of intercrops
1.	No intercrop
2	40% of the area covered with intercrops
3	60% of the area covered with intercrops

The second experiment on the " Effect of four fertilizer levels to the intercrops of turmeric and sweet potato-cowpea in arecanut on the growth and yield attributes of the main and intercrops in maximising productivity and utilization of resources" was laid out in a randomised block design with nine treatments replicated thrice. Fig. 3a & 3b)

Treatments

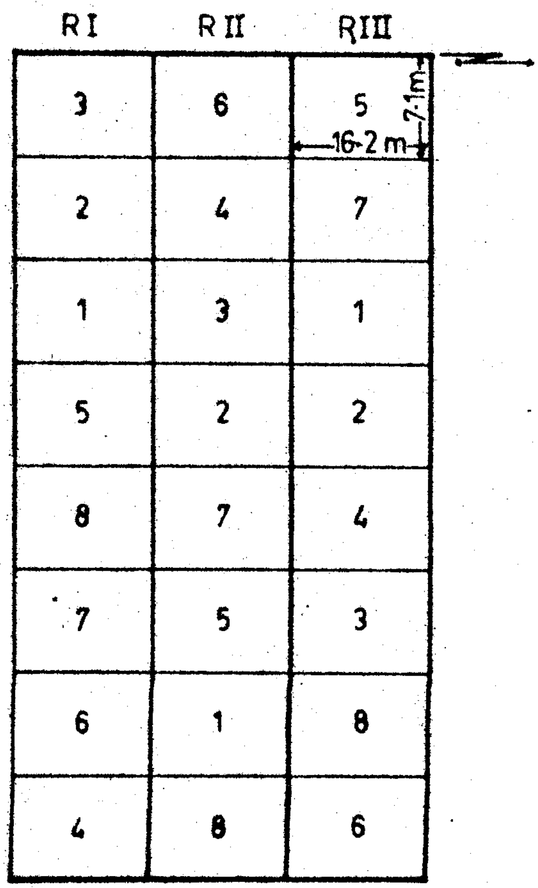
B. Details of treatments are given below:



LAYOUT PLAN OF EXPERIMENT no 2a.

Sl. No.	Treatments	Fertilizer schedules (kg/ha)		
		N	P_2O_5	K_2O
1.	Turmeric	0	0	0
2.	Turmeric	70	60	120
3.	Turmeric	140	120	240
4.	Turmeric	210	180	360
5.	Sweet potato-cowpea	0	0	0
6.	Sweet potato-cowpea	70	50	70
7.	Sweet potat-cowpea	140	100	140
8.	Sweet potato-cowpea	210	150	210
9.	Control			

FIG. 3a. EFFECT OF FERTILIZER LEVELS ON INTERCROPS OF TURMERIC, SWEET-POTATO-COWPEA IN ARECANUT.



Sl. No.	Treatments	Fertilizer schedules (kg/ha)		
		N	P_2O_5	K_2O
1.	Turmeric	0	0	0
2.	Turmeric	70	60	120
3.	Turmeric	140	120	240
4.	Turmeric	210	180	360
5.	Sweet potato-cowpea	0	0	0
6.	Sweet potato-cowpea	70	50	70
7.	Sweet potato-cowpea	140	100	140
8.	Sweet potato-cowpea	210	150	210

LAYOUT PLAN OF EXPERIMENT no 2b

FIG. 3b. EFFECT OF FERTILISER LEVELS ON TURMERIC AND SWEETPOTATO-COWPEA AS SOLE CROPS

	N	P_2O_5 (kg/ha)	K_2O
1. Turmeric	0	0	0
2. Turmeric	70	60	120
3. Turmeric	140	120	240
4. Turmeric	210	180	360
5. Sweet potato-cowpea	0	0	0
6. Sweet potato-cowpea	70	50	70
7. Sweet potato-cowpea	140	100	140
8. Sweet potato-cowpea	210	150	210
9. Control(sole crop of arecanut)			

III.8. Details of cultivation

III.8.1. Preparation of land

At the start of the experimentation, during June, 1978, all the arecanut plots were forked with mummuty fork to a depth of 15 cm and levelled in both the experiments. Under open field experimentation, the soil was ploughed with mould board plough to a depth of 15 cm and levelled. Turmeric and sweet potato were planted simultaneously both in interspaces of areca plantation and in open land as per the treatment schedules. One digging operation was not required for the main crop when it was intercropped. After the harvest of sweet potato, cowpea was taken up in a rotation to equate the duration of sweet potato and cowpea with that of turmeric. The same operations were repeated during 1979-also.

III.8.2. Raising the crops

Both turmeric and sweet potato were sown in areca plantations and open fields simultaneously during June, 1978 and 1979 adopting the recommended spacings by the University of Agricultural Sciences, Bangalore. All the package of practices recommended for arecanut by CPCRI Kasaragod were carried out (Anon; 1977 and 1978).

In the first experiment, only 40% and 60% of the total interspaces were planted with turmeric and sweet potato leaving a plot as absolute control (plate). Whereas in the second experiment, all the interspaces available in areca plantation was made use as per the normal practices adopted.

III.8.3. Planting

Turmeric: Recommended doses of compost and fertilizers were incorporated in the soil prior to planting. Mother rhizomes of local variety turmeric were planted during June, 1978 and May, 1979 after treating with 0.01% agallol, on the already prepared ridges adopting a spacing of 25mm x 15cm and the soil was covered.

Sweet potato: About 15-20 cm length vines were planted in June, 1978 and May, 1979 on the already prepared ridges adopting 20cm x 25cm spacing after the basal application of fertilizers and compost to the soil both in interspaces and open fields.

Cowpea: One month after the harvest of sweet potato, cowpea seeds were dibbled during March, 1979 and February, 1980

PLATE No. 1 ARECANUT PURE CROP

Plate 1

in rows adopting the recommended spacing of 40cm x 25cm by the University of Agricultural Sciences, Bangalore after preparing the land with mummuty (Anon, 1977).

III.8.4. Post planting operations

Earthing up was carried out both in turmeric and sweet potato after each application of fertilizers both in inter-crops and sole crops. The plots were maintained free of weeds by frequent hand weeding. Totally four hand weedings were given in each year for the sole crop of arecanut while only three weedings were required for the intercropping systems.

III.8.5. Irrigation and plant protection measures

Intercrops and sole crops received in total 12 irrigations during 1978-79 and 11 irrigations during 1979-80 during the dry periods of experimentation. Regular plant protection measures as per the package of practices for turmeric, sweet potato, cowpea and arecanut were carried out (Anon, 1978).

III.8.6. Harvesting and processing

Turmeric and sweet potato: Turmeric was harvested during March, 1979 and February, 1980 whereas sweet potato was harvested during December, 1978 and 1979. Turmeric rhizomes were hand picked after giving a light digging. This saved the digging operations required for the main crop of arecanut. Mother rhizomes and fingers were separated, cleaned with water and used for further studies. Sweet potato tubers were also collected in the same way and used for further studies.

Cowpea: Cowpea was harvested in April, 1979 and May, 1980. Cowpea pods were collected as and when they were ripe. The pods were dried and the seeds were separated by hand threshing. They were sun dried till a constant weight was obtained and used for further studies.

III.9. Light and biometric observations

III.9.1. Measurement of light interception

Light intensity measurements were carried out from 11.30 AM to 1.00 PM using a Research Luxo-met 300 instrument. Intensities of light were recorded above and below the arecanut and intercrop canopies. The percentage of light penetration was worked out depending on the amount of light on an open land surface.

III.9.2. Comparative growth and development of intercrops and sole crops

Biometric observations in intercrops of turmeric, sweet potato and cowpea grown under arecanut and in open were recorded simultaneously. Sampling procedure and processing were made according to Kvet *et al.* (1971). The sample plants were uprooted with the help of digging fork. The roots were gently washed in water free and soil. The plant parts were separated into leaves, stem, root/tuber and other storage parts as the case may be and then oven dried at 80-85°C to constant weight. These data were used to compute Net Assimilation Rate (NAR), Leaf Area Ratio (LAR), Relative Growth Rate (RGR) and Relative Leaf Growth Rate(RLGR) using the formulae suggested by Power et al.(1967) and Krishnamurthy et al.(1973).

III.9.2.1. Leaf area

For leaf area estimation, leaf disc method was used to compute the leaf area ($m^2/0.25\ m^2$). The leaves from the plants situated in an area of $0.25\ m^2$ were separated and 50 discs were taken and dried in the oven. The remaining leaves as well as the remnants of the leaves from which the discs were removed were also dried in the oven. The dry weights of both discs and leaves were recorded. The leaf area was computed by using the following formula:

$$\text{Leaf area/unit area of land} = \frac{a \cdot y}{x} (z + x)\ cm^2$$

Where a = area of the disc (πr^2); y = number of discs

x = dry weight of discs ; z = dry weight of leaves

r = 0.5 cm (cm^2 are converted into m^2)

For all other morphological observations five plants were randomly selected and tagged for studying the morphological characteristics during the crop growth.

III.9.2.2. Number of tillers and branches

Number of productive tillers from the tagged plants were counted in turmeric and the number of branches were counted both in sweet potato and cowpea during crop growth and expressed as number for five plants.

III.9.2.3 Number of functional leaves

Number of functional leaves were counted in turmeric, sweet potato and cowpea from the tagged plants at regular intervals.

III.9.3. Yield and yield components of intercrops

III.9.3.1. Number, volume and weight of tubers

At the time of harvest, the tubers of sweet potato and turmeric were collected and counted from the tagged plants. Volume of the turmeric and sweet potato tubers was measured by water displacement technique and expressed in milli litres. The weights of the tubers were taken and expressed as grams for five plants and as kg/ha.

III.9.3.2. Weight of shoot

Weight of the sweet potato shoots was recorded and expressed as q/ha. This weight was taken to calculate the tuber to shoot ratio.

III.9.3.3. Seed weight

Cowpea pods as and when ripe were hand picked and sun dried. They were threshed by hand and again dried to a constant weight. The seed was weighed and expressed as kg/ha.

III.9.3.4. Test weight:

Five hundred numbers of cowpea seeds collected at random were weighed and expressed in grams.

III.9.4. Growth attributes of the main crop of arecanut

III.9.4.1. Girth of the palm

Girth of the palm at permanent mark (PM) and last exposed node (LEN) was recorded during pre and post experimental period.

III.9.4.2. Internodal distance

Internodal distance both at permanent mark and last exposed node were recorded during pre and post experimental period.

III.9.4.3. Height of palm

Palm height was measured from the permanent mark to the last exposed node during pre and post experimental period.

III.9.5. Yield and yield attributes of arecanut

III.9.5.1. Number of bunches

Number of bunches bearing areca fruits were counted and expressed in number per palm.

III.9.5.2. Number and weight of nuts

As and when arecanut bunches were harvested, the total number of nuts were counted and expressed on per palm basis. The nuts were also weighed and expressed in kg/palm.

III.9.6. Chemical analysis

III.9.6.1. Chemical analysis of tissue samples

Representative tissue samples were drawn from leaves, stems, roots and tubers of all the component crops as well as sole crops, dried and ground to fine powder for chemical analysis. Nitrogen was estimated by adepting Microkjeldhal Method, phosphorsus by Vanado Molybdic Acid Method using Klett Summerson Photometer. Potassium and calcium by Elico Flame Photometer by using the plant material digested by double acid mixtures. Calcium and magnesium were estimated from the wet digested material using Varian Titran Atomic Absorption Spector-Photometer. All the mineral contents were expressed as percentage on oven dry weight basis (Jackson, 1973).

III.9.6.2. Chemical analysis of soil samples

Soil samples were collected from 0-25 cm and 25-50 cm depth before and after experimentation both in the intercropped and sole cropped fields, air dried and powdered to fine mesh.

Available nitrogen was estimated using Alkaline Permanganate Method as described by Subbaiah and Asija, (1956). Available phosphorsus was estimated using Bray II Technique and exchangeable potassium by extracting the soil with ammonium acetate and then by flame photometry. Soil pH was determined by using 1:2:5 soil-water suspension with potentio meter (Jackson, 1973).

III.10. Statistical analysis

Appropriate methods of statistical analysis were adapted to draw the conclusions as described by Cochran and Cox (1965).

III.11. Economic analysis

III.11.1. Land Equivalent Ratio (LER)

Land Equivalent Ratio (LER) was worked out based on the yield of inter and sole crops under different NPK schedules following Trenbath (1976).

III.11.2. Crop Intensity Index (CII)

Crop Intensity Index (CII) was worked out according to Monegay *et al.* (1978).

III.11.3. Benefit:Cost Ratio

Benefit: cost ratios were worked out for each crop under different NPK schedules depending on the market values of inputs and consumable products.

EXPERIMENTAL RESULTS

CHAPTER IV

RESULTS

The results of the first experiment entitled "Interaction of plant densities and planting geometries of arecanut with intercropping intensities of turmeric, sweet potato-cowpea on the growth and yield attributes of arecanut and intercrops and in maximising utilization of resources" are presented further in the following sequences: 1) light interception by the crop canopy, 2) growth and yield of intercrop, 3) growth and yield attributes of main crop and 4) labour requirement and income from inter and main crop.

IV.1. Light interception and utilization in crop canopies

IV.1.1. Light interception and utilization in arecanut intercropping system

The data on average light intensity measured above and below the arecanut canopy as influenced by four planting densities of arecanut and intercropping intensities are presented in Table IV.1.1.

Light interception study in arecanut plantation under four plant densities during the period of the current investigations indicated that between September and February of 1978-79, the light intercepted varied as per the plant densities ranging from 35.4 to 40.1×10^3 lux. The light intensity gradually built up from about 26 to 30×10^3 lux in September to 36 to 45 10^3 lux in February. The per cent of light intercepted by arecanut crop increased with the

Table IV.1.1. Light interception by arecanut under four planting densities during crop growth periods of intercrops (1978-79)

Month	Week	Above arecanut	Below arecanut canopy at the crown level			
			1.8m x 3.6m	2.7m x 2.7m	2.7m x 3.6m	3.6m x 3.6m
September	I	59.0	26.0	26.2	28.0	29.5
	III	58.6	28.2	29.6	31.1	32.6
October	I	61.0	35.4	36.8	37.6	36.7
	III	59.6	38.1	39.2	39.9	39.6
November	I	55.2	30.6	36.5	36.0	38.4
	III	56.1	32.4	35.1	36.2	39.2
December	I	58.4	40.4	41.2	42.5	43.1
	III	57.3	41.5	41.8	43.2	44.3
January	I	64.7	37.8	39.6	42.0	44.8
	III	62.3	38.7	39.3	43.0	45.2
February	I	68.2	39.3	40.2	43.5	45.3
	III	70.0	36.5	38.0	42.6	45.0
Mean		60.8	35.4	36.9	38.8	40.1
% passing below arecanut		-	58.2	60.6	63.8	65.9
% intercepted by arecanut		-	41.8	39.4	36.2	34.1

Average light intensity 10^3 lux.
Readings recorded between 11.30 Am and 1.00 PM

increasing level of plant population. At the closer spacings of 1.8m x 3.6m and 2.7m x 2.7m the per cent light intercepted was 41.8 and 39.4, while wider spacings of 2.7m x 3.6m and 3.6m x 3.6m intercepted 36.2 and 34.1 per cent of light, respectively. Thus these two wider spacings allowed 64 to 66 per cent of the incident light to pass through to be utilized by the intercrops which would have been otherwise a waste of energy. In comparison with this, the per cent light that was allowed to pass through the arecanut canopy under the two narrow spacings was 58 to 61 per cent.

IV.1.2. Light interception by intercrops

The average light intensity above and below the intercrop canopy and the per cent light intercepted during different months of 1978-79 are summarised and presented in Table IV.1.2.

Intercrops turmeric, sweet potato and cowpea behaved differently in intercepting the light received at their canopy. Even this was modified by the plant densities of arecanut. Turmeric, average of six monthly readings from September to February, received around 37,000 lux under the spacings of 1.8m x 3.6m and 2.7m x 2.7m and around 47,000 lux under the wider spacings of 2.7m x 3.6m and 3.6m x 3.6m. At the ground level of turmeric, the light intensity got reduced to 11,500 lux to 15,300 lux in different densities of arecanut thus allowing for a light interception of 64 to 75 per cent.

Table IV.1.2. Light interception by intercrops under four planting densities of arecanut.

Crop	Month	Average intensity of light below the arecanut canopy and above the intercrops 10^3 lux				Average intensity below the ground level of the intercrop				Light intercepted (%) by the intercrops			
		1.8m x 3.6m	2.7m x 2.7m	2.7m x 3.6m	3.6m x 3.6m	1.8m x 3.6m	2.7m x 2.7m	2.7m x 3.6m	3.6m x 3.6m	1.8m x 3.6m	2.7m x 2.7m	2.7m x 3.6m	3.6m x 3.6m
Turmeric	September	26.0	34.0	44.8	47.2	12.6	16.2	13.6	18.1	51.5	52.3	69.6	61.6
	October	35.1	36.5	46.7	42.0	9.8	11.0	9.1	18.0	80.3	69.8	80.5	57.1
	November	40.0	41.3	51.1	46.0	14.0	16.2	13.6	18.7	65.0	60.7	73.4	59.3
	December	45.2	44.0	56.0	58.3	16.0	18.0	16.6	21.6	64.6	59.0	70.3	62.9
	January	37.4	30.1	37.3	36.9	7.4	9.3	7.2	6.8	80.2	69.1	81.2	81.5
	February	39.6	38.5	39.0	36.3	9.1	10.1	9.6	8.9	77.0	73.7	75.4	75.4
	Mean	37.2	37.4	47.5	47.8	11.5	13.5	11.6	15.3	69.7	64.1	75.1	66.3
Sweet potato	September	35.8	38.0	47.0	47.2	8.0	7.9	8.2	13.1	77.6	78.9	82.5	72.2
	October	45.4	43.2	40.2	42.0	6.4	6.6	7.6	6.0	85.9	84.7	81.0	85.7
	November	50.2	43.1	46.5	46.0	13.0	12.0	12.2	14.5	74.0	72.1	73.7	68.4
	December	55.1	48.0	49.6	46.0	14.2	14.9	14.8	16.2	74.2	68.9	70.2	64.8
	Mean	46.6	43.1	45.8	45.3	10.4	10.4	10.7	12.4	77.9	76.2	76.9	72.8
Cowpea	January	40.1	39.2	36.8	40.5	15.3	14.6	13.4	18.1	61.8	62.2	63.5	55.3
	February	42.3	38.0	37.1	39.5	15.8	14.2	15.1	15.9	62.6	62.6	59.2	59.7
	Mean	41.2	38.6	36.9	40.0	15.5	14.4	14.2	17.0	62.2	62.4	61.3	57.5

Sweet potato, average of six monthly readings from September to February, received around 43,000 lux under spacing of 2.7m x 2.7m and around 45,000 lux under spacings of 2.7m x 3.6m and 3.6m x 3.6m. At the ground level of sweet potato, the light intensity got reduced to around 10,000 lux at all the spacings excepting at the wider spacing of 3.6m x 3.6m where it was around 12,000 lux thus allowing for a light interception of 73 to 78 per cent by the intercrop under different plant densities.

Cowpea received on an average around 37,000 lux at the spacings of 2.7m x 2.7m and 2.7m x 3.6m whereas in the spacings of 1.8m x 3.6m and 3.6m x 3.6m, the light intensity received was 41,000 lux. At the ground level of this intercrop, the light intensity got reduced to around 14,000 lux at the narrow spacings and to 17,000 lux in the wider spacings of 3.6m x 3.6m. This allowed for a light interception of 57,000 lux against an interception of around 61,000 lux in all the other spacings.

The data on the comparison of light resource utilization in sole and intercropping systms are presented in Table IV.1.3.

The total light interception gradually decreased from 41.8% to 34.1% with the increase in spacings in pure arecanut stand. A similar trend was distinctly seen in the sole crop of turmeric also with a reduction in total light inter-

Table IV.1.3. Comparison of light resource utilisation in sole and intercropping system (%)

Treatments	Spacings				Mean
	1.8m x 3.6m	2.7m x 2.7m	2.7m x 3.6m	3.6m x 3.6m	
Intercropped turmeric	81.1.	77.8	80.9	74.8	78.65
Sole crop of turmeric	38.8	38.5	21.9	21.4	30.15
Intercropped sweet potato-cowpea	78.0	76.3	77.0	76.2	77.10
Sole crop of sweet potato-cowpea	27.8	32.9	30.3	29.8	30.20
Arecanut alone	41.8	39.4	36.2	34.1	38.67

ception from 38.8 to 21.4%. In the other sole crops, the differences under varied plant densities were marginal. The effect of plant densities of arecanut on total light interception in the intercropping systems were not distinct. However, intercropping system of arecanut sweet potato intercepted nearly 82% of light compared to 78% in intercropping system of turmeric and 75% in intercropping system with cowpea.

IV.2. Growth and yield attributes of intercrops

IV.2.1. Number of leaves in intercrops as influenced by intercropping intensities and different spacings of arecanut

The data on the periodical observations relating to number of leaves produced per plant by the intercrops turmeric and sweet potato as influenced by intercropping intensities and different spacings of arecanut are presented in Fig. 4(a) and mean yearly data are provided in Table IV.2.1.

From Fig. 4(a), it is observed that the number of functional leaves in turmeric reached the peak value in all the treatments by 150 days after planting with peaks ranging from 15.1 to 19.9. However, there was no difference among the treatments in respect of the production of number of leaves. Leaf production of turmeric did not show any significant change due to intercropping under various spacings of arecanut or at different intensities of intercropping either during 1978-79 or 1979-80. The mean data

Table IV.2.1. Number of functional leaves produced by the intercrop of turmeric, sweet potato-cowpea as influenced by intercropping intensities at varied level of spacings of arecanut

Treatment	Intensities of intercropping								
Intercrops/arecanut spacings	1978-79			1979-80			Mean of 2 years		
	40%	60%	Mean	40%	60%	Mean	40%	60%	Mean
Turmeric									
1. 1.8m x 3.6m	17.3	18.6	17.9	10.3	9.6	10.0	14.3	14.1	14.2
2. 2.7m x 2.7m	16.9	17.0	16.9	12.3	12.3	12.3	14.5	14.6	14.5
3. 2.7m x 3.6m	16.3	15.1	15.7	11.4	10.9	11.2	14.6	12.5	13.5
4. 3.6m x 3.6m	16.0	19.9	17.9	11.6	11.1	11.3	14.3	16.5	15.4
Mean	16.6	17.6	-	11.4	11.0	-	14.4	14.4	-
CD for spacings	-	-	3.9	-	-	2.5	-	-	2.4
CD for intensities	-	-	2.9	-	-	1.4	-	-	1.2
CD for spacing at the same level of intensity	-	-	6.1	-	-	3.1	-	-	2.9
CD for intensity at the same level of spacing	-	-	3.9	-	-	2.8	-	-	2.5
Sweet potato									
1. 1.8m x 3.6m	145	140	142	143	116	130	144	128	136
2. 2.7m x 2.7m	189	182	186	113	166*	139	151	174*	162
3. 2.7m x 3.6m	171	138	154	130	130	130	151	134	142
4. 3.6m x 3.6m	188	160	174	134	152	143	161	156	159
Mean	173	155	-	130	141	-	152	148	-
CD for spacings	-	-	85	-	-	44	-	-	59
CD for intensities	-	-	21	-	-	17	-	-	10
CD for spacing at the same level of intensity	-	-	71	-	-	44	-	-	46
CD for intensity at the same level of spacing	-	-	41	-	-	34	-	-	20
Cowpea									
1. 1.8m x 3.6m	161	196	178	163	211	187	162	203	182
2. 2.7m x 2.7m	300	236	268*	322	288	305	311*	262	287*
3. 2.7m x 3.6m	195	240	217	211	239	225	203	238	221
4. 3.6m x 3.6m	210	180	195	220	198	209	215	189	202
Mean	216	205	-	229	234	-	223	223	-
CD for spacings	-	-	68	-	-	75	-	-	59
CD for intensities	-	-	49	-	-	55	-	-	34
CD for spacing at the same level of spacing	-	-	56	-	-	38	-	-	29
CD for intensity at the same level of spacing	-	-	51	-	-	39	-	-	28

* significant (0.05)

FIG.4 a. EFFECT OF ARECANUT SPACINGS AND INTERCROPPING INTENSITIES ON THE LEAF PRODUCTION OF TURMERIC AND SWEET POTATO DURING CROP GROWTH STAGES

1a. 1.8 x 3.6m 40% intensity of intercropping

1b. 1.8 x 3.6m 60% intensity of intercropping

2a. 2.7 x 2.7m 40% intensity of intercropping

2b. 2.7 x 2.7m 60% intensity of intercropping

3a. 2.7 x 3.6m 40% intensity of intercropping

3b. 2.7 x 3.6m 60% intensity of intercropping

4a. 3.6 x 3.6m 40% intensity of intercropping

4b. 3.6 x 3.6m 60% intensity of intercropping

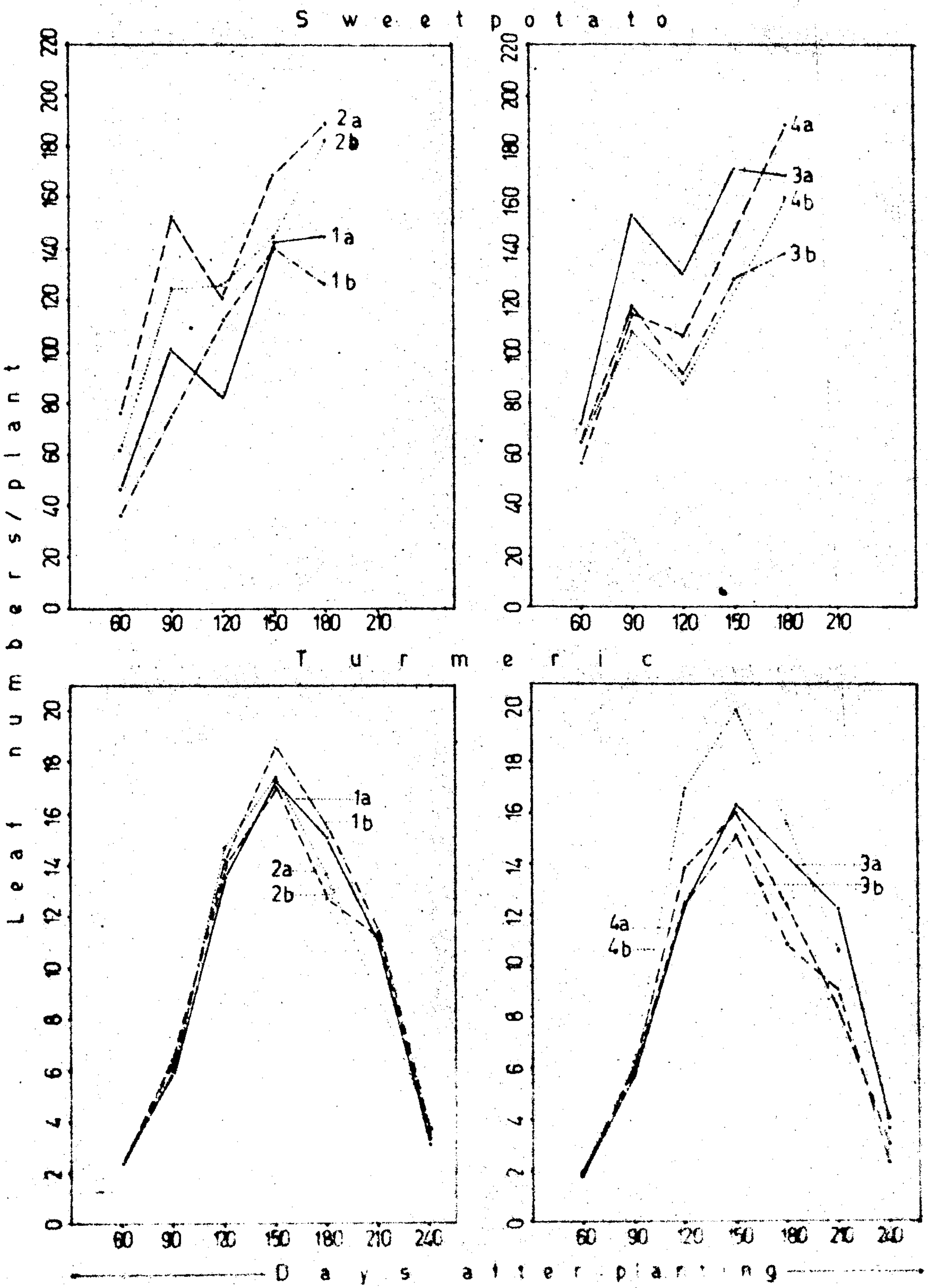

S w e e t p o t a t o
T u r m e r i c
Leaf numbers/plant
Days after planting
2a
2b
1a
1b
4a
3a
4b
3b
1a
1b
2a
2b
3a
3b
4a
4b
0
20
40
60
80
100
120
140
160
180
200
220
0
2
4
6
8
10
12
14
16
18
20
60
90
120
150
180
210
240

FIG 4a

showed a range of 13.5 to 15.4 leaves per plant of turmeric (Plate 2.).

In sweet potato, the maximum number of leaves were found between 150 and 180 days with the peaks ranging from 140 to 189 leaves per plant (Plate 3). Leaf production in sweet potato did not show any significant change due to intercropping under various spacings of arecanut or at different intensities of intercropping during 1978-79. However, during 1979-80 as well as in mean values of both the years, under a spacing of 2.7m x 2.7m, 60% intercropping intensity produced significantly higher number of leaves (166 and 174, respectively) compared to 40% intercropping intensity (113 and 151, respectively). The mean data indicated a range of 136 to 162 leaves per plant of sweet potato.

A spacing of 2.7m x 2.7m for arecanut was found to be significantly superior to all other spacings in the production of leaves in cowpea. This spacing produced 287 leaves/plant while the rest provided 182 to 221 leaves/plant. Intercropping intensities did not bring any changes in leaf production. At the same intensity of 40% intercropping, 2.7m x 2.7m spacing produced 311 leaves/plant which was significantly superior to 162 leaves/plant produced at a spacing of 1.8m x 3.6m.

IV.2.2. Leaf area of intercrops as influenced by intercropping intensities under different spacings of arecanut

The data on the periodical observations on leaf area

PLATE No. 2 TURMERIC AS AN INTERCROP IN ARECANUT WITH 13 to 15 LEAVES PER PLANT

PLATE No. 3 SWEET POTATO AS AN INTERCROP IN ARECANUT WITH 140 to 189 LEAVES PER PLANT

Plate 2

plate 3

of intercrops as influenced by intercropping intensities under different spacings of arecanut are presented in Fig. 4(b) and the yearly mean data are given in Table IV.2.2.

From Fig. 4(b), it is observed that the leaf area of turmeric in general attained high values between 150 and 180 days and declined thereafter. Wider spacings of arecanut did not show any significant effect on the leaf area of turmeric during the course of study. Increasing the level of intensity significantly brought down the leaf area of turmeric during both the years of study. Leaf area produced by intercropping intensity of 40% was significantly superior to 60% intensity in both the years as well as in the mean values of the pooled data. The interaction effects were significant only at the same level of spacing in some cases. During 1979-80, at 2.7m x 2.7m spacing, 40% intensity produced significantly higher leaf area (1.65 m^2/0.25 m^2) compared to 60% intensity (1.08 m^2/0.25 m^2). The same trend prevailed in the pooled data also. In addition, the pooled data showed significantly higher leaf area of 1.20 m^2/0.25 m^2 at 40% intensity compared to 60% intensity (0.89 m^2/0.25 m^2) at the highest spacing of 3.6m x 3.6m. In general, it was observed that 40% intensity of intercropping recorded higher values of leaf area over 60% intensity under the same level of spacings.

In sweet potato, leaf area attained peak values between 150 to 180 days with values ranging from 1.77 to 2.68. Leaf

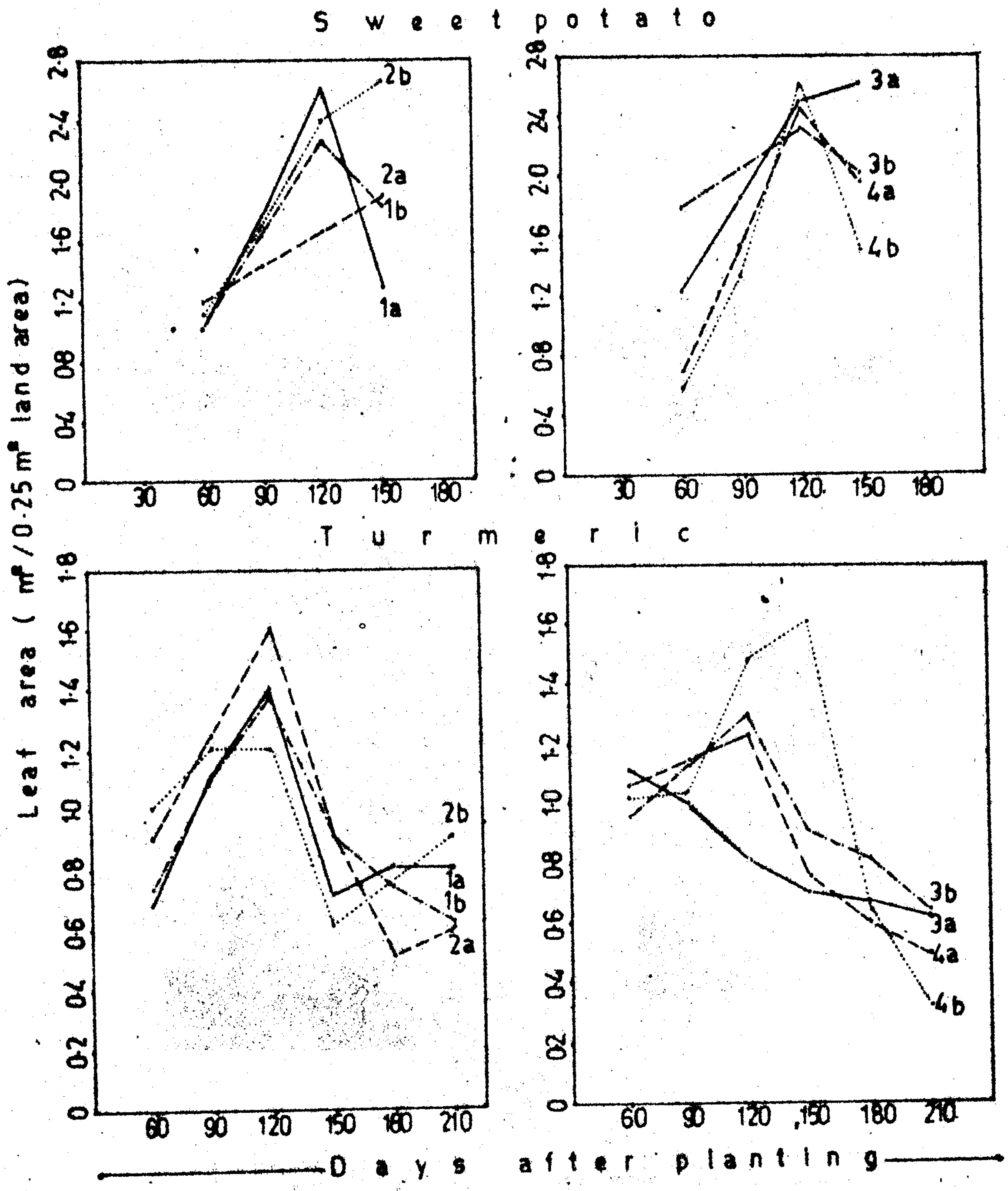
Table IV.2.2. Leaf area of intercrops of turmeric and sweet potato as influenced by intercropping intensities at varied levels of spacings of arecanut ($m^2/0.25\ m^2$)

Treatments	Intensities of intercropping								
	1978-79			1979-80			Mean of two years		
Intercrops/arecanut spacings	40%	60%	Mean	40%	60%	Mean	40%	60%	Mean
TURMERIC									
1. 1.8m x 3.6m	1.15	1.15	1.15	1.55	1.19	1.37	1.36	1.29	1.32
2. 2.7m x 2.7m	1.25	1.05	1.15	1.65*	1.08	1.37	1.37*	1.07	1.32
3. 2.7m x 3.6m	1.25	0.93	1.09	1.39	1.26	1.33	1.32*	1.10	1.21
4. 3.6m x 3.6m	1.10	0.99	1.04	1.30	0.8[illegible]	1.05	1.20	0.89	1.05
Mean	1.19*	1.03	-	1.47*	1.08	-	1.36*	1.09	-
CD for spacings	-	-	0.42	-	-	0.64	-	-	0.32
CD for intensities	-	-	0.14	-	-	0.25	-	-	0.13
CD for spacing at the same level of intensity	-	-	0.39	-	-	0.65	-	-	0.33
CD for intensity at the same level of spacing	-	-	0.28	-	-	0.50	-	-	0.26
SWEET POTATO									
1. 1.8m x 3.6m	2.32	2.24	2.28	1.58	1.24	1.41	1.95	1.75	1.85
2. 2.7m x 2.7m	2.46	2.29	2.37	1.65	1.42	1.54	2.06	1.96	2.01
3. 2.7m x 3.6m	2.92*	1.92	2.42	1.79	1.62	1.70	2.35*	1.77	2.06
4. 3.6m x 3.6m	2.76*	2.24	2.50	2.12*	1.67	1.89	2.44*	1.95	2.20
Mean	2.61*	2.17	-	1.78	1.49	-	2.20*	1.86	-
CD for spacings	-	-	0.61	-	-	0.54	-	-	0.42
CD for intensities	-	-	0.29	-	-	0.20	-	-	0.19
CD for spacing at the same level of intensity	-	-	0.69	-	-	0.54	-	-	0.47
CD for intensity at the same level of spacing	-	-	0.58	-	-	0.41	-	-	0.39

* Significant (0.05)

FIG.4 b EFFECT OF ARECANUT SPACINGS AND INTERCROPPING INTENSITIES ON THE LEAF AREA OF TURMERIC AND SWEET POTATO DURING CROP GROWTH STAGES

1a.	1.8 x 3.6m	40% intensity of intercropping
1b.	1.8 x 3.6m	60% intensity of intercropping
2a.	2.7 x 2.7m	40% intensity of intercropping
2b.	2.7 x 2.7m	60% intensity of intercropping
3a.	2.7 x 3.6m	40% intensity of intercropping
3b.	2.7 x 3.6m	60% intensity of intercropping
4a.	3.6 x 3.6m	40% intensity of intercropping
4b.	3.6 x 3.6m	60% intensity of intercropping



Sweet potato
Turmeric
Leaf area (m² / 0·25 m² land area)
Days after planting
2b
2a
1b
1a
3a
3b
4a
4b

FIG. 4 b.

area of sweet potato did not show any significant variation when grown under different spacings of arecanut. Increasing levels of spacings showed an increasing trend of leaf area during both the years of study. The cumulative data showed that leaf area increased from 1.85 m^2/0.25 m^2 in 1.8m x 3.6m spacing to 2.2 m^2/0.25 m^2 under a wider spacing of 3.6m x 3.6m.

Intercropping intensities showed a significant variation in leaf area with 40% intensity of intercropping significantly recording higher values when compared to 60% intensity. From the mean table, it is seen that leaf area increased from 1.86 m^2/ 0.25 m^2 at 60% intensity to 2.20 m^2/0.25 m^2 at 40% intensity. Interactions showed that during 1978-79 at a spacing of 2.7m x 3.6m 40% intercropping intensity was optimum while during 1979-80, the same intensity was optimum under 3.6m x 3.6m spacing. The pooled data however, indicated that 40% intercropping intensity significantly gave higher leaf area (2.35 and 2.44 m^2/0.25 m^2) compared to 60% intensity (1.77 and 1.95 m^2/0.25 m^2) at the two higher levels of spacings of 2.7m x 3.6m and 3.6m x 3.6m, respectively. The pooled data also indicated that at the same level of 40% intensity of intercropping wider spacing of 3.6m x 3.6m produced significantly higher leaf area of 2.44 m^2/0.25 m^2 compared to 1.95 m^2/0.25 m^2 produced at the lowest spacing of 1.8m x 3.6m.

IV.2.3. <u>Production of tillers/branches as influenced by intercropping intensities at different spacings of arecanut</u>

The data on the periodical observations on the number of tillers produced by turmeric as influenced by intercropping intensities under various spacings of arecanut are presented in Fig. 5 (a) and mean yearly data are given in Table IV.2.3.

From Fig. 5 (a), it is observed that tiller production in turmeric nearly doubled itself in almost all the treatments from 90th day to 120th day and the peak was generally reached around 210 days. Intercropping intensity of 60% had a slight edge over the 40% both at the lowest and the highest spacings. The peaks ranged from 3.5 to 4.7 tillers per plant in different treatments. Growing turmeric under various spacings of arecanut did not bring any significant changes on the production of tillers in turmeric. The variations in tiller count were not conspicuous. Intercropping intensities also did not show any significant differences in tiller count. During 1978-79, the wider spacing of 3.6m x 3.6m under 60% intercropping intensity (4.7 tillers/plant) was (3.3 tillers/plant) significantly superior to 40% intensity. The same trend was observed in the mean data for two years. These data also indicated that under 40% intensity, tiller production was significantly higher (4.0 tillers/plant) under 2.7m x 2.7m spacing than under 3.6m x 3.6m (3.1 tillers/plant).

In case of sweet potato, the peak production of branches was observed only after 150 days. Wider spacings had their peaks by 180 days and they were higher than the lowest spacing in both the intercropping intensities.

Table IV.2.3. Number of tillers/branches produced by the intercrops of turmeric, sweet potato and cowpea as influenced by intercropping intensities at varied levels of spacings of arecanut

Treatments Intercrops/arecanut spacing	Intensities of intercropping								
	1978-79			1979-80			Mean of 2 years		
	40%	60%	Mean	40%	60%	Mean	40%	60%	Mean
TURMERIC									
1. 1.8m x 3.6m	4.5	4.5	4.5	3.1	3.1	3.1	3.8	3.8	3.8
2. 2.7m x 2.7m	4.7	4.1	4.4	3.0	3.3	3.2	4.0	3.8	3.9
3. 2.7m x 3.6m	4.3	3.5	3.9	3.1	3.3	3.2	3.9	3.5	3.7
4. 3.6m x 3.6m	3.3	4.7*	4.0	3.1	3.2	3.2	3.1	4.1	3.6
Mean	4.2	4.2	-	3.1	3.3	-	3.7	3.8	-
CD for spacing	-	-	-	-	-	-	-	-	-
CD for intensity	-	-	0.67	-	-	0.5	-	-	0.4
CD for spacing at the same level of intensity	-	-	-	-	-	-	-	-	-
CD for intensity at the same level of spacing	-	-	-	-	-	-	-	-	-
SWEET POTATO									
1. 1.8m x 3.6m	11.1	10.5	10.8	7.8	7.9	7.9	9.4	9.2	9.3
2. 2.7m x 2.7m	15.1	12.6	13.9	8.4	8.7	8.6	11.7	10.7	11.2
3. 2.7m x 3.6m	14.0	11.8	13.0	8.4	6.2	7.3	11.2	9.0	10.1
4. 3.6m x 3.6m	13.2	13.1	13.2	6.6	8.3	7.5	9.9	10.9	10.4
Mean	13.4	12.0	-	7.8	7.8	-	10.6	10.0	-
CD for spacings	-	-	-	-	-	-	-	-	-
CD for intensities	-	-	-	-	-	-	-	-	-
CD for spacing at the same level of intensity	-$	-	-	-	-	-	-	-	-
CD for intensity at the same level of spacing	-	-	-	-	-	-	-	-	-
COWPEA									
1. 1.8m x 3.6m	12.54	13.10	12.82	13.33	12.66	13.00	12.93	13.21	13.07
2. 2.7m x 2.7m	18.40	16.45	17.42	19.33	15.33	17.33	17.89	15.89	16.89
3. 2.7m x 3.6m	19.50	16.80	18.15	20.33	21.33	20.83	16.37	19.06	17.71
4. 3.6m x 3.6m	20.50	21.67	21.08	20.33	18.33	19.33	21.37	20.00	20.68
Mean	17.73	17.0	-	18.33	16.91	-	17.14	17.04	-
F. Test	NS	NS	NS	NS	NS	NS	NS	NS	NS

* Significant at 5%   NS = Not significant

FIG.5 a EFFECT OF ARECANUT SPACINGS AND INTERCROPPING INTENSITIES ON THE TILLER/BRANCH PRODUCTION OF TURMERIC AND SWEET POTATO DURING CROP GROWTH STAGES

1a. 1.8 x 3.6m 40% intensity of intercropping

1b. 1.8 x 3.6m 60% intensity of intercropping

2a. 2.7 x 2.7m 40% intensity of intercropping

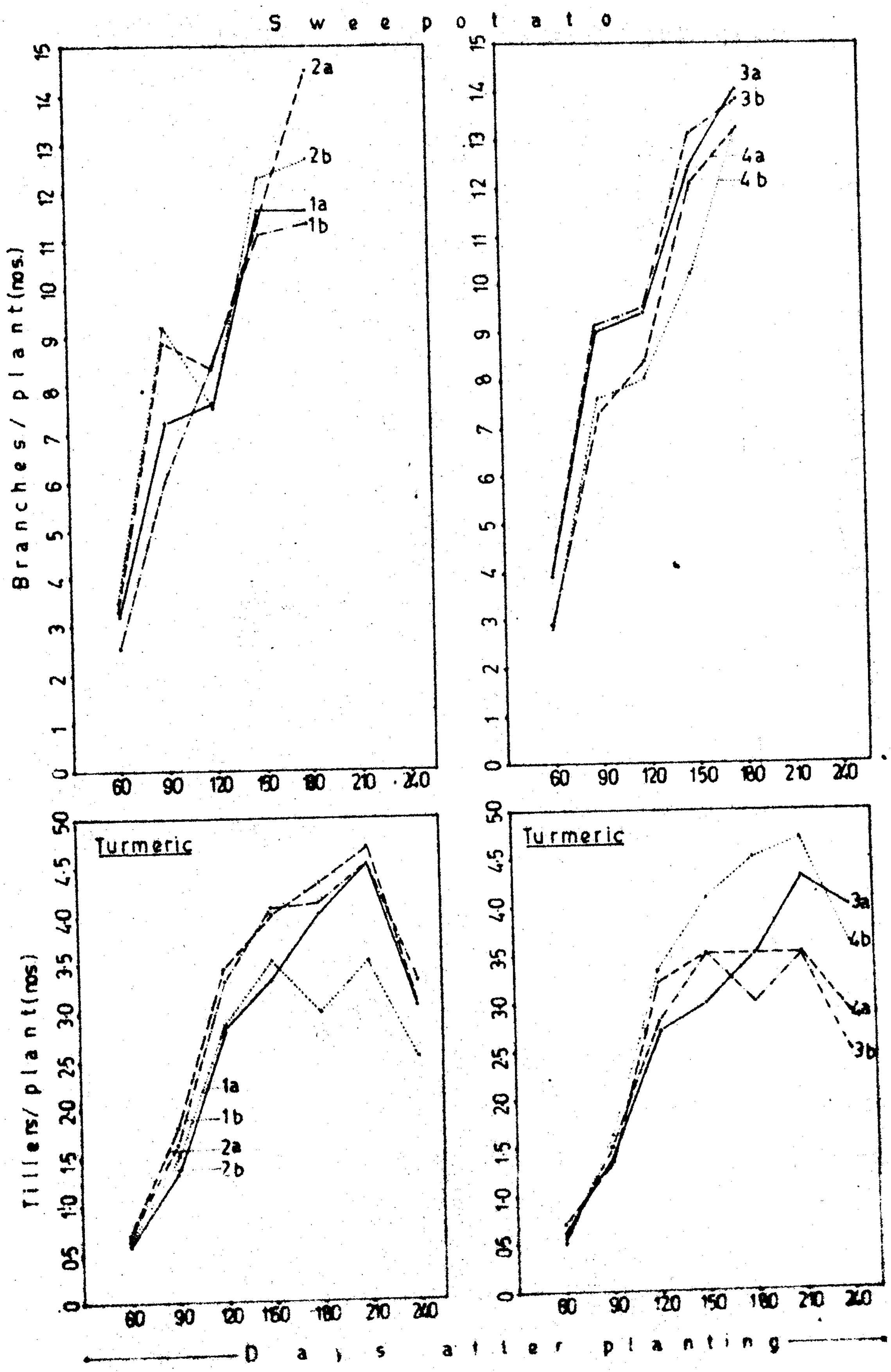
2b. 2.7 x 2.7m 60% intensity of intercropping

3a. 2.7 x 3.6m 40% intensity of intercropping

3b. 2.7 x 3.6m 60% intensity of intercropping

4a. 3.6 x 3.6m 40% intensity of intercropping

4b. 3.6 x 3.6m 60% intensity of intercropping



Sweepotato
Branches/plant (nos.)
Turmeric
Tillers/plant (nos)
1a
1b
2a
2b
3a
3b
4a
4b
60 90 120 150 180 210 240
Days after planting

FIG. 5a

The number of branches produced in various treatments did not differ statistically. However, narrow spacings of arecanut (1.8m x 3.6m) produced fewer branches than other treatments in sweet potato. Intercropping intensities did not have any effect on branching. The differences in various interactions also did not show any significant variation with respect to number of branches.

Growing cowpea after the harvest of sweet potato under different arecanut spacings did not bring about any significant effect on the number of branches. However, it is seen from the Table (IV.2.3) that branching of cowpea was more under wider spacings. Branch numbers ranged from 13.07 to 20.68.

Intercropping intensities did not have any effect on the branching nature of cowpea. Branch number increased from 16.9 under 60% intensity to 18.3 under 40% intercropping intensity. There were no interactions due to intercropping intensities and arecanut spacings.

IV.2.4. Biomass production of turmeric and sweet potato as influenced by intercropping intensities at different spacings of arecanut

The data on the periodical observations on the biomass production of intercrops turmeric and sweet potato as influenced by different intensities at different spacings of arecanut are presented in Fig. 5 (b) and the yearly mean data given in Table IV.2.4.

Table IV.2.4. Biomass production of intercrops of turmeric and sweet potato-cowpea as influenced by intercropping intensities at varied levels of arecanut spacings.

Treatments	Intensities of intercropping								
Intercrops/ arecanut spacings	1978-79			1979-80			Mean of 2 years		
	40%	60%	Mean	40%	60%	Mean	40%	60%	Mean
Turmeric									
1. 1.8m x 3.6m	8627	12333	10480*	4785	7827	6306	6706	10080*	8393*
2. 2.7m x 2.7m	6333	9160	7746	4479	7852	6168	5406	8506	6957
3. 2.7m x 3.6m	5466	9463	7460	4986	7083	6040	5226	8273	6750
4. 3.6m x 3.6m	6120	5960	6040	4534	6692	5614	5327	6326	5827
Mean	6637	9227*	-	4697	7367*	-	5667	8297*	-
CD for spacings	-	-	2942	-	-	-	-	-	2214
CD for intensities	-	-	1998	-	-	-	-	-	998
CD for spacing at the same level of intensity	-	-	4221	-	-	-	-	-	2412
CD for intensity at the same level of spacing	-	-	3997	-	-	-	-	-	1996
Sweet potato-Cowpea									
1. 1.8m x 3.6m	14161	18317	16239	3408	4292	3850	9266	11304	10285
2. 2.7m x 2.7m	14781	25840	20310	3946	4498	4222	12488	11356	11922
3. 2.7m x 3.6m	22532*	24606*	23569*	4216	4587*	4402	13374*	14596*	13985
4. 3.6m x 3.6m	20649*	23473	22061*	4167	5000*	4583	12408	14236*	13323
Mean	18031	23059	-	3934	4594	-	11883	12873	-
CD for spacings	-	-	5728	-	-	1259	-	-	3798
CD for intensities	-	-	2938	-	-	445	-	-	1404
CD for spacing at the same mlevel of intensity	-	-	6750	-	-	1209	-	-	3724
CD for intensity at the same level of spacing	-	-	5876	-	-	890	-	-	2808

* Significant at 5%

FIG.5 b. EFFECT OF ARECANUT SPACINGS AND INTERCROPPING INTENSITIES ON THE BIOMASS PRODUCTION OF TURMERIC AND SWEET POTATO IN ARECANUT DURING CROP GROWTH STAGES

1a. 1.8 x 3.6m 40% intensity of intercropping

1b. 1.8 x 3.6m 60% intensity of intercropping

2a. 2.7 x 2.7m 40% intensity of intercropping

2b. 2.7 x 2.7m 60% intensity of intercropping

3a. 2.7 x 3.6m 40% intensity of intercropping

3b. 2.7 x 3.6m 60% intensity of intercropping

4a. 3.6 x 3.6m 40% intensity of intercropping

4b. 3.6 x 3.6m 60% intensity of intercropping

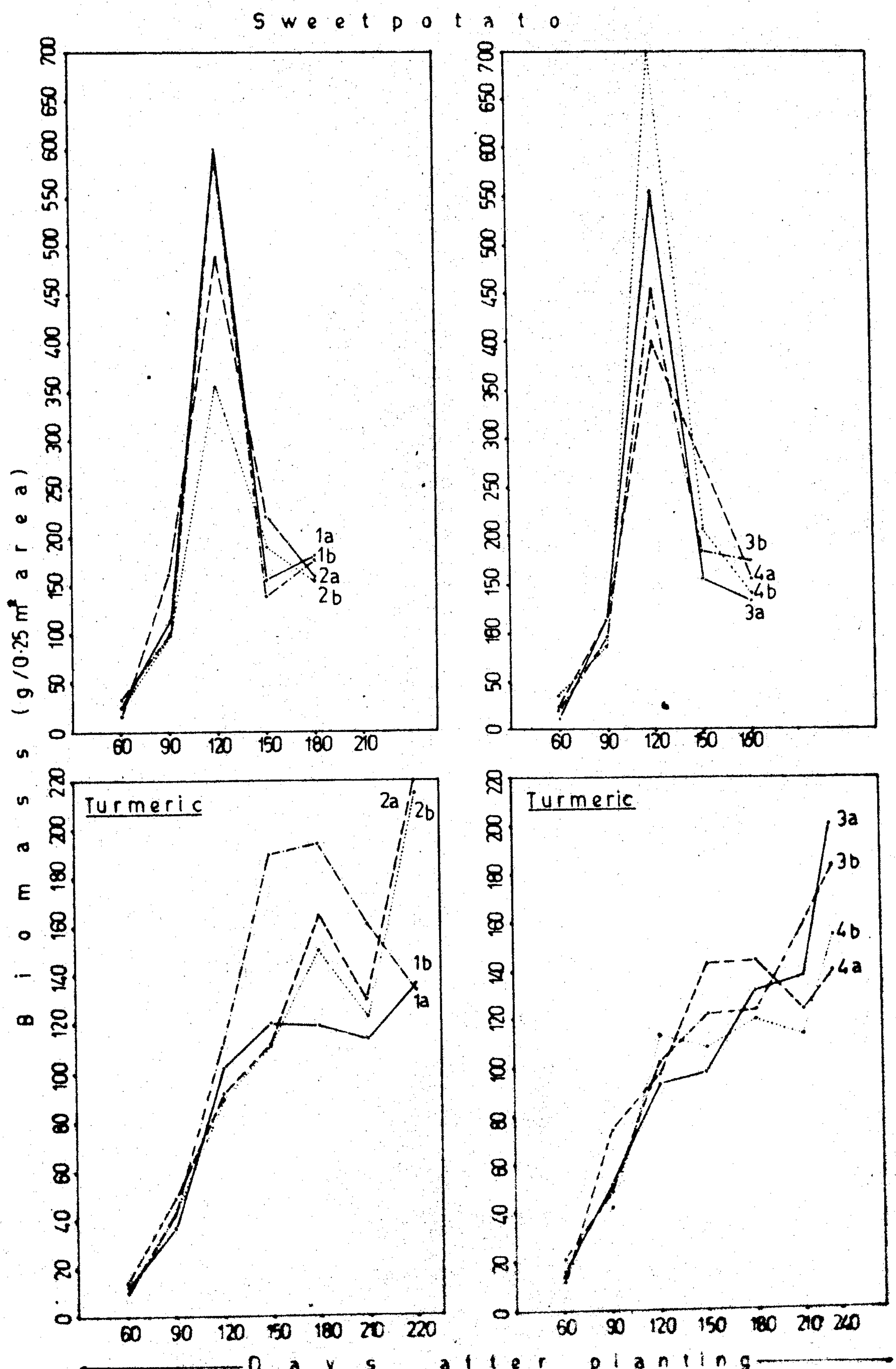

Sweetpotato
Biomass (g/0·25 m² area)
Turmeric
Turmeric
1a
1b
2a
2b
3a
3b
4a
4b
Days after planting

FIG. 5b.

From Fig. 5 (b), it is observed that the biomass production in turmeric was around 100 g/0.25 m^2 by about 120 days in almost all the treatments. But the peak values reached at different times. The biomass production of turmeric was maximum under 1.8m x 3.6m spacing during both the years of study. It was significantly superior to wider spacings of 2.7m x 2.7m and 3.6m x 3.6m during 1978-79 and to 3.6m x 3.6m during 1979-80 and in the mean values of both the years. The biomass production in the other spacings did not differ among themselves statistically but showed a declining trend with the increase in the spacing of arecanut. During the period of study, the biomass production was significantly more at 60% intercropping intensity when compared to 40%. The mean table indicated that dry matter production increased significantly from 5667 kg at 40% intensity to 8297 kg at 60% intensity.

Interaction tables indicated significant differences in certain combinations. From the mean table, it is seen that except at a spacing of 3.6m x 3.6m, all other spacings responded significantly with higher biomass production at an intercropping intensity at 60% than at 40% intensity. The mean data also showed that at the same spacings of 1.8m x 3.6m, 2.7m x 2.7m or 2.7m x 3.6m, it was always 60% intercropping intensity that gave significantly higher biomass production of turmeric than obtained at 40% intensity.

In sweet potato-cowpea, the biomass production attained values around 100 g/0.25 m^2 by 90 days and the peak values in all the treatments reached by 120 days. These values ranged from over 400 to 717 g/0.25 m^2. Biomass production of intercrop sweet potato-cowpea when grown under various spacings of arecanut showed a significant variation during 1978-79. Biomass production increased with the increase in the spacing of arecanut. Biomass production significantly increased when grown under 2.7m x 3.6m (23569 kg/ha) and 3.6m x 3.6m (22061 kg/ha) spacings when compared to 1.8m x 3.6m spacing (16239 kg/ha). Growing sweet potato at 60% intensity significantly increased biomass production (23059 kg/ha) when compared to 40% intensity of intercropping (18031 kg/ha). Interactions showed that at the same level of 40% intercropping intensity wider spacing of 2.7m x 3.6m was significantly superior to narrower spacing of 1.8m x 3.6m. At the 60% intercropping intensity, a spacing of 2.7m x 2.7m was superior to 1.8m x 3.6m spacing.

During the second year of study, biomass production showed a general decline in all the plots. The differences due to growing under various spacings did not show any significant effect. However, biomass increased with the increase in the spacings of arecanuts. Higher intensity of intercropping (4594 kg/ha at 60%) significantly increased the biomass production when compared to low intensity (3934 kg/ha at 40%).

The mean data did not show any significant changes in biomass production either due to areca spacings or intensities of intercrops. Interaction was seen at the same level of 40%

intercropping intensity of sweet potato when a spacing of 2.7m x 3.6m significantly produced higher biomass production of 13374 kg/ha than at 1.8m x 3.6m wibh 9266 kg/ha.

IV.2.5. Number of tubers as influenced by intercropping intensities at different spacings of arecanut

The data on different intensities of intercrops at different spacings of arecanut on the production of tubers are given in Table IV.2.5.

Tuber production in turmeric did not show any significant variation when grown under various spacings of arecanut. In general, tuber production increased from 1978-79 to 1979-80 from 12.3 to 20.7 per plant. The mean data showed the tuber production to range from 16 to 18/plant in different spacings. Intercropping intensities also did not show any significant variation.

Tuber production in sweet potato, when grown under various spacings of areca palm did not show any significant effect during the course of study. Intercropping intensity also did not show any significant trend in the production of tubers. The tuber production ranged from 2.0 to 2.8/plant in different spacings.

IV.2.6. Volume of tubers as influenced by intercropping intensities at different spacings of arecanut

The data on the volume of tubers as influenced by different intercropping intensities of intercrops at differnt spacings of arecanut are given in Table IV.2.6.

Table IV.2.5. Number of tubers produced by intercrops of turmeric, sweet potato as influenced by intercropping intensities at varied levels of arecanut spacings

Treatments	Intensities of intercropping								
Intercrops/arecanut spacings	1978-79			1979-80			Mean of 2 years		
	40%	60%	Mean	40%	60%	Mean	40%	60%	Mean
TURMERIC									
1. 1.8m x 3.6m	13.7	13.9	13.8	16.3	22.3	19.3	15.0	17.9	16.5
2. 2.7m x 2.7m	11.1	12.1	11.6	21.5	20.2	20.9	16.8	15.9	16.4
3. 2.7m x 3.6m	10.9	10.3	10.6	22.9	18.9	20.9	17.6	14.5	16.0
4. 3.6m x 3.6m	13.6	12.9	13.2	22.1	21.7	21.9	18.5	17.4	18.0
Mean	12.3	12.3	-	20.7	20.8	-	17.0	16.4	-
F.Test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SWEET POTATO									
1. 1.8m x 3.6m	1.7	2.8	2.2	3.2	2.2	2.7	2.4	2.5	2.4
2. 2.7m x 2.7m	2.1	1.4	1.7	2.4	1.9	2.2	2.2	1.7	2.0
3. 2.7m x 3.6m	2.6	2.5	2.5	3.2	2.9	3.0	2.9	2.8	2.8
4. 3.6m x 3.6m	2.7	2.0	2.4	2.9	3.3	3.1	2.8	2.6	2.7
Mean	2.3	2.2	-	2.9	2.6	-	2.6	2.4	-
F.Test	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table IV.2.6. Volume of tubers obtained from intercrops of turmeric and sweet potato as influenced by intercropping intensities at varied levels of arecanut spacings (ml/5 plants)

Treatments Intercrops/ arecanut spacings	Intensities of intercropping								
	1978-79			1979-80			Mean of 2 years		
	40%	60%	Mean	40%	60%	Mean	40%	60%	Mean
TURMERIC									
1. 1.8m x 3.6m	259	259	259	218	173	196	230	217	224
2. 2.7m x 2.7m	241	267	254	187	183	185	214	225	219
3. 2.7m x 3.6m	257	256	256	147	144	146	202	200	201
4. 3.6m x 3.6m	169	203	186	125	118	122	147	162	155
Mean	232	246	-	169	155	-	198	201	-
F. Test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SWEET POTATO									
1. 1.8m x 3.6m	111	139	125	330	477	403	220	308	264
2. 2.7m x 2.7m	169	172	171	873*	497	685*	521	401	461*
3. 2.7m x 3.6m	166	200	183	837*	427	632	501	131	407*
4. 3.6m x 3.6m	230	179	205	750*	550	650*	499	365	432*
Mean	169	172	-	698	488	-	435	347	-
CD for spacings	-	-	-	-	-	235	-	-	142
CD for intensities	-	-		-	-	132	-	-	79
CD for spacing at the same level of intensity	-	-		-	-	294	-	-	176
CD for intensity at the same level of spacing	-	-	-	-	-	263	-	-	158

* Significant at 5%

Volume of tubers in general, decreased with the increase in the spacings of arecanut. The variations in volume of tubers due to different spacings however, did not have statistical significance during both the years of study. In general, mean values showed that volume of tubers decreased from 224 ml in 1.8m x 3.6m spacing to 155 ml in 3.6m x 3.6m spacing. Intercropping intensities did not bring about significant changes in the volume of tubers during both the years of study. There were no interactions due to intercropping intensities at the same level of spacing or due to spacings at the same level of intensity.

Tuber volume of sweet potato showed significant variation when grown under different spacings of arecanut during 1979-80 whereas the differences during 1978-79 did not show any statistical significance. Increasing levels of spacings increased tuber volume significantly when compared to narrower spacings (1.8m x 3.6m). The tuber volume ranged from 264 ml to 461 ml from 1.8m x 3.6m to 2.7m x 2.7m spacings in the pooled data.

Intensities of intercropping showed a significant difference on the tuber volume during 1979-80 and in the pooled data. Growing sweet potato at 40% intensity significantly recorded greater tuber volume (435 ml) when compared to 60% crop intensity (347 ml) as seen from the pooled data.

From the interaction table, it is seen that under a spacing of 2.7m x 3.6m, 40% intercropping intensity significantly increased the tuber volume when compared to other spacings. Under 40% intensity of intercropping, wider spacings of arecanut recorded significantly higher value when compared to narrow spacing of 1.8m x 3.6m whereas under 60% intensity, spacings did not show any significant differences.

IV.2.7. Weight of tubers as influenced by intercropping intensities at different spacings of arecanut

The data on the weight of tubers produced from five plants as influenced by intercropping intensities at different spacings of arecanut are given in Table IV.2.7.

Tuber weights did not differ significantly due to increase in arecanut spacings during both the years of study. Mean values showed that with narrower spacings of 1.8m x 3.6m and 2.7m x 2.7m, the tuber weights recorded higher values of 238 g and 225 g/five plants when compared to wider spacings of 2.7m x 3.6m and 3.6m x 3.6m which produced 187 and 158 g/five plants respectively.

Intercropping intensities did not show any significant trend with respect to tuber weight. The pooled data indicated that the tuber weight did not vary with the intercropping intensities.

The interaction effects were not significant in 1978-79. During 1979-80 at the same level of either 40% or 60% intercropping intensity, 2.7m x 3.6m spacing provided higher tuber production than 3.6m x 3.6m spacing.

Table IV.2.% Weight of tubers of intercrops of turmeric(gm/5 plants) as influenced by intercropping intensities at varied levels of arecanut spacings

Treatments Intercrops/ arecanut spacings	Intensities of intercropping								
	1978-79			1979-80			Mean of 2 years		
	40%	60%	Mean	40%	60%	Mean	40%	60%	Mean
TURMERIC									
1. 1.8m x 3.6m	270	273	271	214	193	203	243	233	238
2. 2.7m x 2.7m	245	273	259	192	192	192	218	232	225
3. 2.7m x 3.6m	244	238	241	254	243	149	199	174	187
4. 3.6m x 3.6m	176	211	294	134	110	122	158	157	158
Mean	234	249	-	114	159	-	205	199	-
F. Test	NS	NS	NS	NS	NS	NS	NS	NS	NS
SWEET POTATO									
1. 1.8m x 3.6m	97	102	100	563	523	543	330	312	321
2. 2.7m x 2.7m	228*	162	195	985*	512	748	606*	336	471*
3. 2.7m x 3.6m	180*	219	200	937*	458	698	556*	336	446
4. 3.6m x 3.6m	288*	153	220	860*	607	734	573*	354	464
Mean	198*	159	-	836*	525	-	516*	335	-
CD for spacings	-	-	89	-	-	284	-	-	146
CD for intensities	-	-	37	-	-	162	-	-	82
CD for spacing at the same level of intensity	-	-	93	-	-	362	-	-	182
CD for intensity at the same level of spacing	-	-	74	-	-	325	-	-	163

* Singificant at 5*   NS = Not significant

Sweet potato tuber yield per plant differed significantly with varying levels of spacings of arecanut. During 1978-79, a spacing of 1.8m x 3.6m was inferior to all other spacings while the mean data showed that it was inferior to only 2.7m x 2.7m spacing. With the increase in spacings of arecanut, the tuber yield also increased from 100 g to 220 g during the first year, 543 to 734 g in the second year and from 321 to 464 g as seen from the mean data.

Sweet potato intercropping at 40% intensity (Plate 4) significantly increased the tuber yield in both the years of study, from 159 to 198 g and from 525 to 836 g. It ranged from 335 g under 60% (Plate 5) intercropping intensity to 516 g under 40% intercropping intensity as seen from the pooled data.

Interactions showed that during 1978-79, 60% intercropping intensity was superior to 40% under the same level of spacing at 3.6m x 3.6m. However, during 1979-80, 40% intercropping intensity was superior to 60% intensity at the spacings of 2.7m x 2.7m and 2.7m x 3.6m while the data indicated superiority of 40% intensity at the three higher spacings. Pooled data also indicated that under 40% intensity, wider spacings recorded significantly higher yields (330 to 606 g) whereas under 60% intensity, the yield differences between spacings were not significant (312 to 354 g).

IV.2.8. <u>Test weight of cowpea as influenced by intercropping intensities at different spacings of arecanut</u>

FIG.8 a. EFFECT OF FERTILIZER LEVEL ON THE TILLER PRODUCTION OF INTER AND SOLE CROPS OF TURMERIC AND SWEET POTATO DURING CROP GROWTH STAGES

FIG.8 b. EFFECTS OF FERTILIZER LEVELS ON THE BIOMASS PRODUCTION OF INTER AND SOLE CROPS OF TURMERIC AND SWEET POTATO DURING CROP GROWTH STAGES

FERTILIZER SCHEDULE

	T = Turmeric			SP = Sweet Potato		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1)	0	0	0	0	0	0
2)	70	60	120	70	50	70
3)	140	120	240	140	100	140
4)	210	180	360	210	150	210

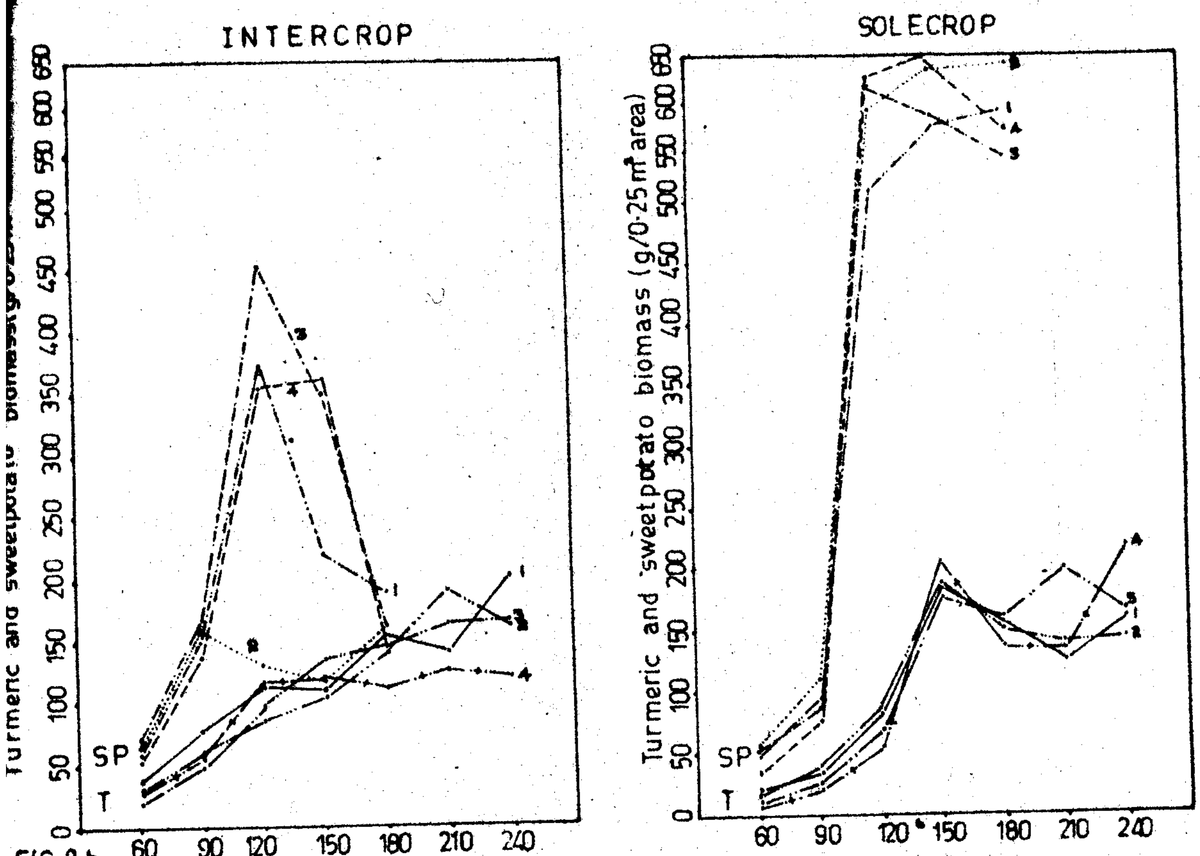

INTERCROP
SOLECROP
Turmeric and sweetpotato biomass (g/0·25 m² area)
SP
T
60 90 120 150 180 210 240

FIG. 8 b.

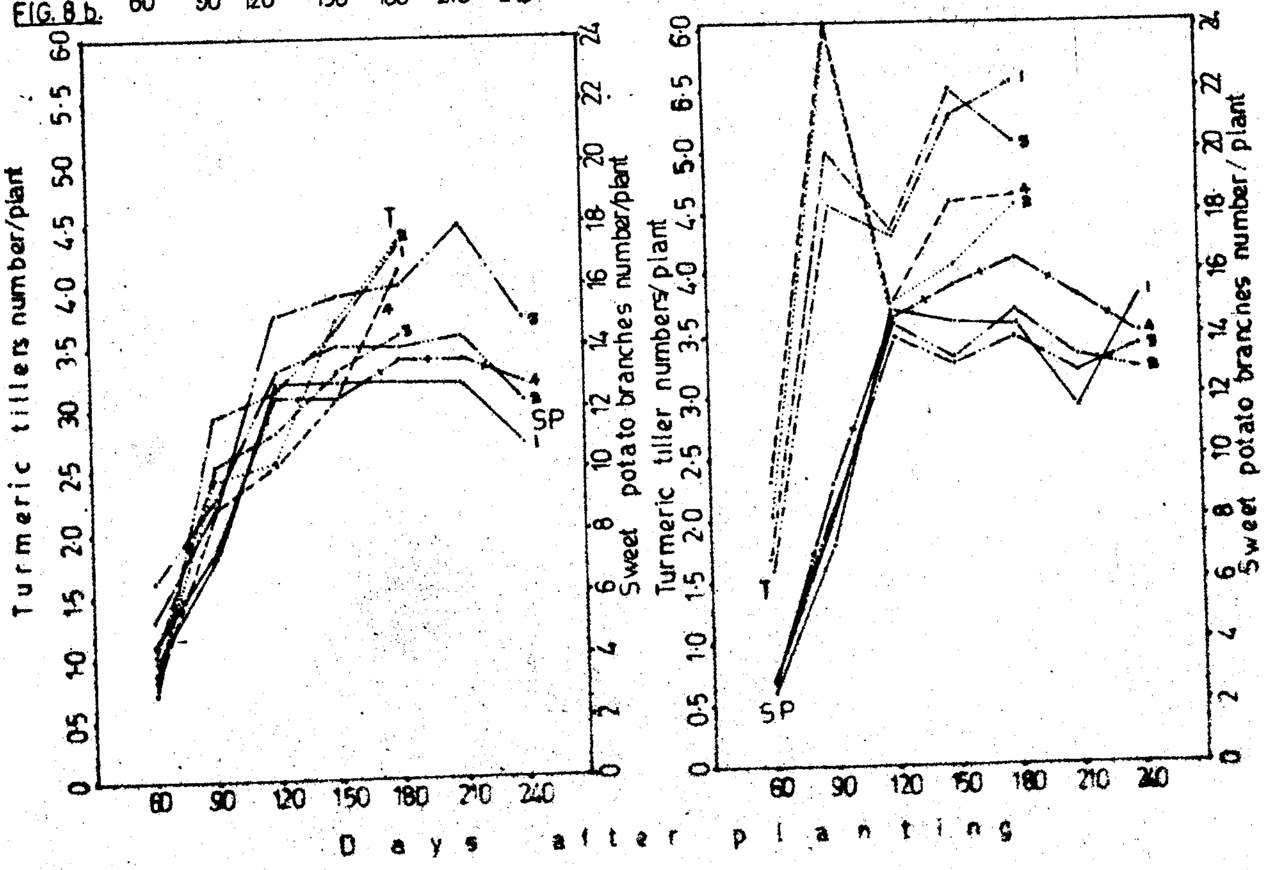

Turmeric tillers number/plant
Sweet potato branches number/plant
Turmeric tiller numbers/plant
T
SP
60 90 120 150 180 210 240
Days after planting

FIG. 8 a.

PLATE No. 4 SWEET POTATO GROWN UNDER 40 PER CENT INTERCROPPING INTENSITY

PLATE No. 5 SWEET POTATO GROWN UNDER 60% INTERCROPPING INTENSITY

Plate 4

Plate 5

The data on test weight of cowpea as influenced by intercropping intensities at different spacings of arecanut are given in Table IV.2.8.

Test weight of cowpea seeds did not show any significant variation due to different levels of arecanut spacings. Intensities of intercropping also did not show any significant effect on this character. The differences due to intensities at the same level of spacing did not show any significant variation. However, growing cowpea at 40% intensity under 2.7m x 2.7m or 3.6m x 3.6m spacings of arecanut could significantly increase the test weight (50 and 51 g) when compared to other spacings (47 and 49 g).

IV.2.9. Yield of intercrops as influenced by intercropping intensities under different spacings of arecanut

The data pertaining to yield of various intercrops grown at varied intercropping intensities under various arecanut spacings are given in Table IV.2.9.

Yield of turmeric grown under various spacings of arecanut did not differ significantly. Increasing the spacings in arecanut substantially decreased the turmeric rhizomes from 5279.4 kg/ha in 1.8m x 3.6m spacing to 3336.5 kg/ha under 3.6m x 3.6m spacing as seen from the pooled data. However, 60% intercropping intensity of turmeric significantly recorded higher yield of 5228 kg/ha (Plate.6),when compared to 40% intensity with 3764 kg/ha (Plate.7). Increasing

PLATE No. 6 TURMERIC GROWN UNDER 1.8m x 3.6m SPACINGS OF ARECANUT

PLATE No. 7 TURMERIC GROWN UNDER 3.6 x 3.6m SPACINGS OF ARECANUT

Plate 6

Plate 7

Table. IV.2.9. Test weight (g) of cowpea as influenced by intercropping intensities at varied levels of arecanut spacings

Spacings	Intercropping intensities		
	40%	60%	Mean
1. 1.8m x 3.6m	47	49	48
2. 2.7m x 2.7m	50	49	49
3. 2.7m x 3.6m	49	49	49
4. 3.6m x 3.6m	51	49	50
Mean	49	49	-
F. Test	NS	NS	NS

NS = Not significant

Table IV.2.9. Yield of intercrops of turmeric, sweet potato-cowpea as influenced by intercropping intensities at varied levels of arecanut spacings(kg/ha)

Treatment Intercrops/ arecanut spacings	Intensities of intercropping								
	1978-79			1979-80			Mean of 2 years		
	40%	60%	Mean	40%	60%	Mean	40%	60%	Mean
TURMERIC									
1. 1.8m x 3.6m	4210	6141*	5175	4771	5916	5343	4490	6028*	5259
2. 2.7m x 2.7m	3646	5312	4479	4833	5833	5083	4240	5322	4781
3. 2.7m x 3.6m	3658	4915	4287	3500	6396	4948	3579	5638	4608
4. 3.6m x 3.6m	2823	3811	3317	2672	4041	3357	2747	3926	3336
Mean	3584	5045*	-	3944	5422*	-	3764	5228*	-
CD for spacings	-	-	-	-	-	-	-	-	-
CD for intensities	-	-	543	-	-	942	-	-	676
CD for spacing at the same level of intensity	-	-	2025	-	-	3284	-	-	2237
CD for intensity at the same level of spacing	-	-	1087	-	-	1885	-	-	1352
SWEET POTATO									
1. 1.8m x 3.6m	3270	3829	3550	3304	3583	3443	3227	3706	3466
2. 2.7m x 2.7m	2600	3550	3075	4308	4137	4222	3453	3841	3647
3. 2.7m x 3.6m	3846	5554	4700	4137	4650	4393	3991	5102	4546
4. 3.6m x 3.6m	4437	6092*	5264	4167	5000	4583	4302	5546*	4924*
Mean	3538	4756*	-	3979	4343	-	3743	4549*	-
CD for spacings	-	-	-	-	-	-	-	-	1139
CD for intensities	-	-	687	-	-	387	-	-	492
CD for ~~intensities~~ spacing at the same level of intensity	-	-	2158	-	-	1137	-	-	122
CD for intensity at the same level of spacing	-	-	1373	-	-	776	-	-	384
COWPEA									
1. 1.8m x 3.6m	442	795	619	567	794	681	505	794	649
2. 2.7m x 2.7m	647	748	697	711	830	771	679	789	734
3. 2.7m x 3.6m	765	838	801	753	843	798	759	840	799
4. 3.6m x 3.6m	794	894	844	788	889	839	790	891	841
Mean	662	818*	-	705	839*	-	683	828*	-
CD for spacings	-	-	-	-	-	-	-	-	-
CD for intensities	-	-	88	-	-	45	-	-	63
CD for spacing at the same level of intensity	-	-	303	-	-	161	-	-	220
CD for intensity at the same level of spacing	-	-	178	-	-	89	-	-	126

* Significant at 5%

intensity of intercropping under various spacings also showed a significant increase in tuber yield, but under the same level of intensity, 60% intensity of cropping under 1.8m x 3.6m spacing, recorded the highest yield of 6028 kg/ha on an average of two years.

Interactions indicated that during 1978-79, under any one given level of spacing, 60% intercropping was always found to be significantly superior to 40% intensity in turmeric yield, while it was so in 1978-80 only under a spacing of 2.7m x 3.6m. In the pooled data both 1.8m x 3.6m and 2.7m x 3.6m spacings responded similarly. Except for significantly higher yield of 6141 kg/ha at 1.8m x 3.6m spacing over that of 3.6m x 3.6m (3810 kg/ha) at the same intercropping intensity of 60% during 1978-79, there were no other interactions.

Sweet potato tuber yields did not differ significantly under various spacings of arecanut in both the years. The pooled data however, showed a significant difference between the spacing of 1.8m x 3.6m (3467 kg/ha) and 3.6m x 3.6m (4924 kg/ha). Increasing arecanut spacing gradually showed an increase in the tuber yield.

Among intercropping intensities, 60% intensity recorded significantly higher yield (4756 kg/ha) compared to 40% intensity (3538 kg/ha) during 1978-79. Though a similar trend was noticed in the next year, the differences were not significant with respect to yield. The cumulative effects of two years expressed significant differences with 60% intensity giving 4549 kg/ha against 3743 kg/ha obtained at lower intensity.

Among the interactions during 1978-79, under the same spacings of 3.6m x 3.6m, 60% intercropping intensity recorded significantly higher yield of 6091.66 kg/ha compared to 4437 kg/ha obtained from that of 40% intensity. During 1979-80 also, 60% intercropping intensity recorded significantly higher yield under the same spacing of arecanut. The cumulative data indicated that irrespective of the levels of spacings, increasing the level of intercropping intensity from 40 to 60% increased the yields significantly. Irrespective of levels of intercropping intensities, there was a consomitant and significant increase in sweet potato yield with every increase in the level of spacing.

Though cowpea yields increased with the increase in the level of spacings of arecanut from 649 kg/ha to 841 kg/ha from 1.8m x 3.6m to 3.6m x 3.6m spacings of arecanut as seen from the pooled data, the differences were not significant. However, cowpea yields during both the years along with the pooled data showed significant increase in yields (829 kg/ha) at 60% intensity over 40% intensity (683 kg/ha).

Interactions indicated that at the same level of spacing of 1.8m x 3.6m, 60% intercropping was superior to 40% intensity in both the years as well as in the average of two years.

During 1979-80, 60% intercropping intensity was also superior to 40% intensity at two other spacings of 2.7m x 2.7m and 3.6m x 3.6m. At the same level of intercropping intensity of 40%, wider spacings of 2.7m x 3.6m and 3.6m x 3.6m were always superior to narrower spacing of 1.8m x 1.8m for cowpea yields.

IV.3. Growth and yield attributes of arecanut

IV.3.1. Effect of intercropping intensities at different spacings of arecanut on the girth at last exposed node of areca palm

The data on the girth at last exposed node of arecanut palm did not show any significant variation due to growing of different intercrops at different intensities under different spacings of arecanut during the experimental period (Table. IV.3.1). During the post experimental period, the girth at last exposed node was found to have significantly increased under wider spacing of 3.6m x 3.6m (50.72 cm) over spacings of 2.7m x 3.6m (48.73 cm) and 1.8m x 3.6m (48.64 cm) and was on par with the 2.7m x 2.7m spacing (49.61 cm). A comparison of the post experimental period with the experimental period indicated that these treatments with either 3.6m x 3.6m spacing or 2.7m x 2.7m spacing enhanced the girth of arecanut palms by over 4.5% and that when sweet potato-cowpea rotation was introducted in arecanut, the girth increase was over 12.7% over the experimental period.

The girth of the palms where sweet potato was grown was found to have significantly increased (53.33 cm) when compared

Table IV.3.1. Girth at last exposed node (cm) as influenced by intercropping intensities at varied levels of arecanut spacings

Treatments	Experimental period(1978)	Post experimental period(1981)	% increase in girth
A. <u>Main plots</u>			
1. 1.8m x 3.6m	46.74	48.64	3.9
2. 2.7m x 2.7m	47.42	49.61	4.6
3. 2.7m x 3.6m	48.09	48.73	1.3
4. 3.6m x 3.6m	48.54	50.72*	4.5
Mean	47.70	49.42	-
B. <u>Sub plots</u>			
1. Turmeric	48.13	48.52	0.88
2. Sweet potato-cowpea	47.28	53.33*	12.79
Mean	47.70	50.92*	-
C. <u>Intensities</u>			
0	47.41	49.45	4.3
40%	47.99	49.67	3.5
60%	47.69	49.15	3.1
Mean	47.70	49.42	-
CD for main plots	2.42	1.88	-
CD for sub plots	1.48	1.65	-
CD for intensities	1.11	1.02	-

* Significant at 5%

to the palms where turmeric was grown (48.52 cm). There was no significant influence on the girth due to intercropping intensities in arecanut garden.

IV.3.2. Effect of intercropping intensities at different spacings of arecanut on the internodal distance at the last exposed node of areca palm

The data on the internodal distance as influenced by intercropping intensities at different spacings of arecanut are given in Table IV.3.2.

Internodal distance of arecanut palm at the last exposed node did not vary significantly by different intercrops under different spacings of arecanut during the pre-experimental period. Post-experimental data also showed the same trend suggesting that intercropping under various spacings of arecanut palms did not influence the internodal distance.

Neither intensities of intercrops nor kinds of intercrops could bring about any significant change in the internodal distance of areca palm. The internodal distance ranged from 7.42 to 7.79 cm in various treatments.

IV.3.3. Effect of intercropping intensities at different spacings of arecanut on the number of bunches produced per palm

The data on the number of bunches produced per palm as influenced by intercropping intensities at different spacings of arecanut are given in Table IV.3.3.

Table IV.3.2. Internodal distance (cm) at the last exposed node as influenced by intercropping intensities at varied levels of arecanut spacings

Treatments	1978	1981
A. <u>Main plots</u>		
1. 1.8m x 3.6m	7.56	7.67
2. 2.7m x 2.7m	7.47	7.50
3. 2.7m x 3.6m	7.79	7.55
4. 3.6m x 3.6m	7.62	7.73
Mean	7.61	7.61
B. <u>Sub plots</u>		
1. Turmeric	7.64	7.60
2. Sweet potato-cowpea	7.61	7.60
Mean	7.62	7.60
C. <u>Intensities</u>		
0	7.54	7.42
40%	7.74	7.68
60%	7.59	7.72
Mean	7.62	7.61
F. Test	NS	NS
CD for main plots	-	-
CD for sub plots	-	-
CD for intensities	-	-
CV%	29.8	30.3

NS = Not significant

Table IV.3.3. Number of arecanut bunches produced per palm as influenced by intercropping intensities at varied levels of arecanut spacings

Treatments	Pre-experimental period			Experimental period			Post-experimental period		
	76-77	77-78	Mean	78-79	79-80	Mean	80-81	81-82	Mean
A. <u>Main plots</u>									
1. 1.8m x 3.6m	2.9	2.6	2.8	3.2	2.4	2.8	3.6	2.5	3.0
2. 2.7m x 2.7m	2.8	2.6	2.2	3.2	2.6	2.9	3.6	2.5	3.1
3. 2.7m x 3.6m	2.8	3.1	2.9	3.4	2.9*	3.2	3.7	2.8	3.2
4. 3.6m x 3.6m	3.0	2.8	2.9	3.6	2.9*	3.3	3.9	2.7	3.3
Mean	2.9	2.8	-	3.3	2.7	-	3.7	2.6	-
B. <u>Sub plots</u>									
1. Turmeric	3.0	2.8	2.9	3.4	2.8	3.1	3.9	2.5	3.2
2. Sweet potato-cowpea	2.8	2.8	2.8	3.3	2.7	3.0	3.5	2.7	3.1
Mean	2.9	2.8	-	3.35	2.75	-	3.75	2.6	-
C. <u>Intensities</u>									
0	2.9	2.9	2.9	3.5	2.7	3.1	3.6	2.4	3.0
40%	2.7	2.8	2.8	3.3	2.8	3.0	3.8	2.8	3.3
60%	3.0	2.7	2.9	3.2	2.6	2.9	3.7	2.6	3.1
Mean	2.9	2.8	-	3.3	2.7	-	3.7	2.6	-
F. test	NS	NS	NS	NS	NS	NS	NS	NS	NS
CD for main plots	-	-	-	-	0.4	0.60	0.9	0.4	0.70
CD for sub plots	-	-	-	-	0.5	0.55	0.6	0.5	0.57
CD for intensities	-	-	-	0.3	0.4	0.35	0.4	0.4	0.40
CV %	19.6	18.7	19.1	24.2	23.7	24.0	22.1	21.8	22.80

S = Significant at 5%   NS = Not significant

Pre-experimental data on the number of bunches produced per palm did not show any significant difference among the palms selected for growing intercrops at different intensities suggesting uniformity among the population means. In general, the bunch production was 2.9 per palm per year. From the post-experimental data, it is seen that, though there was no significant difference in the main plot treatments, bunch production showed an increasing trend with the increase in spacings of arecanut. There were no differences in bunch production due to intercrops or intercropping intensities. However, increasing intensity from 40% to 60% showed a declining trend from 3.1 to 2.9 bunches per palm, during experimentation.

IV.3.4. Effect of intercropping intensities at different spacings of arecanut on the production of number of nuts per palm

The data on the number of nuts produced per palm as influenced by intercropping intensities at different spacings of arecanut are given in Table IV.3.4.

Pre-experimental data did not show any significant variation on the production of nuts among the palms. During experimental period, the number of nuts produced under various spacings due to growing intercrops increased the number of nuts per palm with different degrees. Wider spacings of 2.7m x 3.6m and 3.6m x 3.6m significantly increased the number of nuts per palm (807 and 877 nuts), over the other two lower spacings

Table IV.3.4. Number of arecanuts produced per palm as influenced by intensities or intercrops at varied levels of arecanut spacings

Treatments	Pre-experimental period			Experimental period			Post-experimental period		
	76-77	77-78	Mean	78-79	79-80	Mean	80-81	81-82	Mean
A. Main plots									
1. 1.8m x 3.6m	728	559	644	907	523	715	913	522	717
2. 2.7m x 2.7m	759	601	680	978	655	817	938	620	779
3. 2.7m x 3.6m	752	893	823	1054	807*	913	1082	680	881
4. 3.6m x 3.6m	731	767	749	981	877*	929	928	630	779
B. Sub Plots									
1. Turmeric	829	717	773	1092	772	932	1035	601	818
2. Sweet potato-cowpea	655	694	675	868	659	764	896	624	760
C. Intensities									
0	758	737	748	995	737	866	939	587	763
40%	728	736	732	1018	753	886	1021	690	855
60%	740	646	693	927	656	792	936	611	773
F. Test	NS	NS	NS	NS	S	NS	NS	NS	NS
CD for main plots	-	-	-	-	204	-	-	-	-
CD for sub plots	-	-	-	-	-	-	-	-	-
CD for intensities	-	-	-	-	-	-	-	-	-
CV %	29.6	33.2	26.9	34.0	32.0	25.6	27.3	26.4	22.6

S = Significant at 5%   NS = Not significant

(523 and 655 nuts). The spacing of 3.6m x 3.6m was also significantly superior to that of 2.7m x 2.7m. Though the differences due to intercrops turmeric and sweet potato were not significant, intercropping with turmeric showed substantial increase in nut production per palm (932 against 764 in sweet potato).

Intercropping intensities did not bring any significant variation in the nut production but in general increasing the intensity of intercropping from 40% to 60% decreased the number of nuts from 886 to 792 per palm. Post-experimental period provided a significantly higher number of nuts of 1082 per palm with a spacing of 2.7m x 3.6m compared to 913 per palm in 1.8m x 3.6m spacing.

IV.3.5. Effect of intercropping intensities and spacings of areca palm on the production of nuts

The data on the production of arecanuts as influenced by intercropping intensities at different spacings of areca palms are presented in Table IV.3.5.

The pre-experimental data on the production of arecanut from various spacings showed that significantly higher yields of 148 to 158 q/ha were obtained in the first three spacings compared to the last wider spacing of 3.6m x 3.6m (98.3 q/ha). During the experimental period, the first two lower spacings gave higher yields of 189 and 186 q/ha than that obtained with the wider spacings of turmeric and 40% intensity of cropping

Table IV.3.5. Weight of arecanut (q/ha) as influenced by intercropping intensities at varied levels of arecanut spacings

Treatments	Pre-experimental period			Experimental period			Post-experimental period		
	76-77	77-78	Mean	78-79	79-80	Mean	80-81	81-82	Mean
A. <u>Main plots</u>									
1. 1.8m x 3.6m	169.98	145.50	157.74*	231.79	141.98	188.88*	216.64	123.01	169.82
2. 2.7m x 2.7m	165.24	149.98	157.54*	217.62	155.51	186.57*	192.57	127.03	159.70
3. 2.7m x 3.6m	135.50	160.31	147.90	183.16	143.50	162.46	180.19	113.46	146.88
4. 3.6m x 3.6m	92.78	103.87	98.32*	135.28	101.25	118.27	118.42	82.46	100.40
B. <u>Sub plots</u> -Intercrops									
1. Turmeric	153.10	144.00	148.67	137.56	140.61	174.58	189.63	112.02	150.88
2. Sweet potato-cowpea	130.58	146.45	138.52	180.53	139.10	159.76	168.62	99.77	134.20
C. <u>Intensities</u>									
0	145.16	149.25	147.27	196.40	142.72	169.56	173.41	106.19	138.80
40%	133.84	149.25	141.55	193.89	147.79	170.61	191.27	122.79	167.02
60%	146.45	137.00	141.79	193.72	129.30	161.63	172.83	114.36	143.79
CD for main plots	17.03	55.78	36.41	-	-	-	28.38	-	-
CD for sub plots	-	-	-	-	-	-	-	-	-
CD for intensities	-	-	-	-	-	-	-	-	-
CV%	19.5	22.3	21.5	32.6	29.5	31.5	24.3	25.2	25.5

* Significant at 5%

fared better though there were no significant variations in any of the treatments. In general, intercropping under narrower spacings (1.8m x 3.6m and 2.7m x 3.6m) increased arecanut production when compared to other spacings and that approximateely 18 to 20% increase in nut production was observed from pre-experimental to post-experimental period under various spacings of areca palm.

A critical appraisal of the yield on hectare basis showed that the spacings of areca palm at 1.8m x 3.6m, 2.7m x 2.7m, 2.7m x 3.6m were on par and recorded significantly more yield when compared to 3.6m x 3.6m. However, yield differences between 2.7m x 3.6m and 3.6m x 3.6m spacings were insignificant. Neither intensities nor kinds of the intercrops could bring any significant change in per hectare yield of areca palms.

IV.4. Labour requirements and income from pure and intercropping systems

IV.4.1. Labour requirements of pure and intercropping systems of arecanut under varying plant densities and intercropping intensities

The data on the labour requirements of sole and intercropping syetems of arecanut under varying plant densities and intercropping intensities are given in Table IV.4.1.

The pure stand of arecanut under the four spacings/planting geometries as studied from the table was found to have a labour requirement of 725 mandays per hectare per year in the

Table IV.4.1. Labour requirements for pure and intercropping systems of arecanut/ha/year under varied plant densities and intercropping intensities

A. Labour requirements of sole crop of arecanut

Spacing	Requirements of labour	Requirements of Amount (Rs)
1. 1.8m x 3.6m	725	4,350
2. 2.7m x 2.7m	763	4,578
3. 2.7m x 3.6m	833	4,998
4. 3.6m x 3.6m	863	5,178

B. Labour requirements of intercropping system

Spacing	Intercropping intensities	Arecanut + turmeric		Arecanut + sweet potato + cowpea	
		Labour	Rs	Labour	Rs
1. 1.8m x 3.6m	40%	714	4,284	706	4,236
	60%	784	4,704	778	4,668
	Mean	749	4,494	742	4,452
2. 2.7m x 2.7m	40%	861	5,166	826	4,956
	60%	964	5,784	911	5,466
	Mean	912	5,475	868	5,208
3. 2.7m x 3.6m	40%	976	5,856	931	5,586
	60%	1106	6,636	1021	6,126
	Mean	1041	6,246	976	5,856
4. 3.6m x 3.6m	40%	1051	6,306	995	5,970
	60%	1207	7,242	1100	6,600
	Mean	1129	6,774	1047	6,285

narrow spacing of 1.8m x 3.6m to 863 mandays per hectare per year under the highest level of spacing of 3.6m x 3.6m. The total expenditure on labour charges worked out between Rs 4350 and Rs 5178 indicating that there could be a saving on the cost of labour by about Rs 825/ha/year, if the narrow spacing is adopted compared to the wider spacings.

The intercropping system of arecanut with turmeric under four levels of spacings and two intensities of intercropping indicated that the labour requirement was the least in the narrow spacing of 1.8m x 3.6m (714 and 784 at 40 and 60% intensities) and it increased with widening of the spacing reaching a maximum with 3.6m x 3.6m (Rs.1051 and Rs. 1207 at 40 and 60% intensity). The cost involved in meeting the labour charges was also found to be maximum at the spacing of 3.6m x 3.6m (Rs.6306 and Rs.7242 at 40 and 60% intensities) as against the minimum amount spent on labour charges with the spacing of 1.8m x 3.6m(Rs.4284 and Rs. 4704 at 40 and 60% intensities). It is thus seen that irrespective of the intensities of intercropping, there was a saving in labour requirement by 385 mandays costing Rs.2310 if the narrow spacing of 1.8m x 3.6m was adopted compared to the last level of spacing. Even the conventional spacing of 2.7m x 2.7m was found to be expensive of 163 mandays. Almost a similar trend was observed in arecanut, sweet potato-cowpea intercropping systems with a saving of Rs. 1830 on the labour cost from about 305 mandays when the spacing 1.8m x 3.6m was adopted compared to the last level of spacing.

IV.4.2. Income from main and intercrops in the intercropping system of arecanut as influenced by plant densities and intercropping intensities

The data on the income from the main crop arecanut and from the main and intercrops together in the intercropping system as influenced by plant densities of arecanut and intercropping intensities are presented in Table IV.4.2.

The income from the main crop arecanut was higher when turmeric was intercropped (Rs.27,008/ha) than that obtained when sweet potato-cowpea was intercropped (Rs.23,404/ha). The income was maximum in arecanut (Rs.33,540/ha) in the narrow spacing of 1.8m x 3.6m with turmeric as intercrop. Intercropping intensity of 40% with turmeric also provided higher income from arecanut. The data on the income from the main as well as intercrops indicated that arecanut turmeric intercropping was superior (Rs.30,240/ha) to arecanut sweet potato-cowpea combination (Rs.28,507/ha). Here again in arecant-turmeric, narrower spacings were more beneficial with 1.8m x 3.6m providing the maximum income of Rs 36,798/ha. Intercropping intensities did not bring any variation in the income.

The result of the second experiment entitled "Effects of four fertilizer levels to the intercrops of turmeric and sweet potato-cowpea in arecanut on the growth and yield attributes of the main and intercrops in maximising productivity and utilization of resources" are presented further following the sequences of 1) growth and yield attributes of intercrops, 2)

Table IV.4.2. Income from the main crop arecanut and from the main and intercrops in the intercropping system as influenced by plant densities of arecanut intercropping intensities

Levels of spacing	Income of arecanut only (Rs/ha) In turmeric	Income of arecanut only (Rs/ha) In sweet potato cowpea
A. Turmeric		
1. 1.8m x 3.6m	33,540	22,781
2. 2.7m x 2.7m	28,919	30,690
3. 2.7m x 3.6m	28,857	30,346
4. 3.6m x 3.6m	20,083	17,797
Mean	27,099	25,404
a) Control	26,914	26,162
b) 40% intensity	27,818	25,856
c) 60% intensity	26,566	24,193
Mean	27,099	25,403

	Income from Arecanut + Turmeric (Rs./ha)	Income from arecanut + sweet potato + cowpea (Rs./ha)
B. Sweet potato		
1. 1.8m x 3.6m	36,793	25,082
2. 2.7m x 2.7m	33,173	34,939
3. 2.7m x 3.6m	28,714	33,202
4. 3.6m x 3.6m	22,276	22,001
Mean	30,240	28,806
a) control	26,910	26,162
b) 40% intensity	31,834	26,007
c) 60% intensity	31,974	27,785
Mean	30,299	26,651

growth and yield attributes of main crop, 3) plant nutrition aspects of sole and intercrops, 4) income from inter, sole and main crops, and 5) utilization of land and labour resources.

IV.5. Growth and yield attributes of intercrops

IV.5.1. Effect of fertilizer levels on the number of functional leaves of turmeric and sweet potato

, The periodical observations on the effect of levels of fertilizers on the number of functional leaves in turmeric and sweet potato are presented in Fig. 6(a) and the mean data are given in Table IV.5.1.

The number of functional leaves in turmeric as studied from Fig. 6(a) both as an intercrop in arecanut as well as a sole crop in general, reached a maximum only after 120 days of growth, which more or less remained steady till 180 days from where it declined. The peak values of number of leaves ranged from 14.3. to 16.8 in intercrop and from 13.5 to 15.8 in sole crop under varied fertilizer levels. In sweet potato, production of functional leaves was rapid and early in life cycle of the crop irrespective of whether it was grown as an intercrop or sole crop. By about 60 days of growth, all the fertilizer treatments attained peak values with the highest level of fertilizers producing over 333 leaves/plant. In the intercrops, the peak values were reached at different periods in different fertilizer treatments with control reaching the peak in 90 days and the higher fertiliser levels reaching by 150 days

Table IV.5.1. Number of functional leaves produced by intercrops and sole crops of turmeric and sweet potato as influenced by fertilizer levels

S.No.	Crop	Fertilizer schedules (kg/ha) N	P_2O_5	K_2O	Intercrop 78-79	Intercrop 79-80	Intercrop Mean	Sole crop 78-79	Sole crop 79-80	Sole crop Mean
1.	Turmeric	0	0	0	13.46	11.66	12.56	13.80	16.33	15.10
2.	Turmeric	70	60	120	15.60	14.16	14.86	15.40	22.67	18.96
3.	Turmeric	140	120	240	16.10	14.16	15.13	14.78	21.67	18.06
4.	Turmeric	210	180	360	15.00	15.66	15.33	14.46	18.67	16.36
	Mean				15.04	13.91	14.30	14.61	19.83	17.12
	F. Test				NS	S	NS	NS	S	S
	CD				-	2.44	-	-	2.88	1.77
	CV%				15.65	8.80	10.22	16.39	7.27	5.19
5.	Sweet potato	0	0	0	231.6	146.6	189.3	238.7	165.3	201.6
6.	Sweet potato	70	50	70	217.2	170.0	194.0	302.3	198.3	250.0
7.	Sweet potato	140	100	140	205.3	185.0	195.3	235.0	193.7	214.3
8.	Sweet potato	210	150	210	210.5	158.7	184.3	333.6	202.7	268.0
	Mean				216.2	165.0	190.7	277.4	190.0	233.4
	F. Test				NS	NS	NS	NS	NS	S
	CD				-	-	-	-	-	57.9
	CV %				19.32	20.11	10.46	21.27	8.84	12.41

S = Significant at 5%

NS = Not significant

FIG.6 a. EFFECT OF FERTILIZER LEVELS ON THE LEAF PRODUCTION OF INTERCROPS AND SOLE CROPS OF TURMERIC AND SWEET POTATO DURING CROP GROWTH STAGES

FIG.6 b. EFFECT OF FERTILIZER LEVELS ON THE LEAF AREA OF INTERCROP AND SOLE CROPS OF TURMERIC AND SWEET POTATO DURING CROP GROWTH STAGES

1a. 1.8 x 3.6m 40% intensity of intercropping

1b. 1.8 x 3.6m 60% intensity of intercropping

2a. 2.7 x 2.7m 40% intensity of intercropping

2b. 2.7 x 2.7m 60% intensity of intercropping

3a. 2.7 x 3.6m 40% intensity of intercropping

3b. 2.7 x 3.6m 60% intensity of intercropping

4a. 3.6 x 3.6m 40% intensity of intercropping

4b. 3.6 x 3.6m 60% intensity of intercropping

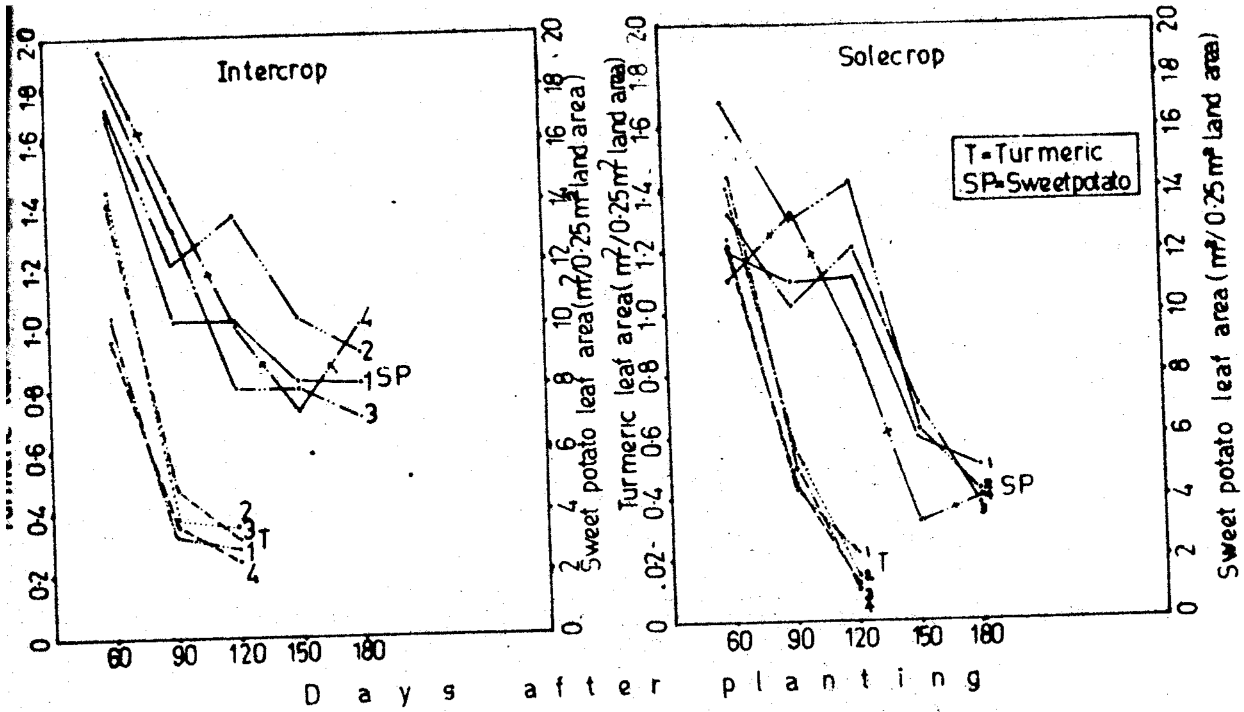

Intercrop
Solecrop
T=Turmeric
SP=Sweetpotato
Sweet potato leaf area (m²/0.25 m² land area)
Turmeric leaf area (m²/0.25 m² land area)
SP
T
60
90
120
150
180
D a y s a f t e r p l a n t i n g

FIG. 6 b.

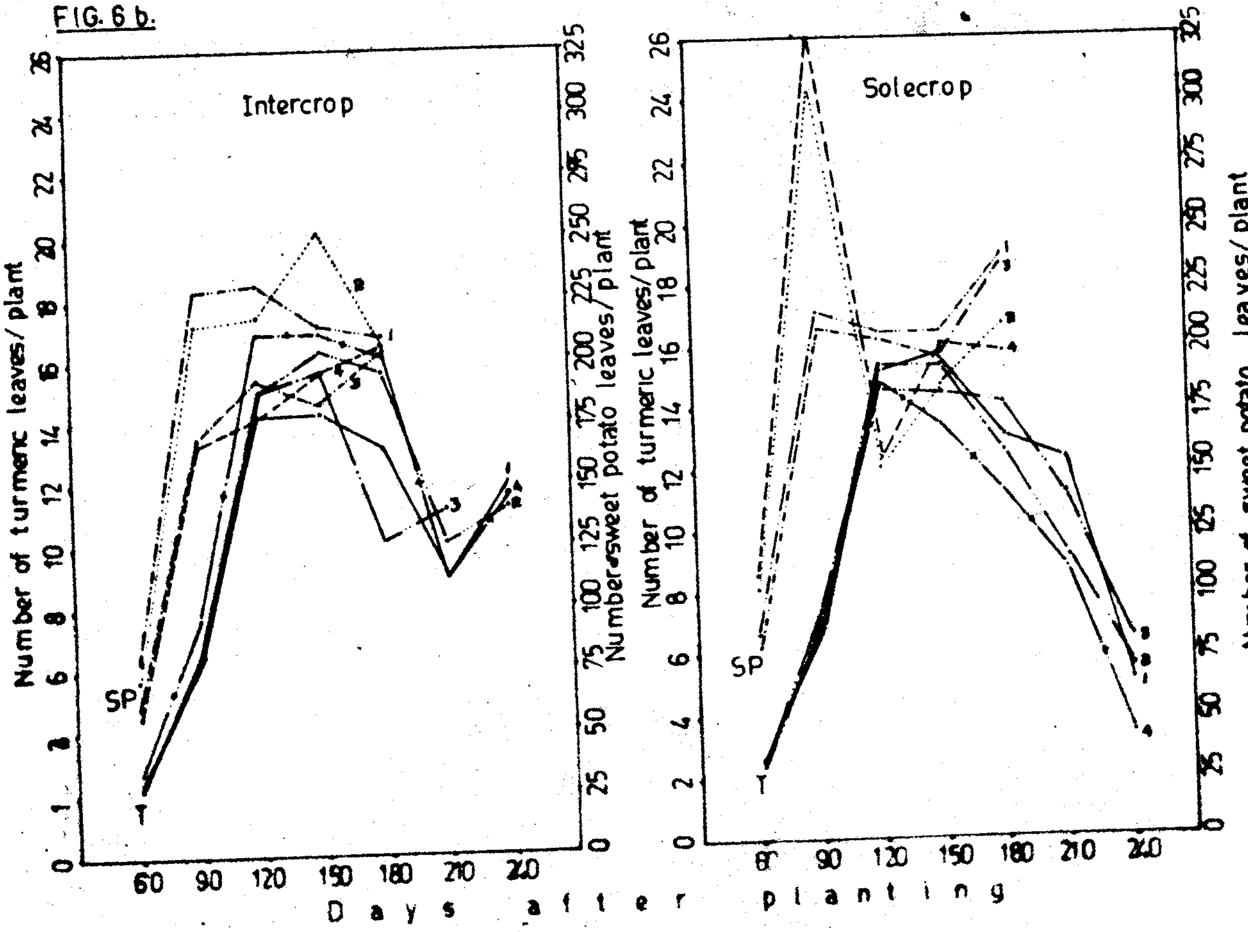

Intercrop
Solecrop
Number of turmeric leaves/plant
Number of sweet potato leaves/plant
SP
T
60
90
120
150
180
210
240
D a y s a f t e r p l a n t i n g

FIG. 6 a.

of growth. At their peak production, there was a trend of higher levels producing lower number of leaves (205 to 210) compared to control (231) and the first level of fertilizer (259).

During 1978-79, levels of fertilizers did not have any significant impact on the production of functional leaves in turmeric, either as an intercrop or as a sole crop. During 1979-80, intercropping of turmeric was found to be beneficial when properly fertilized. Fertilizer levels were superior to control although there were no significant differences among the levels of fertilizers. The mean data showed a non-significant increase of functional leaves (around 15 leaves/plant) in intercropped turmeric with the increase in fertilizer doses over control (11.9 leaves/plant). The sole crop of turmeric on the other hand produced significantly higher number of functional leaves at first and second levels of fertilizers (18.96 and 18.06) when compared to control (15.10). The highest level of fertilizer (16.36) was on par with control as well as with the second level of fertilizer.

Under sweet potato intercropping system, fertilizer levels did not influence the number of functional leaves of sweet potato either as a sole or as an intercrop in both the years. However, there appeared to be a marginal benefit from higher doses of fertilizers in some cases with an increasing trend with the increase in levels. The mean data indicated that the number of functional leaves in the intercrop sweet potato increased with the increase in the fertilizer schedules upto second level and thereafter it declined, whereas in the sole crop there was a significant increase in the number of functional leaves (268) over the control (201.6) though there were no significant differences amongst control and the first two levels of fertilizers.

IV.5.2. Effect of fertilizer levels on the leaf area of turmeric and sweet potato

The data on the periodical observations on the effect of fertilizer levels on the leaf area production by turmeric and sweet potato are presented in Fig.6(b) and the mean yearly data are given in Table IV.5.2.

From Fig.6(b) , it is seen that there were no marked differences in leaf area as expressed by either sole or intercrops of turmeric under varied fertilizer levels. Leaf area declined in both the cases with time from the first month itself. Higher levels of fertilizers appeared to be beneficial to intercrop in the initial stages.

In sweet potato, sole crop exhibited better leaf area with no marked variation between fertilizer treatments while higher dose of fertilizers produced lower leaf area in the intercrop.

Mean data showed that the leaf area did not differ significantly due to application of fertilizers, when turmeric was grown either as a sole crop or when it was intercropped in arecanut during both the years. In general, mean data showed that increasing levels of NPK fertilizers could marginally increase

Table IV.5.2. Leaf area of intercrops and sole crops of turmeric and sweet potato as influenced by fertilizer levels ($m^2/0.25\ m^2$)

Treatments					Intercrop			Sole crop		
S.No.	Crop	Fertilizer schedules (kg/ha)			78-79	79-80	Mean	78-79	79-80	Mean
		N	P_2O_5	K_2O						
1.	Turmeric	0	0	0	1.73	2.00	1.86	1.25	1.46	1.41
2.	Turmeric	70	60	120	1.73	1.33	1.53	1.71	1.76	1.73
3.	Turmeric	140	120	240	1.97	2.10	1.99	1.36	1.45	1.40
4.	Turmeric	210	180	360	2.55	2.01	2.28	1.30	1.65	1.47
	Mean				1.99	1.86	-	1.40	1.58	-
	F. Test				NS	NS	NS	NS	NS	NS
	CD				-	-	-	-	-	-
	CV %				35.53	16.12	19.58	25.75	8.95	17.87
5.	Sweet potato	0	0	0	10.38	9.98	10.18	10.01	11.85	10.93
6.	Sweet potato	70	50	70	14.49	9.05	11.76	14.25	12.33	13.30
7.	Sweet potato	140	100	140	14.07	10.55	12.28	14.32	13.16	13.74
8.	Sweet potato	210	150	210	9.61	9.56	9.58	12.38	13.83	13.10
	Mean				12.13	9.78	-	12.74	12.79	-
	F. Test				NS	NS	NS	NS	NS	NS
	CD				-	-	-	-	-	-
	CV %				30.40	10.37	12.21	37.21	11.02	20.56

NS = Not significant

the leaf area of turmeric in intercropping system.

The leaf area production both in sole and intercrops of sweet potato was almost the same and did not show any significant differences due to different levels of fertilisers during 1978-79. However, during 1979-80, sole crop of sweet potato tended to record a higher leaf area compared to intercrop. From the mean data, it is observed that the leaf area increased marginally upto 140 N, 100 P_2O_5 and 140 K_2O kg/ha in intercrop and sole crop and thereafter it declined. However, the decline was maximum in intercrop when compared to sole crop.

IV.5.3. Effect of fertilizer levels on Leaf Area Ratio (LAR), Relative Leaf Growth Rate (RLGR), Relative Growth Rate (RGR) and Net Assimilation Ratio (NAR) on turmeric and sweet potato as sole and intercrops in arecanut

The data on LAR, RLGR, RGR and NAR of sole and intercrops of turmeric are presented in Fig. 7 and Table IV.5.3.

In turmeric, LAR was found to be higher (0.40 to 0.96) in the intercrop by about three times that of sole crop (0.016 to 0.030) irrespective of the fertilizer levels. Leaf Area Ratio was highest under the fertilizer dose of 140 N, 120 P_2O_5, 240 K_2O/kg/ha both under sole crop (0.030) as well as in intercrop (0.096). The next dose of fertilizer brought down the LAR considerably in both the systems. In case of sweet potato also the LAR values were nearly two to three times higher (0.069 to 0.089) in the intercrop than under sole crop (0.033 to 0.038). The sole crop did not have any marked variation in LAR values

Table IV.5.3. Effect of fertiliser levels on the growth attributes of sole and intercrops of turmeric and sweet potato

Treatment					Intercrop				Sole crop			
Sl. No.	Crop	Fertiliser schedule (kg/ha)			NAR (g/ m^2/ day)	LAR (cm^2/ g)	RGR (g/g/ day)	RLGR (g/g/ day)	NAR (g/m^2/ day)	LAR (cm^2/ g)	RGR (g/g/ day)	RLGR (g/g/ day
		N	P_2O_5	K_2O								
1.	Turmeric	0	0	0	3.43	0.044	15.40	8.88	8.892	0.025	22.57	6.38
2.	Turmeric	70	60	120	3.82	0.040	15.43	8.22	8.736	0.023	20.11	5.86
3.	Turmeric	140	120	240	1.80	0.096	17.32	6.20	6.610	0.030	20.00	6.21
4.	Turmeric	210	180	360	2.85	0.078	16.12	3.68	7.760	0.016	26.28	5.80
5.	Sweet potato	0	0	0	3.82	0.069	26.50	2.71	6.350	0.035	22.27	9.88
6.	Sweet potato	70	50	70	3.05	0.089	27.17	4.58	5.836	0.038	22.32	9.60
7.	Sweet potato	140	100	140	3.11	0.081	25.06	4.51	6.561	0.036	23.61	9.40
8.	Sweet potato	210	150	210	2.85	0.073	20.93	5.66	7.478	0.033	25.06	8.81

NAR = Net Assimilation Rate
LAR = Leaf Area Ratio
RGR = Relative Growth Rate
RLGR = Relative Leaf Growth Rate

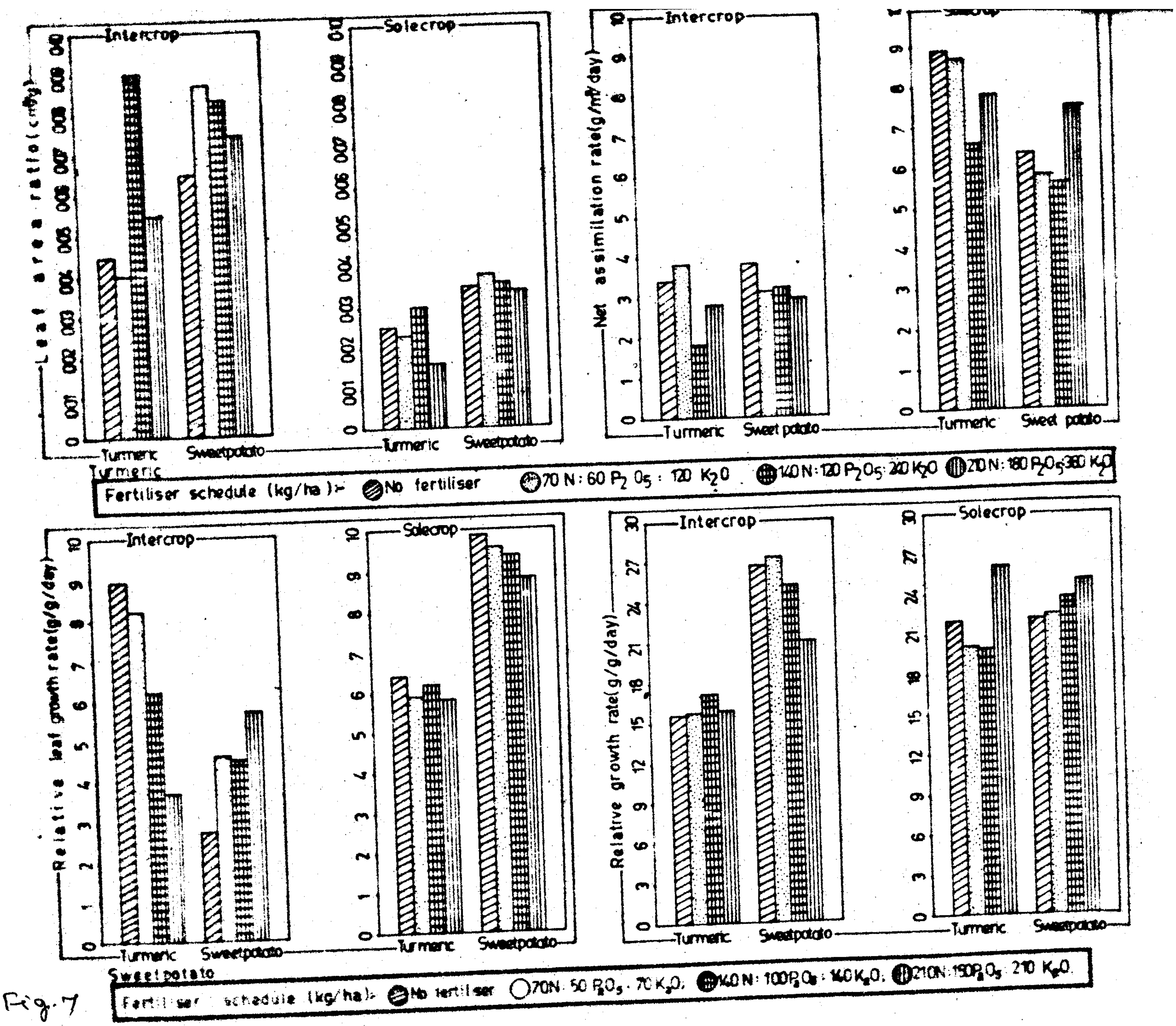
FIG.7 EFFECT OF FERTILIZER LEVELS ON THE GROWTH ATTRIBUTES LIKE NAR, LAR, RGR AND RLGR OF TURMERIC AND SWEET POTATO AS INTER AND SOLE CROPS

1. NAR - NET ASSIMILATION RATE(g/m^2/day)

2. LAR - LEAF AREA RATIO(cm^2/g)

3. RGR - RELATIVE GROWTH RATE(g/g/day)

4. RLGR - RELATIVE LEAF GROWTH RATE(g/g/day)



Leaf area ratio (cm²/g)
Intercrop
Solecrop
Turmeric
Sweetpotato
Net assimilation rate (g/m²/day)
Sweet potato
Fertiliser schedule (kg/ha):- No fertiliser 70 N : 60 P2 O5 : 120 K2O 140 N : 120 P2O5 : 240 K2O 210 N : 180 P2O5 : 360 K2O
Relative leaf growth rate (g/g/day)
Relative growth rate (g/g/day)
Fertiliser schedule (kg/ha):- No fertiliser 70 N : 50 P2O5 : 70 K2O; 140 N : 100 P2O5 : 140 K2O; 210 N : 150 P2O5 : 210 K2O.

Fig. 7

among the fertilizer treatments. In the intercrop, LAR was found to be higher under 70N, 60 P_2O_5, 120 K_2O kg/ha (0.089) and 140 N, 120 P_2O_5, 240 K_2O kg/ha (0.081). The RLGR in turmeric ranged from 5.80 to 6.38 in sole crop compared to 3.68 to 8.88 in the intercrop with the lower dose of fertilizers providing higher values of RLGR particularly the intercrop. Relative Leaf Growth Rate was found to decline gradually with the increasing levels of fertilizers (8.83, 8.22, 6.20 and 3.68) in the intercrop. The RLGR in sweet potato ranged from 9.40 to 9.88 in the sole crop and from 2.71 to 5.66 in the intercrop. While there was no marked difference in the values of RLGR of sole crop, there was a trend of increased values of RLGR (2.71, 4.58, 4.51 and 5.66) with the increasing levels of fertilizers. The RGR in turmeric was higher in sole crop compared to the intercrop. Highest level of fertilizer (210 N, 180 P_2O_5, 360 K_2O kg/ha) recorded a RGR value of 26.3 compared to the values of 20.0 to 22.5 in other treatments with the sole crop. The RGR values in the intercrop ranged from 15.40 in control to 17.32 with 140 N, 120 P_2O_5, 240 K_2O kg/ha. In sweet potato, the sole crop recorded a range of RGR value of 22.27 to 25.06 while in the intercrop the highest dose of fertilizer provided an RGR of 20.93 compared to 25.60 to 27.17 in other treatments. Net Assimilation Ratio in the sole crop of turmeric was nearly two to three times (6.62 to 8.89) that of the intercrop (1.79 to 3.82). In both the sole and intercrops, there was a decline in NAR values at the last two higher levels of fertilizers (from 8.89 and 8.74 to 6.61 and 7.76) in sole crop and from 3.43 and 3.82 to 1.79 and 2.84 in intercrop). In case of sweet potato, the NAR values in the sole crop were nearly two times those of the intercrops. Fertilizer levels to the sole crop did not show much variation from the control (6.35) except for a small change in the highest level (7.47). There was a gradual declining trend in NAR values from 3.82 to 2.85 with the increasing levels of fertilizers to the intercrop.

IV.5.4. Effect of fertilizer levels on the number of tillers/branches per plant in turmeric and sweet potato

The data on the periodical obervations on the production of tillers/branches in turmeric and sweet potato as influenced by different levels of fertilizers are presented in Fig.8(a) and the mean yearly data are given in Table IV.5.4.

From Fig. 8(a), it is seen that there were no marked differences in the pattern of production of tillers in turmeric when grown either as a sole crop or an intercrop in arecanut Intensity of tillering was found to be low in the first two months with peaks being steady for about next three months with 3-4 tillers/plant in most of the treatments. In sweet potato, branching was high in sole crop reaching high values early by about 60 days which were maintained so in most treatments. In intercropping, the peak values were low and reached gradually by about the end of the growth period of the crop.

From the table, it is seen that the production of tillers

Table IV.5.4. Number of tillers/branches produced by the inter and sole crops of turmeric and sweet potato as influenced by fertilizer levels.

Treatments					Intercrop			Sole crop		
Sl. No.	Crop	Fertilizer Schedules (kg/ha)			78-79	79-80	Mean	78-79	79-80	Mean
		N	P_2O_5	K_2O						
1.	Turmeric	0	0	0	3.20	3.73	3.46	3.80	4.86	4.33
2.	Turmeric	70	60	120	3.06	4.80	3.93	3.60	4.46	4.03
3.	Turmeric	140	120	240	4.53	4.60	4.56	4.00	5.33	4.70
4.	Turmeric	210	180	360	3.40	4.73	4.06	3.46	4.46	3.96
	Mean				3.54	4.46	-	3.73	4.77	-
	F. Test				NS	S	S	NS	NS	NS
	CD				-	0.48	0.83	-	-	-
	CV %				20.5	5.01	12.75	32.61	13.39	23.00
5.	Sweet potato	0	0	0	17.46	13.8	15.7	22.3	20.0	21.1
6.	Sweet potato	70	50	70	17.9	16.4	17.1	24.3	21.7	23.0
7.	Sweet potato	140	100	140	14.5	15.1	14.8	21.8	19.3	20.5
8.	Sweet potato	210	150	210	16.6	13.9	15.2	23.7	19.7	21.7
	Mean				16.6	14.8	-	23.0	20.2	-
	F.Test				NS	NS	NS	NS	S	NS
	CD				-	-	-	-	2.4	-
	CV %				21.2	12.5	12.4	20.3	5.8	13.5

S = Significant at 5% NS = Not significant

per plant did not differ when turmeric was grown either as an intercrop or a sole crop during the year 1978-79. During 1979-80, turmeric when intercropped produced significantly higher number of tillers at all levels of fertilizers (4.6 to 4.8 tillers/plant) compared to control (3.73). However, there were no differences among the fertilizer levels. The production of tillers in the intercrop was significantly higher (4.36) at 140 N, 120 P_2O_5, 240 K_2O kg/ha compared to control when the mean data for two years were considered.

Sweet potato did not exhibit any improvement in branching with the increase in the level of fertilizers when grown either as an intercrop or as a sole crop during the year 1978-79. However, branching was higher in sole crop when compared to intercrop. During 1979-80, while there was no significant difference in the branching caused due to fertilisers in the intercrop sweet potato, sole crop at 70N, 50 P_2O_5, 70 K_2O kg/ha proved significantly superior to the next higher level of fertilizer of 140 N, 100 P_2O_5 and 140 K_2O kg/ha. The mean of the two years did not indicate any significant differences amongst the treatments.

IV.5.5. Effect of fertilizer levels on the biomass production of turmeric, sweet potato and cowpea in areca plantation

The data on periodical observations on the biomass production of turmeric, sweet potato and cowpea in arecanut either as sole or as intercrops in response to varied fertilizer levels are presented in Fig. 8(b) and the annual mean data are presented in Table IV.5.5.

The pattern of biomass production as influenced by fertilizer levels was found to vary between sole and intercrops of turmeric as seen from Fig.8(b). While the biomass production in all the treatments in the sole crop reached fairly high values of over 175 g/m^2 by 120 days, values of 140 to 151 g/m^2 were reached by 150 days in the control and the first two levels of fertilizers and the highest level of fertilizer reached its peak of just 125 g/m^2 only by 180 days in the intercropped turmeric.

In sweet potato-cowpea rotation in the open, high values of biomass production were observed from about 90 days which were maintained at high levels till the end of the crop growth period, irrespective of fertilizer levels. In the intercropping system, the biomass production declined to nearly half the peak values in most cases at the end of the crop growth. These final values were nearly one third the values obtained under open area.

Turmeric either as a sole crop or as an intercrop in arecanut did not show any significant differences to varying levels of fertilizers during 1978-79. However, during 1979-80, turmeric when intercropped produced significantly higher amount of biomass of 10,400 kg/ha (Plate.8) at fertilizer level of 140 N, 120 P_2O_5 and 240 K_2O kg/ha compared to 8,000 kg/ha(Plate.9)

Table IV.5.5. Biomass production of inter and sole crops of turmeric and sweet potato as influenced by fertilizer levels (kg/ha)

Treatments					Intercrop			Sole crop		
Sl. No.	Crop	Fertilizer schedules (kg/ha)			78-79	79-80	Mean	78-79	79-80	Mean
		N	P_2O_5	K_2O						
1.	Turmeric	0	0	0	8093	9333	8713	7480	9533	8507
2.	Turmeric	70	60	120	7840	8000	7920	7466	8973	8220
3.	Turmeric	140	120	240	7827	10400	9113	8146	9693	8920
4.	Turmeric	210	180	360	8813	9600	9206	8200	11133	9666
	Mean				8143	9333	-	7823	9833	-
	F. Test				NS	S	NS	NS	NS	NS
	CD				-	2114	-	-	-	-
	CV %				26.73	11.33	8.12	16.89	21.92	16.83
5.	Sweet potato	0	0	0	14920	12600	13760	25640	27466	26553
6.	Sweet potato	70	50	70	13280	11933	12606	29253	26133	27693
7.	Sweet potato	140	100	140	18120	14066	16093	24400	30400	27400
8.	Sweet potato	210	150	210	16053	12933	14493	28520	30000	29260
	Mean				15705	12883	-	26953	28499	-
	F. Test				NS	S	NS	NS	NS	NS
	CD				-	2739	-	-	-	-
	CV %				30.63	10.63	14.25	27.20	7.93	4.42

S = Significant at 5% NS = Not significant

PLATE No. 8 TURMERIC GROWN WITH A FERTILIZER LEVEL OF 140N, 120 P_2O_5 AND 240 K_2O kg per Ha.

PLATE No. 9 TURMERIC GROWN WITH A FERTILIZER LEVEL OF 70N, 60 P_2O_5 AND 120 K_2O kg per Ha.

Plate 8

Plate 9

produced by the lower level of 70 N, 60 P_2O_5 and 120 K_2O kg/ha. There were no differences in biomass production of turmeric amongst the rest of the treatments. The mean data for 1978-80, showed no significant differences either as a sole crop or as an intercrop though there was an increasing trend in biomass production with the increase in the levels of fertilizer schedule particularly at higher levels.

Under sweet potato-cowpea rotation, the differences due to various levels of fertilizers both in sole as well as in intercropping systems did not bring any significant differences in biomass production. However, higher levels of fertilizers provided slightly higher yields in many cases. The mean data for the years did not show any significant differences in biomass production in the sweet potato-cowpea, either as an intercrop or sole crop. In general, highest level of fertilizers recorded maximum amount of biomass (29260 kg/ha) when compared to control (26553 kg/ha).

IV.5.6. Effect of fertilizer levels on the number of fingers and tubers produced in turmeric and sweet potato

The data on the number of fingers and tubers produced by turmeric and sweet potato respectively are presented in Table IV.5.6.

From the table, it is seen that the fertilizers did not show any significant effect on the number of fingers produced by turmeric either as an intercrop or as a sole crop. In general, turmeric fingers for five plants decreased from 1978-79 to 1979-80. Sole crop of turmeric exhibited a decreasing trend

Table IV.5.6. Number of tubers (/ plants) of inter and sole crops of turmeric and sweet potato as influenced by fertilizer levels

Sl. No.	Crop	Fertilizer schedules (kg/ha) N	P_2O_5	K_2O	Intercrop 78-79	Intercrop 79-80	Intercrop Mean	Sole crop 78-79	Sole crop 79-80	Sole crop Mean
1.	Turmeric	0	0	0	113	68	90	102	75	88
2.	Turmeric	70	60	120	126	50	88	104	84	94
3.	Turmeric	140	120	240	106	59	83	98	93	95
4.	Turmeric	210	180	360	129	53	92	64	89	76
	Mean				118	57	-	92	85	-
	F. Test				NS	NS	NS	NS	NS	NS
	CD				-	-	-	-	-	-
	CV %				22.61	14.49	18.65	33.68	18.88	18.28
5.	Sweet potato	0	0	0	8	6	7	29	19	24
6.	Sweet potato	70	50	70	6	5	6	11	23	17
7.	Sweet potato	140	100	140	8	5	6	29	19	24
8.	Sweet potato	210	150	210	8	7	7	26	22	24
	Mean				7.5	6	-	24	21	-
	F. Test				NS	NS	NS	S	NS	NS
	CD				-	-	-	16	-	-
	CV %				3.48	42.30	30.17	33.24	19.08	25.84

S = Significant at 5%   NS = Not significant

with the increase in the fertilizer schedules during 1978-79 whereas during 1979-80 an inconsistent trend was observed. Sudden decline in the number of tubers at the highest level of fertilizers (76) was observed compared to the first level of fertilizer (94).

Sweet potato as an intercrop did not respond significantly to the differential fertilizer schedules from the point of tuber production. An inconsistent higher number of tubers (29) in control and in the second level of fertilizer 140 N, 100 P_2O_5 and 140 K_2O kg/ha (29) was observed compared to the first level of fertilizer (11). Mean data indicated that heavy fertilization was not helpful in increasing the number of tubers per plant either in sole crop or in intercrop.

IV.5.7. Effect of fertilizer levels on the volume of tubers of turmeric and sweet potato

Data pertaining to the volume of tubers of turmeric and sweet potato respectively are given in Table IV.5.7.

Application of fertilizers did not bring any differences in the volume and on the production of tuber by turmeric as an intercrop in arecanut during both the years. In general, increasing levels of fertilizers had a negative trend in tuberisation. The sole crop, however, responded to fertilization. During 1978-79, a dose of 70 N, 60 P_2O_5, 120 K_2O kg/ha was significantly superior to the highest level of fertilization while during 1979-80, as well as from the mean data of two years, a

Table IV.5.7. Volume of tubers of intercrops and sole crops of turmeric and sweet potato as influenced by fertilizer levels (ml)

Treatments					Intercrop			Sole crop		
Sl. No.	Crop	Fertilizer schedules (kg/ha)			78-79	79-80	Mean	78-79	79-80	Mean
		N	P_2O_5	K_2O						
1.	Turmeric	0	0	0	1333	900	1116	1383	1238	1311
2.	Turmeric	70	60	120	1653	657	1155	1795	1546	1670
3.	Turmeric	140	120	240	1266	1110	1188	1687	2008	1847
4.	Turmeric	210	180	360	1408	825	1116	763	1735	1249
	Mean				1415	873	-	1407	1632	-
	F. Test				NS	S	NS	S	S	S
	CD				-	891	-	977	591	446
	CV %				29.16	51.10	22.85	34.78	18.15	15.10
5.	Sweet potato	0	0	0	1183	356	770	4080	1437	2758
6.	Sweet potato	70	50	70	243	123	183	3626	1523	2575
7.	Sweet potato	140	100	140	103	220	162	4350	1220	2785
8.	Sweet potato	210	150	210	346	193	270	2806	1676	2241
	Mean				469	223	-	3515	1464	-
	F. Test				NS	NS	NS	NS	NS	NS
	CD				-	-	-	-	-	-
	CV %				14.39	16.48	13.29	32.95	28.79	25.47

S = Significant at 5% NS = Not significant

dose of 140 N, 120 P_2O_5, 240 K_2O kg/ha was found to be significantly superior to control. This dose was also superior to the highest level of fertilization from the mean data of two years. In general, the volume of tubers was more in sole crop when compared to its intercrop.

Tuber volume of sweet potato did not show any significant trend either as a sole crop or as an intercrop. Mean data showed that fertilizer application had a negative trend on the volume of tubers when grown as an intercrop. However, sole crop of sweet potato did not exhibit any trend in this character. It was noticed that the sole crop of sweet potato produced stout tubers compared to those of its counterpart of intercrop and that the volume of tubers was four to ten times greater in sole crop than in intercrop.

IV.5.8. Effect of fertilizer levels on the weight of tubers(kg) of turmeric and sweet potato

The data on the weight of tubers of turmeric and sweet potato respectively are given in Table IV.5.8.

The number of tubers produced by turmeric either as sole crop or intercrop did not show any definite trend in the differences due to fertilizers in both the years. However, the cumulative effect at the end of two years indicated that a fertilizer level of 140 N, 120 P_2O_5 and 240 K_2O kg/ha was significantly superior to control and the highest level of fertilizers under sole cropping system. This is corroborated by the fact that the sole

Table IV.5.8. Weight of tubers of intercrops and sole crops of turmeric and sweet potato as influenced by fertilizer levels (kg/5 plants)

Treatments					Intercrop			Sole crop		
Sl. No.	Crop	Fertilizer schedules (kg/ha)			78-79	79-80	Mean	78-79	79-80	Mean
		N	P_2O_5	K_2O						
1.	Turmeric	0	0	0	1.43	1.09	1.26	1.35	1.28	1.32
2.	Turmeric	70	60	120	1.76	0.68	1.22	1.80	1.70	1.72
3.	Turmeric	140	120	240	1.38	1.06	1.22	1.80	2.10	1.97
4.	Turmeric	210	180	360	1.51	0.90	1.21	0.77	1.80	1.30
	Mean				1.52	0.93	-	1.71	1.72	-
	F. Test				NS	NS	NS	NS	NS	S
	CD				-	-	-	-	-	0.59
	CV %				28.97	55.32	26.47	39.55	19.16	29.35
5.	Sweet potato	0	0	0	0.67	0.22	0.45	4.30	1.55	2.92
6.	Sweet potato	70	50	70	0.39	0.37	0.38	2.39	1.56	2.00
7.	Sweet potato	140	100	140	0.23	0.27	0.25	4.80	1.28	3.04
8.	Sweet potato	210	150	210	0.45	0.27	0.37	4.36	1.76	3.06
	Mean				0.43	0.28	-	3.96	1.53	-
	F. Test				NS	NS	NS	S	NS	NS
	CD				-	-	-	2.40	-	-
	CV %				26.20	24.23	27.83	30.38	25.87	28.01

S = Significant at 5%   NS = Not significant

crop of turmeric in general recorded more weight at first and second levels of fertilizers in both the years. The maximum weight recorded was 1.97 kg at the second level of fertilizer compared to 1.32 and 1.30 kg in the control and the highest fertilizer level treatments.

The data indicated that intercropping of sweet potato in arecanut had an adverse effect on the tuber weight with a reduction upto 10 times the weight obtained in the sole crop in many instances. Fertilizer levels did not effect any improvement in tuber weight under intercropping situation. Even under sole cropping, fertilizers did not very much influence the tuber weight of sweet potato except at 140 N, 100 P_2O_5 and 140 K_2O kg/ha which was superior to the lower dose of 70 N, 50 P_2O_5 and 70 K_2O kg/ha during 1978-79. Mean data showed a general inconsistent decline of tuber weight over control.

IV.5.9. Effect of fertilizer levels on the yields of turmeric and sweet potato intercrops

The data on the yield of intercrops turmeric, sweet potato as influenced by fertilizer levels to intercrops are given in Table IV.5.9.

Application of fertilizers to turmeric when grown as sole crop or intercrop in arecanut did not have any significant impact on turmeric yield during 1978-79.

During 1979-80, fertilizer application had a negative impact on the yield of turmeric in both the systems of cropping. Highest

Table IV.5.9. Effect of fertilizer levels on the yields of intercrops of turmeric and sweet potato in arecanut (kg/ha)

Treatments					1978-79		1979-80		Mean	
S.No.	Crop	Fertilizer schedules (kg/ha)			IC	SC	IC	SC	IC	SC
		N	P_2O_5	K_2O						
1.	Turmeric	0	0	0	2840	6766	2073	10233	2437	8500
2.	Turmeric	70	60	120	2747	7933	2180	6633	2463	7283
3.	Turmeric	140	120	240	3147	6767	1987	7733	2567	7250
4.	Turmeric	210	180	360	3087	6500	1547	5333	2317	5900
	Mean				2955	6991	1947	7483	-	-
	F. Test				NS	NS	S	S	NS	S
	CD				-	-	425	3776	-	2365
	CV %				11.84	18.62	10.93	25.25	8.42	16.36
5.	Sweet potato	0	0	0	5147	17883	2985	16333	4066	17108
6.	Sweet potato	70	50	70	1650	14843	1011	15833	1331	15338
7.	Sweet potato	140	100	140	1527	19730	981	15833	1239	14782
8.	Sweet potato	210	150	210	1593	18496	899	17667	1246	18082
	Mean				2479	17738	1469	16416	-	-
	F.Test				NS	NS	S	NS	S	NS
	CD				-	-	686	-	1638	-
	CV %				63.32	32.65	23.37	6.86	41.61	16.86

IC = Intercrop SC = Sole Crop

S = Significant at 5% NS = Not significant

level of fertilizers significantly brought down the yield of intercrop turmeric (1547 kg/ha)(Plate.10) and sole crop of turmeric (5333 kg/ha) from their respective controls (2073 kg (Plate.10) and 10233 kg/ha). However, the yields of turmeric at the first two levels of fertilizer schedule recorded significantly higher than their third level in the intercropping system only. No significant variations amongst the treatments were observed in the mean values of the intercropping system. However, a negative trend was observed in the sole cropping system only where the highest level of fertilizers recorded 5900 kg/ha when compared to its control (8500 kg/ha).

Intercropping sweet potato in arecanut with different levels of fertilizers had a significant effect on the yield of tubers only in the second year of cropping. Highest yield of 2985 kg/ha (Plate.12) was obtained with no fertilizers in the intercropping system which was significantly superior to all other fertilizer treatments. Fertilization did not have any influence on the sole cropping system. Mean data showed that all levels of fertilizers substantially brought down the tuber yields (1331 to 1239 kg/ha) (Plate.13) when compared to control (4066 kg/ha) when grown as intercrops. As a sole crop, sweet potato did not respond to applied fertilizers significantly throughout the period of study.

IV.5.10. Residual effect of fertilizers applied to sweet potato on the grain yield of cowpea in sweet potato-cowpea intercrop rotation in arecanut

The data on the grain yield of cowpea as influenced by the

PLATE No. 10 TURMERIC GROWN WITHOUT FERTILIZERS

PLATE No. 11 TURMERIC GROWN WITH A FERTILIZER LEVEL OF 210 N, 180 P_2O_5 AND 360 K_2O kg per Ha.

Plate 10

Plate 11

PLATE No. 12 SWEET POTATO GROWN WITHOUT FERTILIZERS

PLATE No. 13 SWEET POTATO GROWN WITH A FERTILIZERS LEVEL OF 140N, 150 P_2O_5 AND 210 K_2O kg. per Ha.

Plate 12

Plate 13

residual effect of fertilizers applied to sweet potato in arecanut intercropped with sweet potato-cowpea rotation are presented in Table IV.5.10.

Cowpea yield data showed that residual effect of fertilizers to sweet potato did not have any significant impact on the production of grain yield during both the years of study though there was a general increase in the yield of cowpea with the increase in the fertilizer levels to the previous crop of sweet potato. The mean data indicated yield increases from 1302 kg in control to 1584 kg/ha with 140 N, 100 P_2O_5, 140 K_2O kg/ha in the intercropping system while it was 1868 kg in control and 2239 kg/ha at the same fertilizer level in the sole cropping system.

IV.5.11. Effect of fertilizer levels on the shoot weight of sweet potato

The data pertaining to shoot weight of sweet potato both as an intercrop and as a sole crop are presented in Table IV.5.11.

Application of fertilizers to sweet potato when intercropped in arecanut brought significant variation among the treatment means with respect to shoot weight. Though application of fertilizers in general, showed an increasing trend with the increase in level of fertilization, the highest level of fertilization alone (800 q/ha) could establish significant difference with control (588 q/ha) during 1978-79. Fertilization to sole crop did not bring any significant differences among the levels of fertilizer

Table IV.5.10. Grain yield of cowpea as an intercrop and a sole crop as influenced by residual effect of fertilizers to sweet potato (kg/ha)

S.No.	Crop	Fertilizer schedules (kg/ha) N	P_2O_5	K_2O	1978-79 IC	1978-79 SC	1979-80 IC	1979-80 SC	Mean IC	Mean SC
1.	Sweet potato-cowpea	0	0	0	1367	1919	1238	1818	1302	1868
2.	Sweet potato-cowpea	70	50	70	1493	2308	1271	2142	1382	2225
3.	Sweet potato-cowpea	140	100	140	1690	2451	1478	2148	1584	2299
4.	Sweet potato-cowpea	210	150	210	1645	2516	1326	2055	1485	2285
	Mean				1549	2296	1328	2048	-	-
	F. Test				NS	NS	NS	NS	NS	NS
	CD				-	-	-	-	-	-
	CV %				27.05	18.36	26.54	11.81	26.90	15.12

IC = Intercrop SC = Sole crop

NS = Not significant

Table IV.5.11. Shoot weight of sweet potato as an intercrop and a sole crop as influenced by fertilizer levels to sweet potato (q/ha)

S.No.	Treatments: Crop	Fertilizer schedules (kg/ha): N	P_2O_5	K_2O	1978–79: IC	1978–79: SC	1979–80: IC	1979–80: SC	Mean: IC	Mean: SC
1.	Sweet potato	0	0	0	588	530	471	525	529	527
2.	Sweet potato	70	50	70	704	483	512	574	608	526
3.	Sweet potato	140	100	140	706	448	562	754	633	601
4.	Sweet potato	210	150	210	800	498	544	638	672	568
	Mean				700	490	522	623	-	-
	F. Test				S	NS	NS	NS	S	NS
	CD				121	-	-	-	124	-
	CV %				18.70	28.13	13.16	30.80	10.16	26.47

S = Significant at 5% NS = Not significant

application. During 1979-80, the differences did not show any significant trend when grown as an intercrop. The sole crop responded well to all levels of fertilizers with increasing levels increasing the shoot weight of sweet potato over control. Highest shoot weight of 754 q/ha was obtained at a dose of 140 N, 100 P_2O_5 and 140 K_2O kg/ha compared to control with 525 q/ha. Mean data showed that application of fertilizers increased the shoot growth of sweet potato in the intercropping system whereas similar trend was not seen with the sole crop.

IV.5.12. Effect of fertilizer levels on the tuber to shoot weight ratio of sweet potato

The data on the tuber to shoot weight ratio of sweet potato are presented in Table IV.5.12.

In intercropping sweet potato in arecanut, the tuber to shoot weight ratio of sweet potato was increased as the fertilizer levels increased. This ratio increased from 1:13 in control to 1:54 at highest level of fertilizers. In sole crop of sweet potato, the ratio increased upto a certain level of fertilizers, thereafter it declined. The ratio increased from 1:3.0 in control to 1:4.1 in the second level of fertilizers. The ratio decreased at the third level of fertilizers.

The tuber to shoot ratio (1:41) as seen from the mean figures irrespective of fertilizer levels tremendously increased in the intercropped sweet potato when compared to sole crop of sweet potato (1:3.4).

Table IV.5.12. Tuber to shoot ratio of sweet potato as an intercrop and a sole crop as influenced by fertilizer levels

Treatments					Intercrop	Sole crop
S.No.	Crop	Fertilizer schedules (kg/ha)				
		N	P_2O_5	K_2O		
1.	Sweet potato	0	0	0	1:13	1:31
2.	Sweet potato	70	50	70	1:46	1:34
3.	Sweet potato	140	100	140	1:51	1:40
4.	Sweet potato	210	150	210	1:54	1: 31
Mean					1:41	1: 34

IV.5.13. Effect of fertilizer levels on 1000 grain weight of cowpea

The data pertaining to 1000 grain weight of cowpea as influenced by levels of fertilization to sweet potato are given in Table IV.5.13.

There were no differences due to fertilizer application on the test weight of cowpea both in inter and sole crops. In general, test weight of sole crop was comparatively higher (105.5 g) than the intercrop (97.3 g) at the highest level of fertilizers.

IV.6. Growth and yield attributes of arecanut

IV.6.1. Effect of fertilizer levels and growing of intercrops on the girth, internodal length and height of arecanut

The data related to girth, internodal length and plant height as influenced by different intercrops with varying levels of fertilizer applications are given in Table IV.6.1.

Girth of areca palm at the permanent mark did not exhibit any significant difference due to intercropping with turmeric or sweet potato-cowpea rotation under different levels of fertilizers. In general, increasing levels of fertilizers to the intercrops showed a marginal increase in the girth of areca stem both in turmeric and sweet potato-cowpea intercropped plots. Maximum development of stem was under high dose of fertility with 47.7 cm and 47.5 cm in turmeric and sweet potato-cowpea respectively when compared to their respective control plots of 44.10 and 45.10 cm. Girth of the last exposed node also showed a similar trend.

Table IV.5.13. Thousand grain weight of cowpea as an intercrop and a sole crop as influenced by residual effect of fertilizer levels to sweet potato

S.No.	Treatments				Intercrop (g)	Sole crop (g)
	Crop	Fertilizer schedules (kg/ha)				
		N	P_2O_5	K_2O		
1.	Sweet potato-cowpea	0	0	0	95.6	105.6
2.	Sweet potato-cowpea	70	50	70	96.1	110.0
3.	Sweet potato-cowpea	140	100	140	93.8	101.0
4.	Sweet potato-cowpea	210	150	210	97.3	105.3
	Mean				95.7	105.5
	F. Test				NS	NS
	CD				-	-
	CV %				2.91	3.26

NS = Not significant

Table IV.6.1. Girth (cm), internodal length (cm) and plant height (m) of arecanut palm as influenced by fertilizer levels to intercrops of turmeric/sweet potato-cowpea and

S.No.	Crop	Fertilizer schedules (kg/ha) N	P_2O_5	K_2O	Girth (cm) PM	Girth (cm) LEN	Internodal length (cm) PM	Internodal length (cm) LEN	Plant height (m)
1.	Turmeric	0	0	0	44.10	40.33	10.50	7.03	7.09
2.	Turmeric	70	60	120	45.86	38.90	11.10	7.43	7.10
3.	Turmeric	140	120	240	45.20	41.33	11.63	7.83	7.51
4.	Turmeric	210	180	360	47.70	41.63	12.33	8.66	7.50
5.	Sweet potato	0	0	0	45.10	41.30	10.96	7.16	7.17
6.	Sweet potato	70	50	70	46.10	40.23	11.53	8.53	6.35
7.	Sweet potato	140	100	140	46.03	42.40	11.53	8.43	7.88
8.	Sweet potato	210	150	210	47.50	42.40	12.60	9.10	7.89
9.	Control (pure crop of arecanut)	-	-	-	46.56	40.63	10.90	7.76	7.54
	F. Test				NS	NS	NS	NS	NS
	CD				-	-	-	-	-

PM = Permanent mark LEN = Last Exposed Node

NS = Not significant

Internodal distance both at permanent mark (PM) and last exposed node (LEN) increased with the increase in the amount of fertilizers applied to intercrops, though not significant. Internodal distance increased from 10.5 cm in turmeric intercropped plots without fertilizers to 12.33 cm with high dose of fertilizers, whereas in sweet potato-cowpea rotated plots stem girth ranged from 10.96 to 12.60 cm. Internodal distance of the last exposed node increased from 7.03 cm to 8.66 cm in turmeric grown plots and from 7.16 to 9.10 cm in sweet potato-cowpea grown plots. The control recorded a girth of 7.76 cm.

Plant height increased with the increase in the amount of fertilizer applied to the intercrops. Palm height in case of turmeric combination ranged from 7.09 m (turmeric without fertilizers) to 7.50 m (turmeric with high level of fertilizers) and in sweet potato combinations from 7.14 m (sweet potato-cowpea without fertilizers) to 7.89 m (sweet potato-cowpea with high level of fertilizers) with an absolute control palm recording 7.54 cm.

IV.6.2. Effect of fertilizer levels and intercrops on the bunch production in arecanut palm

The data pertaining to the number of bunches produced by areca palm as influenced by levels of fertilizers and intercrops are presented in Table IV.6.2.

Mean bunch production per palm did not vary significantly during pre-experimental period 1977 and 1978. During the period

Table IV.6.2. Number of arecanut bunches produced by areca palm as influenced by different levels of fertilizers and intercrops

Treatments					Pre-treatment period (77-78)	Treatment peridd (79-80)	Post-treatment period (81-82)
S.No.	Crop	Fertilizer schedules (kg/ha)					
		N	P_2O_5	K_2O			
1.	Turmeric	0	0	0	3.15	3.96	2.86
2.	Turmeric	70	60	120	3.09	4.25	3.70
3.	Turmeric	140	120	240	3.08	3.89	3.40
4.	Turmeric	210	180	360	3.20	4.44	3.50
5.	Sweet potato -cowpea	0	0	0	3.18	3.98	3.60
6.	Sweet potato -cowpea	70	50	70	3.10	3.59	3.33
7.	Sweet potato -cowpea	140	100	140	3.18	3.75	3.55
8.	Sweet potato -cowpea	210	150	210	3.13	3.92	3.66
9.	Control (pure crop of arecanut)				2.73	3.99	3.36
	F. Test				NS	NS	NS
	CD				-	-	-
	CV %				19.08	17.69	13.67

NS = Not significant

of experimentation from 1979 to 1980, the effects of fertilizers and intercropping were not significant on the bunch production. However, bunch production, in general, increased from pre-experimental period to experimental period from 3.13 to 4.13 and 2.73 to 3.99 in the turmeric and sweet potato-cowpea intercropped systems respectively. During the experimental period though the differences were not significant, intercropping with turmeric helped areca palm to produce more bunches (4.13) than intercropping with sweet potato-cowpea rotation (3.99). The maximum number of bunches were 4.44/palm produced where turmeric was intercropped with 210 N, 180 P_2O_5 and 360 K_2O kg/ha when compared to control (3.99). Post experimental data showed a marginal decline in the bunch production in all the treatments.

Mean data showed that intercropping with turmeric or sweet potato-cowpea rotation with or without fertilizers for a period of three years did not significantly affect the bunch production in arecanut palm.

IV.6.3. Effect of fertilizer levels and intercrops on the production of arecanuts

The data pertaining to the number of nuts produced by areca palm as influenced by growing turmeric and sweet potato-cowpea intercrops with different levels of fertilizers are given in Table IV.6.3.

Mean number of nuts produced by areca palms did not vary significantly either in the pre-experimental period (1977 and 1978) or during the experimental period (1979-81). Intercropping

Table IV.6.3. Number of nuts produced by areca palm as influenced by growing turmeric and sweet potato-cowpea as intercrops with varied levels of fertilizers

S.No.	Crop	Fertilizer schedules (kg/ha) N	P_2O_5	K_2O	Pre-treatment period (mean of 2 years)	Treatment period (mean of 2 years)	Post-treatment period (mean of 2 years)
1.	Turmeric	0	0	0	762	1085	633
2.	Turmeric	70	60	120	999	1472	1290
3.	Turmeric	140	120	240	784	1213	995
4.	Turmeric	210	180	360	742	1124	1000
	Mean				824	1224	979
5.	Sweet potato -cowpea	0	0	0	681	969	939
6.	Sweet potato -cowpea	70	50	70	678	821	955
7.	Sweet potato -cowpea	140	100	140	626	997	1031
8.	Sweet potato -cowpea	210	150	210	573	974	958
	Mean				639	940	971
9.	Control (pure crop of arecanut)				545	870	834
	F. Test				NS	NS	NS
	CD				-	-	-
	CV %				22.68	39.65	42.50

NS = Not significant

in arecanut generally increased the number of nuts in almost all the treatments though there were no significant differences in the treatment means in any of the years under study (1979-82). However, the number of nuts produced in control (870) were comparable with these of turmeric and sweet potato-cowpea rotation raised under varying levels of fertilizers. From the mean data of the experimental period, it can be seen that the production of nuts was more in turmeric (1224) intercropped plots than in sweet potato-cowpea rotation (940). However, intercropping either with turmeric or sweet potato-cowpea without fertilizers brought down the yield when compared to their fertilized plots.

IV.6.4. Effect of fertilizer levels and intercrops on the production of areca fruits (kg/ha)

The data on the weight of arecanut fruits as influenced by growing turmeric and sweet potato-cowpea intercrops with varying fertilizer levels are given in Table IV.6.4.

Arecanut production did not vary significantly among the experimental palms during pre-experimental period (1977-78). With the start of the experimentation, during 1978-79, arecanut yield greatly enhanced from 25 to 50 per cent in the plots where turmeric and sweet potato were grown.

Intercropping with turmeric in areca gardens without fertilizers resulted in an yield of 19,239 kg/ha compared to the yields (26087 to 30570 kg/ha) in fertilizer treated plots. During the

Table IV.6.4. Weight of nuts (kg/ha) as influenced by the fertiliser levels to the intercrops of turmeric and sweet-potato-cowpea

Sl.No.	Crop	Fertiliser schedules (kg/ha) N	P_2O_5	K_2O	Pre-treatment period (mean of 2 years)	Treatment period (mean of 2 years)	Post-treatment period (mean of 2 years)
1.	Turmeric	0	0	0	15501	19239	12762
2.	Turmeric	70	60	120	20013	30570	27730
3.	Turmeric	140	120	240	17492	26087	19647
4.	Turmeric	210	180	360	16177	26983	22181
	Mean				17296	25711	20580
5.	Sweet potato-cowpea	0	0	0	14856	20732	17802
6.	Sweet potato-cowpea	70	50	70	14110	18753	18124
7.	Sweet potato-cowpea	140	100	140	14767	21712	22464
8.	Sweet potato-cowpea	210	150	210	12323	19941	17475
	Mean				14614	20284	18966
9.	Control (pure crop of arecanut)				12548	18506	16502
	F. Test				S	S	S
	CD				6812	8612	6467
	CV %				38.14	27.34	21.66

S = Significant at 5%

post-experimental period the same trend persisted.

Mean data during the experimental period showed that intercropping turmeric or sweet potato-cowpea rotations in arecanut had a cumulative effect on the production of nuts as evidenced by the significant variation among treatment means. Intercropping areca palm with turmeric significantly increased the yield of arecanut (25711 kg/ha) when compared to sweet potato-cowpea rotation (18506 kg/ha). The intercrop of turmeric when fertilized at 70 N, 60 P_2O_5 and 120 K_2O kg/ha provided significantly higher yield of arecanut (30,570 kg/ha) when compared to other two levels of fertilizers. However, different levels of fertilizers to sweet potato could not bring about any significant difference in the production of arecanut. Arecanut yield was found to decline generally in all the treatments during the post experimental period when compared to the period of experimentation.

IV.7. Economic yields and gross income from sole and intercrops and comparison of incomes from main crop, sole and intercrops

IV.7.1. Comparison of economic yields of sole and intercrops in arecanut

The data on the economic yields of sole and intercrops in arecanut as influenced by varied fertilizer levels to the intercrops are presented in Table IV.7.1.

Irrespective of the fertilizer levels the intercrops turmeric, sweet potato and cowpea provided yields of 2455, 1970 and

Table IV.7.1. Economic yields of sole and intercrops in arecanut (kg/ha)

S.No.	Crop	Fertilizer schedules (kg/ha) N	P2O5	K2O	Economic yield (kg/ha) Inter-crop	Sole crop	Ratio of IC yield vs SC yield %	Reduction in yield %
1.	Turmeric	0	0	0	2437	5833	41.7	58.2
2.	Turmeric	70	60	120	2497	7283	34.3	65.7
3.	Turmeric	140	120	240	2567	7250	35.4	64.5
4.	Turmeric	210	180	360	2317	5900	39.3	60.7
	Mean				2455	6566	37.7	62.3
5.	Sweet potato	0	0	0	4066	17108	23.8	76.2
6.	Sweet potato	70	50	70	1331	15305	8.6	91.4
7.	Sweet potato	140	100	140	1239	17782	7.0	93.0
8.	Sweet potato	210	150	210	1246	18082	6.9	93.1
	Mean				1970	17069	11.6	88.4
	Cowpea with residual effect of fertilizers applied to sweet potato							
5.	Sweet potato-cowpea	0	0	0	1584	2201	71.9	28.1
6.	Sweet potato-cowpea	70	50	70	1303	1879	69.3	30.7
7.	Sweet potato-cowpea	140	100	140	1382	2299	60.1	39.9
8.	Sweet potato-cowpea	210	150	210	1485	2286	65.0	35.0
	Mean				1439	2166	66.6	33.4

	IC	SC	Ratio of SC/IC(%)	% increase in IC/SC
1. Arecanut and turmeric	44124	32696	74.1	25.9
2. Arecanut and sweet potato - cowpea	34491	32696	94.7	5.3
Mean	39308	32696	84.4	15.6

1439 kg/ha respectively. The respective figures for these sole crops were 6566, 17069 and 2166 kg/ha. When the ratio of intercrops yields and sole crop yields were considered turmeric showed 38%, sweet potato 11.6% and cowpea 66.6%. From these, it is observed that the reduction in yield in the intercrops was maximum in sweet potato with 88% and minimum in cowpea with 33%. Turmeric recorded 62.3% reduction in yield when grown as an intercrop compared to sole crop on an equal area basis.

It is interesting to observe how the intercropping system as a whole compared with the sole cropping system. For this the economic yields obtained from the components of the intercropping system together were compared with the economic yields obtained from their respective sole crops together. These data indicated that the economic yields were higher under intercropping systems with arecanut turmeric providing 44124 kg/ha. This intercropping system was found to give 26% higher yields over the combined yields of the respective sole crops. The yield advantage in arecanut, sweet potato-cowpea combination was only marginal to the extent of 5%.

IV.7.2. Effect of fertilizer levels and the gross income from turmeric and sweet potato-cowpea intercrops and their sole crops

The data on the effect of different levels of fertilizers on the gross income from intercrops and their sole crops are presented in Table IV.7.2.

Table IV.7.2. Gross income from intercrops and sole crops of turmeric and sweet potato-cowpea as influenced by fertilizer levels to intercrops (Rs./ha)

Treatments					Intercrop			Sole crop		
Sl. No.	Crop	Fertilizer schedules (kg/ha)			78-79	79-80	Mean	78-79	79-80	Mean
		N	P_2O_5	K_2O						
1.	Turmeric	0	0	0	2640	2073	2457	6767	10233	8500
2.	Turmeric	70	60	120	2747	2180	2463	7933	6633	7283
3.	Turmeric	140	120	240	3107	1987	2547	6767	7733	7250
4.	Turmeric	210	180	360	2847	1547	2197	6500	5333	5917
	Mean				2885	1947	-	6992	7483	-
	F. Test				NS	NS	NS	NS	S	S
5.	Sweet potato-cowpea	0	0	0	7130	5628	6375	14078	12958	13518
6.	Sweet-potato-cowpea	70	50	70	4760	4151	4455	11670	11847	11758
7.	Sweet-potato-cowpea	140	100	140	5092	4026	4559	15244	12776	14010
8.	Sweet-potato-cowpea	210	150	210	5574	4329	4950	14947	13231	14089
	Mean				5639	4533	-	13979	12703	-
	F. Test				NS	NS	S	S	NS	NS
	CD				-	-	1359	3514	2673	2569
	CV%				14.60	13.15	11.52	[illegible]	18.00	16.70

S = Significant at 5%

NS = Not significant

During 1978-79, application of different levels of fertilizers to intercrops had a significant effect on the gross income from the turmeric crop. Intercropping turmeric with a fertilizer schedule of 140 N, 120 P_2O_5 and 240 K_2O kg/ha recorded the maximum gross income of Rs.3107/-. When grown as sole crop, turmeric recorded a two fold increase in the gross income of Rs.7933/- with a fertilizer schedule of 70 N, 60 P_2O_5 and 120 K_2O kg/ha.

During the same period of 1978-79, sweet potato-cowpea intercropping system provided higher gross income of nearly reaching double the amount that obtained from turmeric intercropping system. This high income was because of cowpea having high sole price for its produce compared to the produce of turmeric and sweet potato. Application of NPK fertilizers to sweet potato-cowpea had however, a depressing effect on the gross income. The gross income of Rs.7130 from control plots fell down to a minimum of Rs.4760 at the first level of fertilizer application and to Rs.5092 and Rs.5574 at the second and third levels of fertilizer applications. When grown as a sole crop, a maximum of Rs.15,244 was obtained at a fertilizer dose of 140 N, 100 P_2O_5 and 140 K_2O kg/ha which was significantly superior to Rs 11,670 obtained at the lower level of fertilization.

During 1979-80, application of fertilizers to turmeric did not show any significant difference on the gross income. Contrary to 1978-79 trend, during 1979-80, increasing levels of fertilizers brought down the gross income from turmeric. During the year, intercropping with turmeric with a fertilizer dose of 70 N, 60 P_2O_5 and 120 K_2O kg/ha recorded the maximum gross income of Rs.2180 while the sole crop of turmeric without any fertilizers provided the highest gross income of Rs.10,233.

Mean data showed that the gross income due to application of different fertilizer schedules to intercrop turmeric did not vary significantly (Rs.2547 to Rs.2197). The sole crop recorded a marginal but significant increase in control plots (Rs.8500) compared to the fertilized plots (Rs.7283 to Rs.5917). The negative effects were more conspicuous at the higher level of fertilizer application.

Gross income from sweet potato-cowpea rotation either as intercrop or as sole crop recorded two fold increase and significantly superior to the income realised from turmeric. As an intercropping system sweet potato-cowpea rotation in arecanut recorded the highest income in control plots (Rs.6375). Application of fertilizers brought down the gross income to Rs.4,455 at the first level. The gross income from sweet potato-cowpea sole cropping system was higher by almost three times compared to that from intercropping. However, fertilizers did not have any significant impact on the gross income realised from this rotation.

IV.7.3. Income from the main crop of arecanut, inter and sole crops and of the intercropping system as influenced by fertilizer levels to intercrops

The data on the income from the main crop of arecanut, inter and sole crops of turmeric and sweet potato-cowpea and of the intercropping systems as influenced by fertilizer levels to the intercrops are presented in Table IV.7.3(a) and (b).

Income from the main crop of arecanut was higher when turmeric was intercropped (Rs.44,124) compared to the income (Rs.34,491) obtained in arecanut with sweet potato-cowpea as intercrops. A fertilizer level of 70 N, 60 P_2O_5 and 120 K_2O kg/ha for the intercrop of turmeric provided a maximum income of Rs.50,797 from the main crop of arecanut. When the incomes from the inter and sole crops were compared, it is observed that the intercrop of turmeric provided an income of Rs.2,463 compared to Rs.7,437 obtained from the sole crop irrespective of the fertilizer levels tried. Thus, the sole crop gave nearly three times the income of this intercrop. Increasing levels of fertilizers decreased the income from the sole crop of turmeric from Rs.8,500 to Rs.5,917. The intercropping combination of sweet potato-cowpea provided Rs.4,990 as against Rs.13,341 by growing them as sole crops. The income from the intercropping system as a whole was found to be higher with arecanut, turmeric intercropping (Rs.46,540) than that obtained with arecanut sweet-potato-cowpea intercropping (Rs.39,481). The fertilizer level of 70 N, 60 P_2O_5 and 120 K_2O kg/ha to turmeric gave the maximum income of Rs.53,260 to this intercropping system.

IV.8. Land and labour utilization in sole and intercropping systems

Table IV.7.3(a); Income from the main crop of arecanut, inter and sole crops and of the intercropping systems as influenced by fertilizer levels to intercrops

Intercrops	Fertilizer levels			Income (Rs./ha)		
	N	P2O5 (kg/ha)	K2O	Arecanut	Intercrops/ sole crops	
Turmeric	0	0	0	32,465		
	70	60	120	50,797		
	140	120	240	45,418		
	210	180	360	47,819		
	Mean			44,124		
Sweet potato-cowpea	0	0	0	34,381		
	70	50	70	34,680		
	140	100	140	36,265		
	210	150	210	32,639		
	Mean			34,491		
Control-Arecanut				32,696		
					IC	SC
Turmeric	0	0	0		2,457	8,500
	70	60	120		2,463	7,283
	140	120	240		2,547	7,250
	210	180	360		2,197	5,917
	Mean				2,416	7,237
Sweet potato-cowpea	0	0	0		6,378	13,158
	70	50	70		4,455	11,758
	140	100	140		4,648	14,010
	210	150	210		4,480	14,081
	Mean				4,990	13,341

Table IV.7.3(b). Income from main and intercrops in the intercropping systems of arecanut as influenced by varied fertilizer levels to the intercrops

Intercrops	Fertilizer schedules (kg/ha)			Income(Rs/ha)
	N	P_2O_5	K_2O	
Turmeric	0	0	0	34,922
	70	60	120	53,260
	140	120	240	47,965
	210	180	360	50,540
	Mean			46,540
Sweet potato-cowpea	0	0	0	40,759
	70	50	70	39,135
	140	100	140	40,913
	210	150	210	37,119
	Mean			39,481

IV.8.1. Land Equivalent Ratios for intercropping systems in areoanut at varying fertilizer levels

Land Equivalent Ratios for different intercropping systems in areoanut at varying levels of fertilizers are presented in Table IV.8.1.

Land Equivalent Ratios showed a positive trend when intercropped with turmeric. Fertilizer application increased LER from 1.24 in the control to 1.76 at the highest level of fertilizers. When intercropped with sweet potato LER showed a declining trend. While there was an LER of 1.93 in control with no fertilizers, with the increase in fertilizer doses along with intercropping with sweet potato-cowpea, the LER declined from 1.82 to 1.72.

IV.8.2. Crop Intensity Indec (CII) for different cropping systems in areoanut

The data on Crop Intensity Index (CII) for various intercrops are given in Table IV.8.2.

Intercropping arecanut with turmeric or sweet potato-cowpea rotation had a conspicuous positive effect on the CII. It increased from 0.70 in the sole crop of turmeric to 1.28 when it was intercropped. Similarly, CII increased from 0.64 in sweet potato-cowpea rotation as a sole crop system to 1.29 when this rotation was adopted in areca plantation.

IV.8.3. Labour requirement of sole and intercropping systems of areoanut under varying fertility levels

Table IV.8.1. Land Equivalent Ratio (LER) for intercropping systems as influenced by fertilizer levels

S.No.	Crop	Fertilizer Levels (kg/ha) N	P2O5	K2O	Yield components under inter cropping (Yi) (Kg/ha)	Yield components under sole cropping (yii) (Kg/ha)	$\frac{Yi}{Yii}$	$LER = \sum_{1}^{m} \frac{Yi}{Yii}$
1.	Arecanut +	0	0	0	17535	18351	0.95	1.24
	Turmeric				2437	8500	0.29	
2.	Arecanut +	70	60	120	26403	18351	1.44	1.78
	Turmeric				2463	7283	0.34	
3.	Arecanut +	140	120	240	23414	18351	1.28	1.63
	Turmeric				2567	7250	0.35	
4.	Arecanut +	210	180	360	25175	18351	1.37	1.76
	Turmeric				2317	5900	0.39	
5.	Arecanut +				18034	18351	0.98	
	Sweet potato	0	0	0	4066	17108	0.24	1.93
	+ Cowpea				1584	2225	0.71	
6.	Arecanut +				19038	18351	1.04	
	Sweet potato	70	50	70	1331	15338	0.09	1.82
	+ Cowpea				1302	1879	0.69	
7.	Arecanut +				19038	18351	1.04	
	Sweet potato	140	100	140	1239	14782	0.08	1.72
	+Cowpea				1382	2299	0.60	
8.	Arecanut +				19699	18351	1.07	
	Sweet potato	210	150	210	1246	18082	0.07	1.79
	+ Cowpea				1485	2285	0.56	

Table IV.8.2. Crop intensity index for various cropping systems

S.No.	Cropping systems	Area grown (ai) Inter crop	Area grown (ai) Sole crop	Field duration (ti) (days)	$CII = \frac{ai \times ti}{ad}$ Inter crop	$CII = \frac{ai \times ti}{ad}$ Sole crop
1.	Arecanut	1.00	-	365	1.28	0.70
	Turmeric	0.40	1.00	255		
2.	Arecanut	1.00	-	365		
	Sweet potato	0.40	1.00	165	1.29	0.64
	Cowpea	0.60	1.00	70		
3.	Arecanut alone	-	1.00	365	-	1.00

a = Land area considered for calculation (1 ha)
d = Duration of cropping in days (365 days)

The data on the labour requirements of sole and intercropping systems of arecanut with turmeric and sweet potato-cowpea as influenced by four levels of fertilizers are presented in Table IV.8.3.

The pure stand of arecanut as observed from Table under fertilizer experiment was found to require a labour force of 763 persons/ha/yr on an average of two years. The total expenditure on labour charges worked out to Rs.4,578/ha/yr. The sole crop of arecanut required 160 persons for labour involving Rs. 960/ha/yr irrespective of the fertilizer levels tried while as an intercrop, 135 persons were required costing Rs.810/ha/yr. The total labour requirement in the intercropping system of the arecanut and turmeric irrespective of the fertilizer level was 723 persons involving an expenditure of Rs.4,338/ha/yr. The total labour requirement in the intercropping system of arecanut and sweet potato-cowpea irrespective of fertilizer level was 713 persons involving an expenditure of Rs.4,278/ha/yr. Thus, intercropping of arecant with turmeric and sweet potato-cowpea was found to effect a saving of Rs.240 and Rs.300/ha/yr, respectively as the labour requirement were cut down by 40 and 50 persons in these intercropping systems compared to the labour requirement of the sole crop of arecanut.

IV.9. Results on cost:benefit ratio relationships from both the experiments on plant densities and intercropping intensities and fertilizer levels to intercrops

IV.9.1. Cost:benefit ratio relationships as influenced by plant densities of arecanut and intensities of intercropping

Table IV.8.3. Labour requirement for intercropping systems in arecanut with turmeric and sweet potato - cowpea under varied fertilizer levels*

Cropping systems	Labour/ha	Rs/ha
Sole crop of arecanut	763	+ 4,578
Sole crop of turmeric	160	+ 960
Sole crop of sweet potato-cowpea	150	+ 900
Intercrop of arecanut	588	+ 3,528
Intercrop of turmeric	135	+ 810
Intercrop of sweet potato-cowpea	125	+ 750
Intercrop of arecanut + Turmeric	723	+ 4,338
Intercrop of arecanut + Sweet potato - cowpea	713	+ 4,278

* Since there were no differences in labour requirements under the four levels of fertilizers tried, data on only intercropping systems are provided

The data on cost:benefit ratio relationships as influenced by plant densities of arecanut and intensities of intercropping for turmeric and sweet potato are given in Table IV.9.1(a) and IV.9.1(b) respectively.

With increasing intensity of intercropping under each plant density, it was observed that the cost on inputs like seeds, manures and fertilizers and labour proportionately increased thus increasing the total expenditure in raising both the inter-crops of turmeric and sweet potato-cowpea. However, the net returns of Rs.3,710 in turmeric and Rs.2,134 in sweet potato-cowpea were highest under a plant density of 1.8m x 3.6m at 60% intensity of intercropping. These treatments had high cost benefit ratio of 2.6 and 2.2 for the intercrops of turmeric and sweet potato-cowpea respectively.

IV.9.2. Cost:benefit ratio relationships as influenced by fertilizer levels to turmeric and sweet potato-cowpea as sole and intercrops in arecanut

The data on the cost:benefit ratio relationships as influenced by fertilizer levels to the intercrops of turmeric and sweet potato-cowpea in arecanut plantation and as sole crops are given in Tables IV.9.2(a) and IV.9.2(b).

In these studies on sole crops, it was observed that the total cost on inputs between the treatments varied only because of change in the levels of fertilizers which was also marginal. Between turmeric and sweet potato-cowpea, the total cost differed substantially. In turmeric, the total cost increased from Rs.2,005 to Rs.2,997 with the increased fertilizer levels. These costs were

Table IV.9.1(a): Cost benefit ratio relationships as influenced by plant densities of arecanut and intensities of intercropping of turmeric (Mean of 2 years)

		Cost (Rs/ha)					Yield of tuber (kg/ha)	Yield value (Rs/ha)	Net return (Rs/ha)	Benefit/cost ratio
		Seeds	Manures and fertilisers	Other inputs	Labour Amount	Total				
1) 1.8m x 1.8m	a)	562	348	136	816	1862	4490	4490	2628	2.41
	b)	674	418	206	1020	2318	6028	6028	3710	2.60
										2.50
2) 2.7m x 2.7m	a)	843	522	205	1230	2800	4239	4239	1439	1.51
	b)	1011	626	308	1537	3482	5637	5322	1840	1.53
										1.52
3) 2.7m x 3.6m	a)	1053	652	255	1300	3490	5637	5637	2147	1.61
	b)	1264	782	383	1912	4339	4928	4925	586	1.13
										1.37
4) 3.6m x 3.6m	a)	1263	785	306	1536	3880	4823	4823	943	1.24
	b)	1516	938	462	1920	4836	6010	6010	1174	1.24
										1.24

a) = 40% intensity of intercrop b) = 60% intensity of intercrop

Table IV.9.1(b). Cost benefit ratio relationships as influenced by plant densities of arecanut and intensities of intercropping of sweet potato - cowpea (Mean of 2 years)

		Cost (Rs/ha)						Yield of tuber Kg/ha	Yield value Rs/ha	Net return Rs/ha	Benefit/ cost ratio
		Seeds	Manures & fertilizers	Other inputs	Labour No.	Labour Amt.	Total				
1) 1.8m x 3.6m	a)	19	353	13		768	1158	3827 505	2806	1648	2.4
	b)	25	475	20		1200	1730	3706 794	3864	2134	2.2
											2.3
2) 2.7m x 2.7m	a)	30	470	18		1020	1538	3454 679	3418	1880	2.2
	b)	38	564	27		1530	2159	3841 788	3900	1741	1.8
											1.8
3) 2.7m x 3.6m	a)	32	537	22		1260	1901	3991 759	3813	1912	2.0
	b)	40	704	32		1800	2576	5102 840	4560	1984	1.8
											1.8
4) 3.6m x 3.6m	a)	38	681	26		1500	2245	4302 791	4093	1848	1.8
	b)	48	817	38		2130	3038	5545 891	4891	1858	1.6
											1.7

a) = 40% intensity of intercropping b) = 60% intensity of intercropping

Table IV.9.2(a) Benefit cost relationships of sole crops at varied fertilizer levels (Mean of two years)

Treatments					Cost (Rs./ha)						Yield of tubers (kg/ha)	Yield value (Rs/ha)	Net return (Rs/ha)	Benefit/ cost ratio
Sl. No.	Crop	Fertilizer schedules (kg/ha)			Seeds	Manures & fertilizers	Other inputs	Labour		Total				
		N	P2O5	K2O				No.	Amt.					
1.	Turmeric	0	0	0	843	175	27	160	960	2005	8500	8500	6495	4.24
2.	Turmeric	70	60	120	843	522	27	160	960	2352	7283	7283	4931	3.10
3.	Turmeric	140	120	240	843	844	27	160	960	2674	7250	7250	4576	2.71
4.	Turmeric	210	180	360	843	1167	27	160	960	2997	5916	5916	2919	1.97
	Mean				843	677	27	160	960	2507	7232	7232	4730	3.00
5.	Sweet potato-cowpea	0	0	0	25	175	20	150	900	1120	17108 (2225)	13558	12398	12.07
6.	Sweet-potato-cowpea	70	50	70	25	470	20	150	900	1415	15338 (1879)	11758	10343	8.31
7.	Sweet potato-cowpea	140	100	140	25	740	20	150	900	1685	14882 (2299)	14010	12325	8.31
8.	Sweet potato-cowpea	210	150	210	25	1010	20	150	900	1955	18082 (2285)	14081	12126	7.20
	Mean				25	599	20	150	900	1544	-	13352	11798	8.97

(Figures in parenthesis indicate the yield of cowpea)

Table IV.9.2.(b). Benefit cost relationships of different intercrops in arecanut as influenced by fertilizer levels in intercrops

(Mean of two years)

Crops	N	P_2O_5	K_2O	Cost (Rs/ha) Seeds	Fertilizers	Other inputs	Labour No.	Labour Amt.	Total	Yield of tubers (kg/ha)	Yield value (Rs/ha)	Net return (Rs/ha)	Benefit/cost ratio
Turmeric	0	0	0	871	175	27	135	810	1883	2457	2457	574	1.30
	70	60	120	871	522	27	135	810	2230	2463	2463	233	1.10
	140	120	240	871	844	27	135	810	2552	2547	2547	-005	1.00
	210	180	360	871	1167	27	135	810	2875	2197	2197	-678	0.76
	Mean			871	677	27	135	810	2385	-	-	-	1.04
Sweet potato-cowpea	0	0	0	27	175	20	125	750	972	4066 (1584)	6378	5406	6.56
	70	50	70	27	470	20	125	750	1267	1331 (1302)	4455	3188	3.51
	140	100	140	27	740	20	125	750	1537	1239 (1382)	4648	3111	3.02
	210	150	210	27	1010	20	125	750	1807	1246 (1485)	4480	2673	2.48
	Mean			27	599	20	125	750	1396				3.89

(Figures in parenthesis indicate the yield of cowpea) lower in sweet potato-cowpea ranging from Rs.1,120 to Rs.1,955. The total cost benefit ratio was observed to be highest under no fertilizers with a ratio of 4.24 in turmeric and 12.07 in sweet potato-cowpea.

As intercrops also, the same trend of expenditure was observed with the total expenditure in turmeric increasing from Rs.1,883 to Rs.2,875 while in sweet potato-cowpea, it ranged from Rs.972 to Rs.1,807. It was observed that in turmeric, the net returns in the two higher doses of fertilizers were on the negative side losing a value of Rs.5 and Rs.678 respectively. The highest cost benefit ratios of 1.30 and 6.56 were observed in turmeric and sweet potato-cowpea respectively.

IV.10. Analytical results on plant samples

IV.10.1(a) Effect of fertilizer levels on leaf nitrogen status of turmeric and sweet potato in the intercropping system

Data pertaining to the leaf nitrogen content of turmeric and sweet potato are presented in Fig.9(a).

Turmeric: Leaf nitrogen content of turmeric did not show any significant differences among the treatment means at 60, 90 and 120 days after planting. However, increasing levels of NPK consistently showed an increase in the nitrogen content. Nitrogen content gradually decreased from 60 days to 120 days in all the treatments and an increasing trend from 90 days to 120 days during 1978-79. Similar trends were observed in the

FIG. 9 a. EFFECT OF FERTILIZER LEVELS ON NITROGEN CONTENT IN LEAF, STEM AND TUBER OF TURMERIC AND SWEET POTATO AS INTERCROPS IN ARECANUT

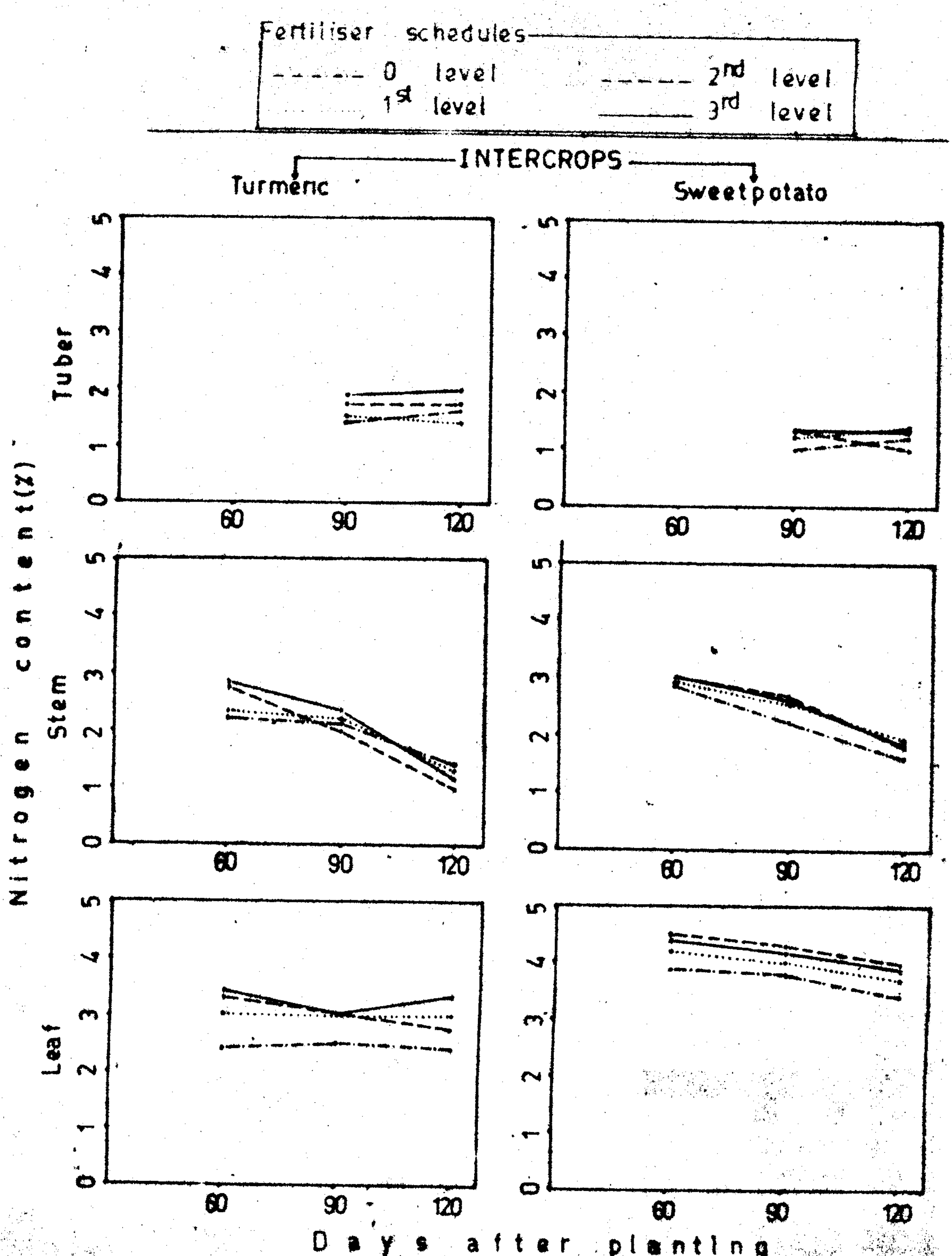

Fertiliser schedules
0 level
1st level
2nd level
3rd level
INTERCROPS
Turmeric
Sweetpotato
Nitrogen content (%)
Tuber
Stem
Leaf
0
1
2
3
4
5
60
90
120
Days after planting

FIG. 9 a.

mean values. Differences in N content from 60 to 120 days were marginal.

Sweet potato: Leaf nitrogen content of sweet potato did not show any significant difference among the fertilizer schedules, either at 90 days or 120 days. In general, increasing levels of NPK schedules recorded a steady increase in leaf N content. It ranged from 3.80% to 4.2% in the plots receiving highest level of NPK fertilizer at 90 days and from 3.36% to 4.07% from control to highest level of NPK schedules at 120 days.

IV.10.1(b). Effect of fertilizer levels on leaf nitrogen status of turmeric and sweet potato in the sole cropping system

Data pertaining to the leaf nitrogen content of sole crops of turmeric and sweet potato in relation to NPK fertilizers are presened in Fig. 9(b).

Turmeric: Increasing levels of NPK fertilizers increased the leaf nitrogen in turmeric though the differences were not significant at 90 days after planting. It ranged from 2.70% in control to 2.98% with highest dose of fertilizers during 1978-79, under the sole cropping system. There was a declining trend in N in all the fertilized plots from 90 days to 120 days. While during 1979-80, turmeric leaf N increased in general in all the treatments from 90 days to 120 days.

Sweet potato: Increasing levels of fertilizers to sole crop of sweet potato increased leaf N consistently, though

FIG. 9 b. EFFECT OF FERTILIZER LEVELS ON NITROGEN CONTENT IN LEAF, STEM AND TUBER OF TURMERIC AND SWEET POTATO AS SOLE CROPS

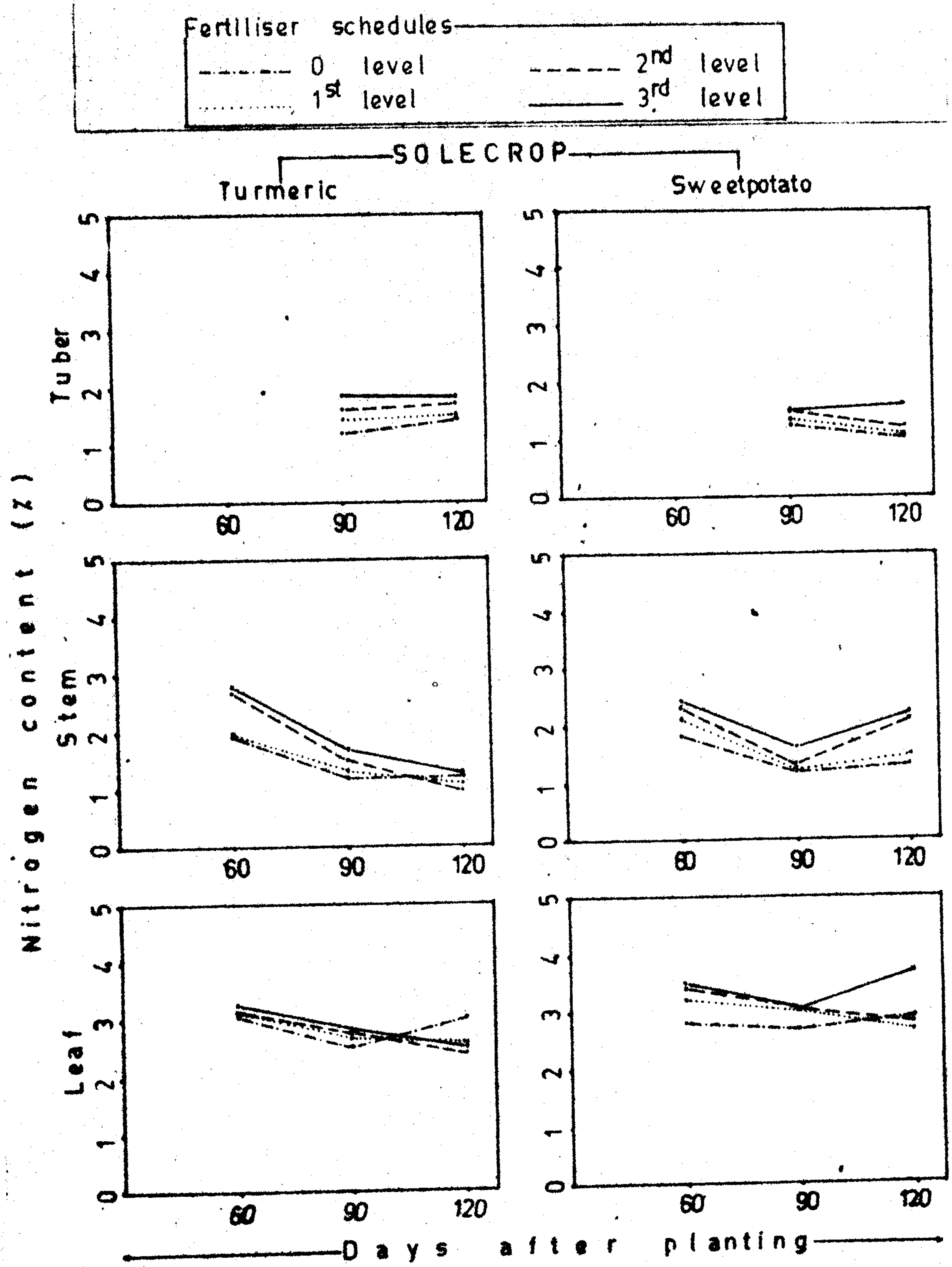

Fertiliser schedules
0 level
1st level
2nd level
3rd level
SOLECROP
Turmeric
Sweetpotato
Nitrogen content (%)
Tuber
Stem
Leaf
0
1
2
3
4
5
60
90
120
Days after planting

FIG. 9 b.

there were no significant variations amongst these either at 90 days or 120 days during both the years. The pooled data indicated that leaf nitrogen increased with the increase in NPK schedules from 2.70% in control to 3.13% in the highest level at 90 days and from 2.88% to 3.68% at 120 days.

IV.10.2(a). Effect of fertilizer levels in nitrogen contents in stems of turmeric and sweet potato as inter crops in arecanut plantation

Data pertaining to nitrogen content in stems of turmeric and sweet potato are presented in Fig.9(a).

Turmeric: Nitrogen in pseudo stem of turmeric did not show any significant effect due to fertilizer application when grown with arecanut at 90 and 120 days after planting during both the years. In general, nitrogen in stem decreased from 90 to 120 days.

Sweet potato: Nitrogen of sweet potato stems did not differ statistically due to any of the fertilizer treatments. Though stem N concentration at 90 days did not show any definite trend, it increased with the increase in fertilizer levels at 120 days from 1.44% at first level to 1.81% at the third level of NPK schedule.

IV.10.2(b). Effect of fertilizer levels on the nitrogen content in stems of turmeric and sweet potato grown as sole crops

Data pertaining to the nitrogen concentration of stems of turmeric and sweet potato are given in Fig.9(b).

Turmeric: Nitrogen in turmeric stems was significantly higher at the highest schedule of fertilizer at 90 days after planting during 1978-79 as well as at 120 days during the observations of mean values of both the years. In general, N increased with the increase in NPK schedule at 90 days during both the years. However, during 1978-79, nitrogen declined from 90 to 120 days after planting, whereas such decline was not observed during 1979-80.

Sweet potato: Except for a significant raise in N at the highest level of fertilizers at 90 days nitrogen of sweet potato stems did not vary significantly under different schedules of fertilizers either at 90 days or 120 days after planting during both the years of study. Increasing fertilizer levels, however, increased N from 1.40% in control to 1.94% at the highest fertilizer level at 90 days during 1978-79. Content of N tended to improve from 90 to 120 days after planting during both the years of study.

IV.10.3(a). Effect of fertilizer levels on nitrogen in tubers of turmeric and sweet potato in arecanut as inter crops

Data relating to nitrogen content of turmeric and sweet potato tubers are presented in Fig.9(a).

Turmeric: Fertilizer levels failed to bring any significant variation in N content of tubers either at 90 days or 120 days after planting. Increasing levels of fertilizers, however, shoed a marginal increase in N content of turmeric tubers at 90 days during both the years. It ranged from 1.77% in control to 2.10% at the highest level of fertilizers. Whereas, such variation was not observed at 120 days.

Sweet potato: Nitrogen content in sweet potato tubers did not show any significant variation due to varying levels of fertilizers. Mean data showed that N content increased with the increase in the level of NPK doses at 90 days but not at 120 days after planting.

IV.10.3(b). Effect of fertilizer levels on nitrogen content in tubers of turmeric and sweet potato grown as sole crops

Data pertaining to nitrogen content of turmeric and sweet potato tubers as influenced by different levels of fertilizers are given in Fig.9(b).

Turmeric: The nitrogen content of turmeric tubers did not differ due to different fertilizer schedules either at 90 or 120 days. In general, increasing levels of NPK increased the N content of tubers from 1.21% in control to 1.82% in the highest schedule of NPK at 90 days. Nitrogen in general did not vary between 90 and 120 days. Almost a similar trend was observed during the second year of study.

Sweet potato: Fertilizer levels failed to bring any significant variation among the treatment means with respect to tuber nitrogen content. However, a steady increase with successive schedules of fertilizers was observed during both the years. The mean data showed a similar trend. At 90 and 120 days, N content in controls was 1.24% and 0.96% and it increased upto 1.49% and 1.58% respectively with the highest dose of fertilizers.

IV.10.4(a). Effect of fertilizer levels on leaf phosphorus content of turmeric and sweet potato in arecanut as intercrop

The data on leaf phosphorus content of turmeric and sweet potato as intercrops in arecanut in response to varied fertilizer levels are presented in Fig.10(a).

Turmeric: Increasing schedules of NPK decreased leaf phosphorus content of turmeric in general. Phosphorus declined from 90 to 120 days after planting during both the years. Mean data showed that highest fertilizer significantly brought down leaf P to 0.22% from 0.27% in control plots at 90 days after planting. At 120 days after planting the reduction was from 0.20% to 0.15% P.

Sweet potato: Sweet potato also showed the same trend during both the years. It ranged from 0.32% and 0.28% in controls to 0.30% and 0.21% at highest level of fertilizer application at 90 and 120 days after planting respectively. Phosphorus content decreased from 90 days after planting.

FIG.10 a. EFFECT OF FERTILIZER LEVELS ON PHODPHORUS CONTENT IN LEAF, STEM AND TUBER OF TURMERIC AND SWEET POTATO AS INTERCROPS IN ARECANUT

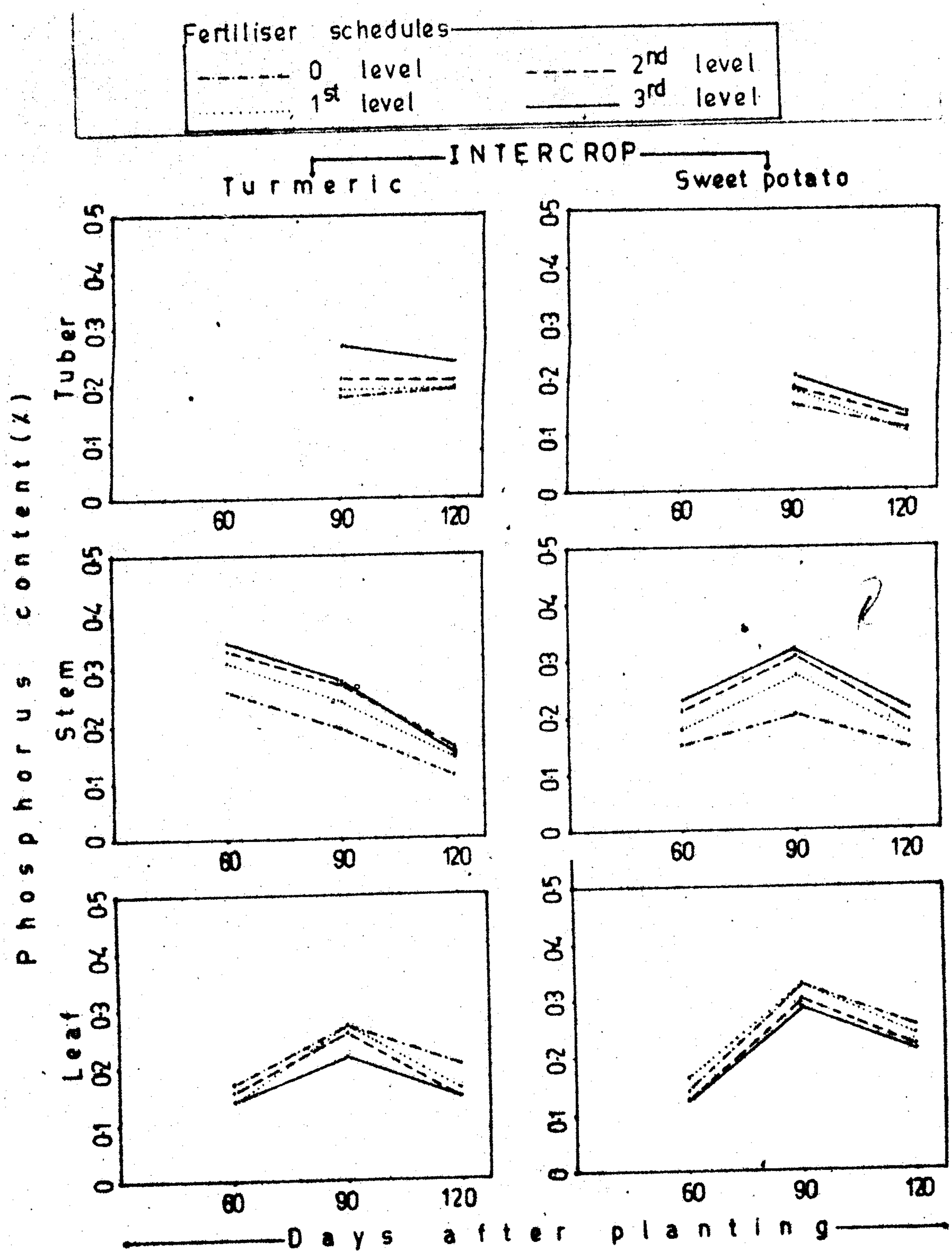

Fertiliser schedules
0 level
1st level
2nd level
3rd level
INTERCROP
Turmeric
Sweet potato
Phosphorus content (%)
Tuber
Stem
Leaf
0
0.1
0.2
0.3
0.4
0.5
60
90
120
Days after planting

FIG. 10 a.

IV.10.4(b). Effect of fertilizer levels on leaf phosphorus content in turmeric and sweet potato as sole crops

The data on leaf phosphorus content of turmeric and sweet potato as sole crop in response to varied fertilizer levels are presented in Fig.10(b).

Turmeric: Turmeric leaf P content did not show any significant variation among treatments either at 90 or 120 days after planting. The differences were significant only in the mean data at 120 days where the highest level of NPK schedule recorded the lowest P (0.18%) compared to other schedules (0.19 to 0.23%).

IV.10.5(a). Effect of fertilizer levels on phosphorus content of stems of turmeric and sweet potato grown in arecanut

The data on phosphorus concentration of turmeric and sweet potato stems grown as intercrops in response to varied levels of fertilizers are given in Fig.10(a).

Turmeric: During 1978-79, increasing fertilizers levels increased phosphorus content of stems only marginally, whereas in 1979-80, the difference were statistically significant at 90 days after planting, control being inferior (0.10%) to other treatments (0.19% to 0.25%).

Sweet potato: Sweet potato stems recorded higher amounts of phosphorus with increase in the NPK schedule both at 90 and 120 days after planting only during 1978-79. The P per cent in stem increased from 0.24% and 0.16% in controls to 0.34% and 0.23% in the highest level of fertilizers at 90 and 120 days respectively. However, such a trend was not observed during 1979-80 or in the mean values.

IV.10.5(b). Effect of fertilizer levels of phosphorus content of stems of turmeric and sweet potato grown as sole crops

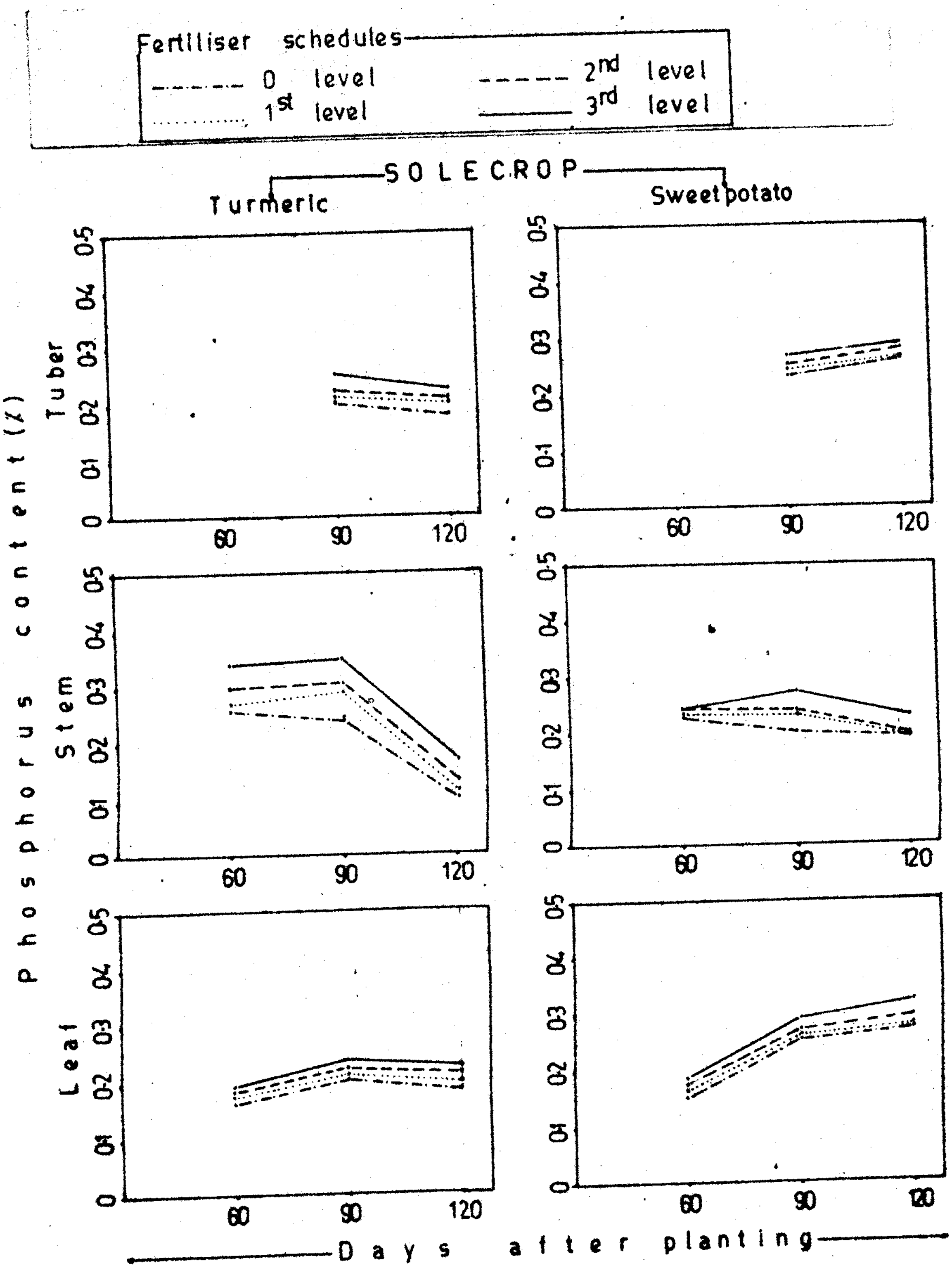
The data on phosphorus of turmeric and sweet potato stems grown as sole crops in response to varied levels of fertilizers are given in Fig.10(b).

Turmeric: Increasing levels of fertilizers increased the phosphorus content of turmeric stem though the variations were not significant in the first year. The variations were significant only at 90 days during 1979-80 where control plot significantly recorded lower values (0.19%) compared to the rest (0.26% to 0.32%). In general, stem P content declined from 90 days to 120 days after planting.

Sweet potato: Sweet potato stem contents for phosphorus showed significant differences only at 90 days after planting during 1978-79. The two higher levels of fertilizers (0.27% and 0.34%) were superior to the control (0.22%). Even the mean values at 90 days showed the same trend.

IV.10.6(a). Effect of fertilizer levels on phosphorus content of roots in turmeric and sweet potato grown in arecanut

FIG. 10 b. EFFECT OF FERTILIZER LEVELS ON PHOSPHORUS CONTENT IN LEAF, STEM AND TUBER OF TURMERIC AND SWEET POTATO AS SOLE CROPS



Fertiliser schedules
0 level
1st level
2nd level
3rd level
SOLECROP
Turmeric
Sweet potato
Phosphorus content (%)
Tuber
Stem
Leaf
0
0.1
0.2
0.3
0.4
0.5
60
90
120
Days after planting

FIG. 10 b.

The data on the phosphorus content of roots of turmeric and sweet potato as intercrops in areca plantation in response to varied fertilizer levels are presented in Fig.10(a).

A marginal increase in phosphorus content of turmeric roots was observed with increase in the levels of NPK scheduels, ranging from 0.18% and 0.19% in controls to 0.27% and 0.24% in the highest level of fertilizers at 90 and 120 days respectively. In sweet potato, root P content also followed almost the same trend. During 1979-80, at 120 days, the last two higher doses of fertilizers were significantly superior to other treatments. The mean values indicated a slight rise in P from 0.15% to 0.20% at 90 days and from 0.11% to 0.13% at 120 days.

IV.10.6(b). Effect of fertilizer levels on phosphorus content of roots in turmeric and sweet potato grown as sole crops

The data on the phosphorus content of roots of turmeric and sweet potato as sole crops in response to varied fertilizer levels are presented in Fig.10(b).

Root contents of phosphorus in turmeric and sweet potato did not differ significantly due to application of fertilizers except in the mean values at 120 days in turmeric. In general, increase in fertilizer schedules increased phosphorus content of roots marginally both at 90 days (0.20% to 0.25%) and 120 days after planting (0.18% to 0.23%) in turmeric. In sweet potato, the concurrent figures were 0.23% to 0.26% at 90 days and 0.26% to 0.22% at 120 days.

IV.10.7(a). Effect of fertilizer levels on leaf potassium content of turmeric and sweet potato in arecanut intercrops

Data pertaining to leaf potassium content of turmeric and sweet potato in arecanut are presented in Fig.11(a).

Turmeric: None of the fertilizer schedules could bring about any significant change in leaf K either at 90 days or 120 days after planting. In general, leaf K during 1978-79 was more when compared to 1979-80. During both the years, K declined from 90 to 120 days. Increasing fertilizer levels increased K of leaf. Mean values showed that K of leaf in control plots varied from 3.94% to 3.87% from 90 days to 120 days and from 4.92% to 4.29% at highest level of fertilizers.

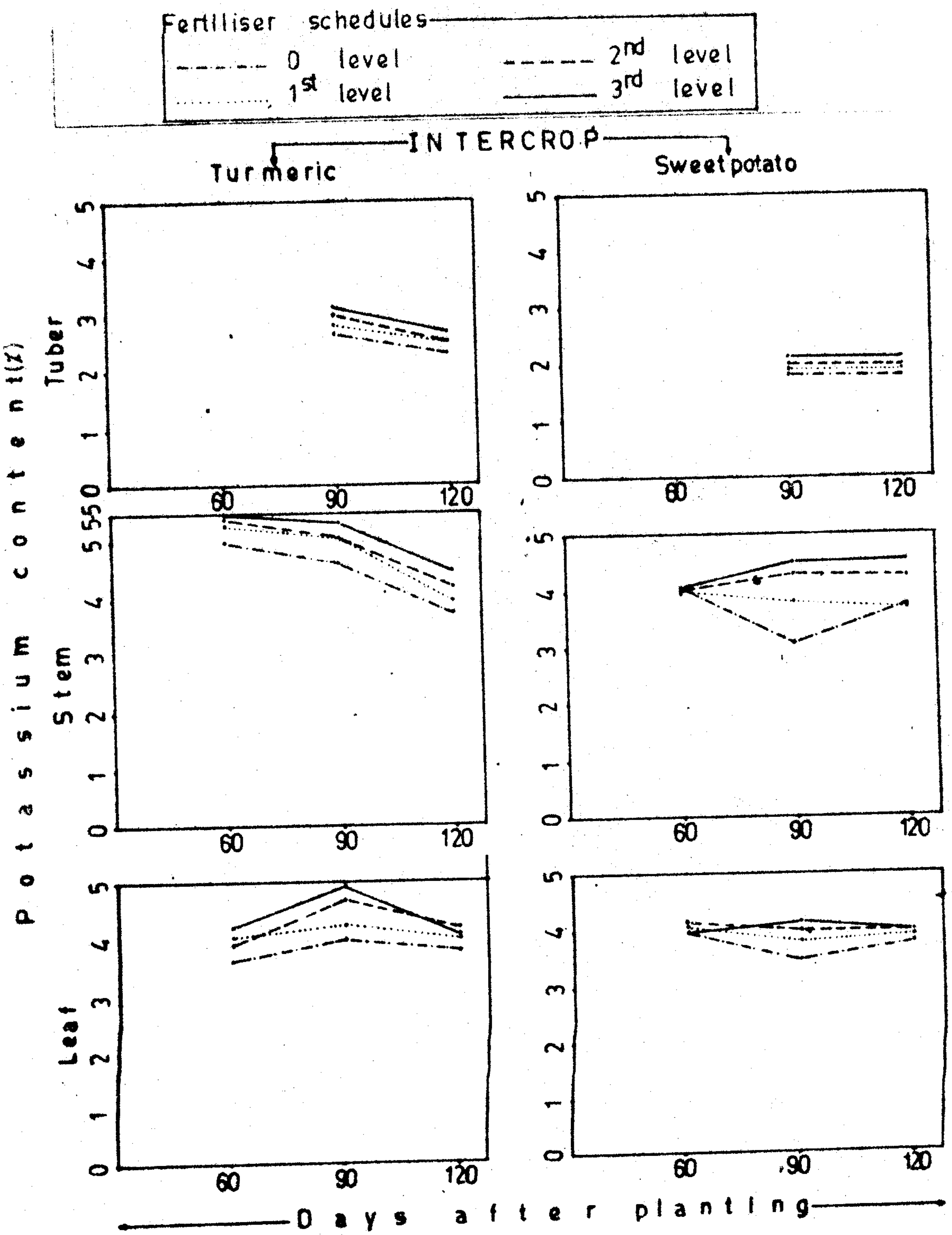
Sweet potato: The K content of leaf due to fertilizer levels did not show any significant trend both at 90 or 120 days after planting. In general, the increment in K content due to successive increase in fertilizer schedule was marginal both at 90 days (3.47 to 4.15) and 120 days (3.69 to 3.99).

IV.10.7(b). Effect of different levels of fertilizer on leaf potassium content of turmeric and sweet potato under sole cropping system

Data pertaining to leaf potassium content of turmeric and sweet potato under sole cropping system are presented in Fig. 11(b).

Different fertilizer schedules could not bring any significant changes in the leaf K content during 90 or 120 days. During

FIG.11 a. EFFECT OF FERTILIZER LEVELS ON POTASSIUM CONTENT OF LEAF, STEM AND TUBER OF TURMERIC AND SWEET POTATO AS INTERCROPS IN ARECANUT



Fertiliser schedules
0 level
1st level
2nd level
3rd level
INTERCROP
Turmeric
Sweet potato
Potassium content(%)
Tuber
Stem
Leaf
0
1
2
3
4
5
60
90
120
Days after planting

FIG. 11 a.

FIG.11 b. EFFECT OF FERTILIZER LEVELS ON POTASSIUM CONTENT OF LEAF, STEM AND TUBER OF TURMERIC AND SWEET POTATO AS SOLE CROPS

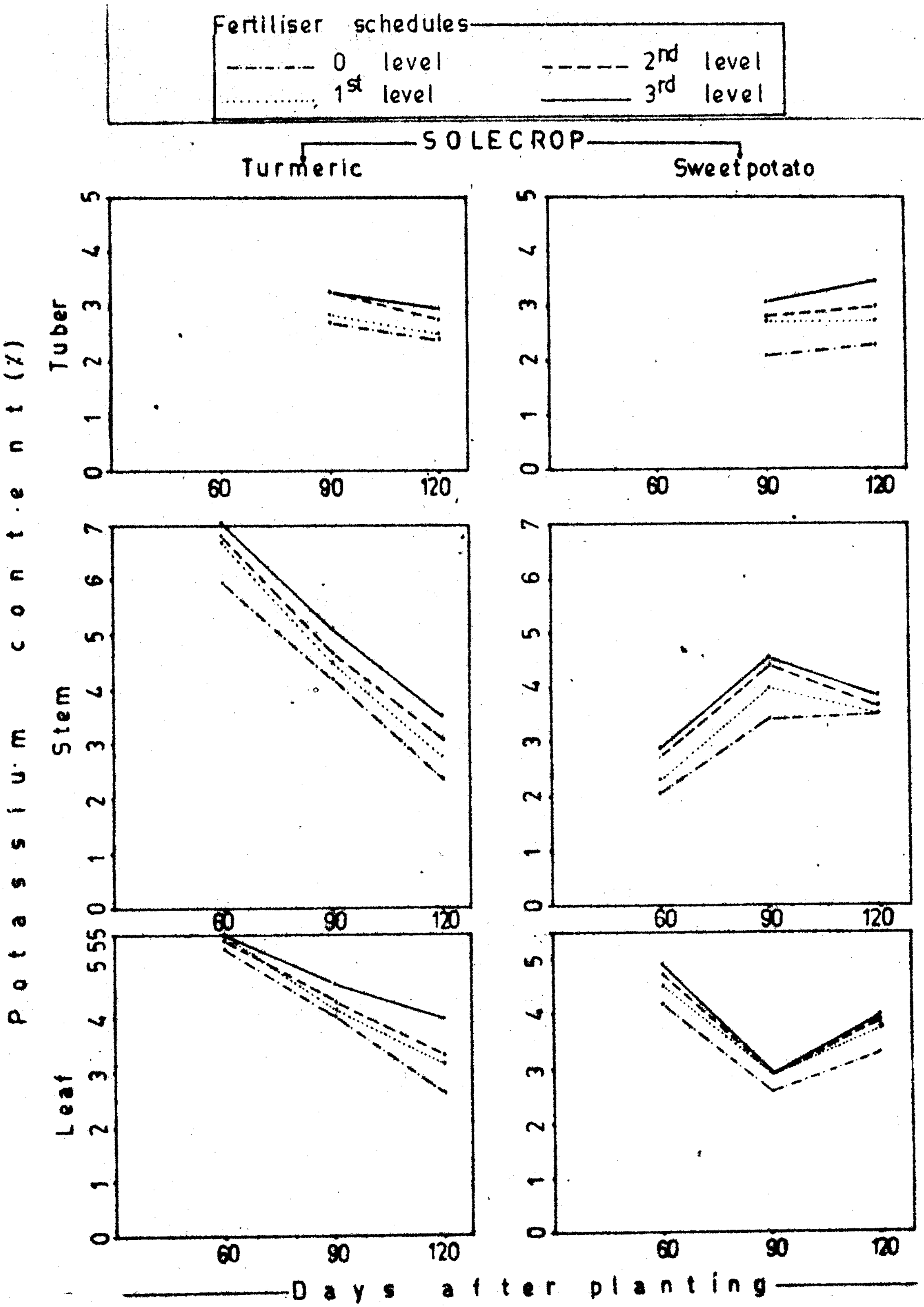

Fertiliser schedules
0 level
1st level
2nd level
3rd level
SOLECROP
Turmeric
Sweet potato
Potassium content (%)
Tuber
Stem
Leaf
0 1 2 3 4 5 6 7
60 90 120
Days after planting

FIG. 11 b.

1979-80, control (2.50) differed significantly over all other treatments (3.20 to 3.83). During both the years, leaf K declined from 90 to 120 days. Mean values showed an increase in K content from 3.96% in control to 4.58% at the highest level of fertilizers at 90 days and 2.61% to 3.83% at 120 days. The reduction in K from 90 to 120 days was conspicuous at low levels of fertilizer compared to the higher schedules.

Sweet potato: Leaf K content of sweet potato did not exhibit any significant variation due to different fertilizer levels either at 90 or 120 days after planting during both the years. The K content at 120 days was more than that at 90 days. The K content of mean values increased from 2.62% to 3.36% in controls and from 3.00% to 3.86% at the highest fertilizer schedules from 90 to 120 days respectively.

IV.10.8(a). Effect of fertilizer levels on potassium content in stems of turmeric and sweet potato in arecanut as intercrops

Data relating to K content in stems of turmeric and sweet potato are presented in Fig. 11(a).

Turmeric: Potassium content of turmeric stems did not vary significantly due to fertilizer levels at 90 days after planting where at 120 days, all the fertilizer schedules significantly recorded higher content of potassium (4.96% to 5.63%) when compared to control (4.15%) during 1978-79. The differences in K content among fertilizer treatments did not, however, vary significantly. In general, K declined from 90 to 120 days. Similar trends were observed during 1979-80 but they did not show any significant variation among treatment means. Mean values showed decreased K from 4.66% to 3.77% from 90 to 120 days in control with comparable reduction from 5.41% to 4.59% under highest fertiliser schedules during the same period.

Sweet potato: Potassium content of sweet potato stems showed significant variation only at 120 days during 1978-79 due to highest fertilizer scheduels (5.0%) compared to control (3.85%). Similarly, the mean values of the two years at 120 days showed a significant superiority of the last two higher levels of fertilizers (4.27% and 4.51%) to the control (3.69%).

IV.10.8(b). Effect of fertilizer levels on potassium contents in the stems of turmeric and sweet potato as sole crops

Data pertaining to potassium content of the stems of turmeric and sweet potato under sole cropping systems are presented in Fig. 11(b).

Turmeric: Fertilizer levels did not bring any significant changes in K content in stems of turmeric though there was a general increase in K with the increase in fertiliser schedule both at 90 and 120 days after planting during both the years. Potassium content declined from 90 to 120 days after planting. Mean data showed an increase in K from 4.19% and 2.33% in controls to 5.08% and 3.50% with highest fertiliser schedule at 90 and 120 days after planting respectively.

Sweet potato: Increasing fertilizer schedules increased the potassium content in the stems of sweet potato, but the differences were not statistically significant during both the years. Potassium content declined in all the treatments from 90 to 120 days after planting during 1978-79 whereas a reverse trend was seen during the next year. An increase from 3.3% in control to 4.60% K at the highest level of fertilizer at 90 days and with corresponding figures of 3.51% and 3.76% at 120 days after planting was seen in the mean data.

IX.10.9(b). Effect of fertilizer levels in potassium content of turmeric and sweet potato tubers in arecanut as intercrops

The data pertaining to potassium content of turmeric rhizomes and sweet potato tubers are given in Fig.11(a).

Turmeric: Increasing fertilizer levels increased potassium content in the turmeric rhizomes. However, the difference were significant only during 1978-79 at 90 days after planting. The last two higher levels of fertilizer significantly recorded higher values (3.0% and 3.16%) when compared to the control (2.73%). However, there were not significant differences either at 90 or 120 days after planting in the mean values of two years.

Sweet potato: Potassium content of tubers under varied levels of fertilizers did not show any significant differences at 90 or 120 days after planting, during 1978-79 though there was higher levels of fertilizers. During the second year, the differences were significant only at 90 days after planting. Control and first schedule of fertilizers recorded significantly lower values (2.06% and 2.03%) when compared to the two higher levels (2.13% and 2.20%) respectively. Mean data exhibited no significant variations in K content of tubers either at 90 or 120 days after planting.

IV.10.10. Effect of fertilizer levels on potassium content in turmeric and sweet potato tubers when grown as sole crops

The data pertaining to potassium content in turmeric rhizomes and sweet potato tubers are presented in Fig.11(b).

Fertilizers to turmeric increased K content in the tubers. During 1978-79, at 120 days after planting as well as in the mean values, the potassium content was significantly higher at the two levels of fertilizers (3.1% and 2.54%).

Sweet potato: Potassium content in sweet potato tuber increased with the increase in the levels of fertilizers at 90 days during 1978-79 and at 120 days during 1979-80. Control tubers significantly recorded the lowest K content (2.0% and 2.26%) over the two higher levels of fertilizer schedules (3.23%, 3.76% and 3.06%, 3.36%).

The mean data showed an increase in K content in tubers with the increase in NPK both at 90 and 120 days from 2.18 to 3.08% and from 2.29% to 3.43% respectively. While all the fertilizer levels were significantly superior to control at 90 days, the last two higher fertilizer levels were significantly superior to control at 120 days after planting.

IV.10.11(a) Effect of fertilizer levels on leaf magnesium content of turmeric and sweet potato as intercrops in arecanut

The data on leaf magnesium content of turmeric and sweet potato leaves grown as intercrops in arecanut in response to varied fertilizer levels are presented in Fig.12(a).

Turmeric : Though there was an increase in magnesium content of leaves with increasing levels of fertilizers in both the years, significant differences in fertilizer schedules were observed in 1978-79 at 120 days, in 1979-80 at 90 days and in the mean values of both dates of observation. The magnesium content increased from 2.86 to 3.71% at 90 days and from 2.74% to 3.32% at 120 days after planting.

Sweet potato: Fertilizers could not bring any significant differences in magnesium content of leaves. However, magnesium content increased with the increase in fertilizer schedules durin the course of study from 2.13% to 2.24% at 90 days and 2.15% to 2.37% at 120 days after planting.

IV.10.11(b) Effect of fertilizer levels on magnesium content in turmeric and sweet potato leaves grown as sole crops

The data on the magnesium content of leaves in turmeric and sweet potato grown as sole crops in response to varied fertilizer levels are presented in Fig.12(b).

Turmeric: Mean data showed significant differences among the fertilizer schedules with respect to magnesium content of leaf. Increasing fertilizer levels increased leaf

FIG.12 a. EFFECT OF FERTILIZER LEVELS ON MAGNESIUM CONTENT IN LEAF, STEM AND TUBER OF TURMERIC AND SWEET POTATO AS INTERCROPS IN ARECANUT

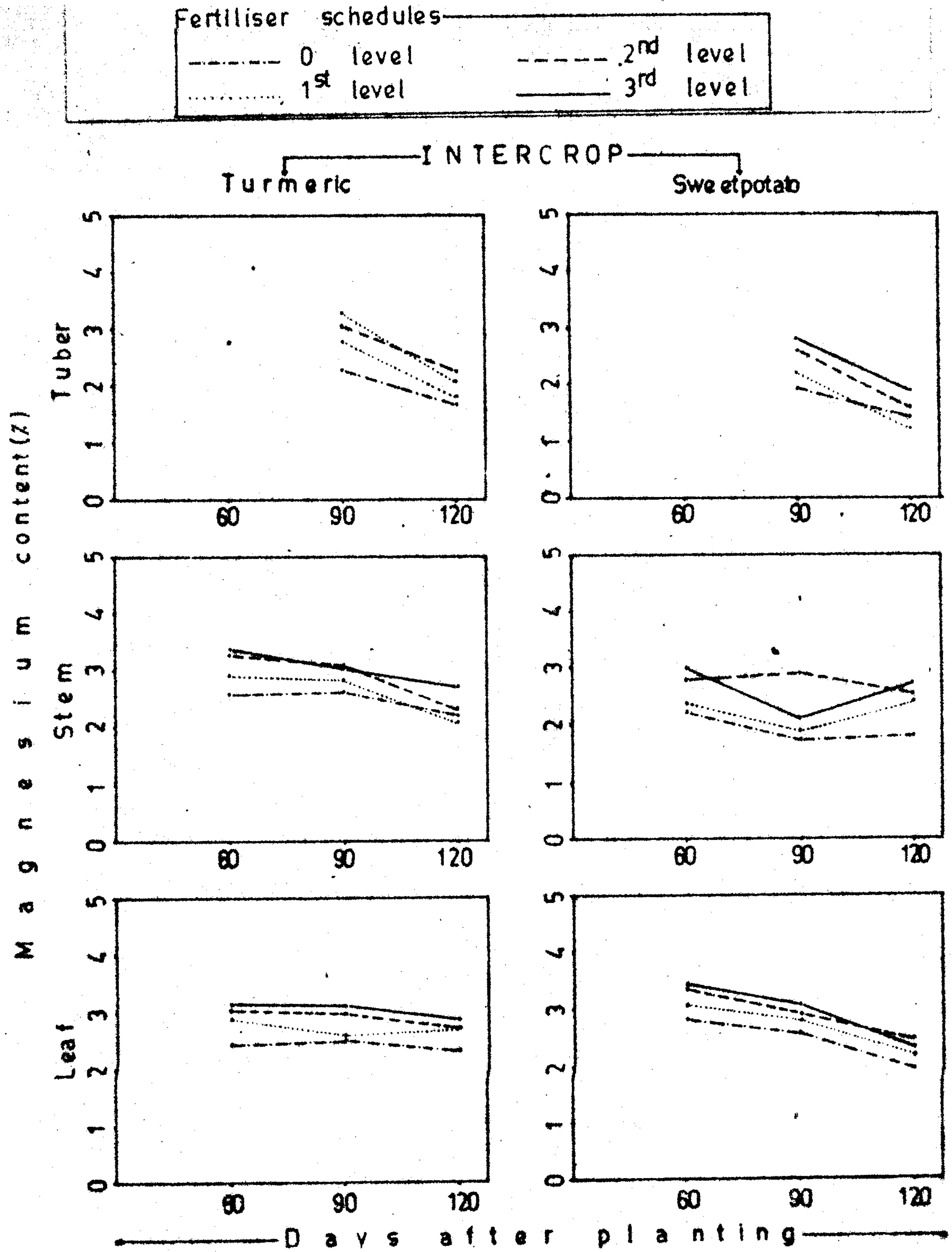

Fertiliser schedules
0 level
1st level
2nd level
3rd level
INTERCROP
Turmeric
Sweetpotato
Magnesium content (%)
Tuber
Stem
Leaf
0
1
2
3
4
5
60
90
120
Days after planting

FIG. 12 a.

FIG. 12 b. EFFECT OF FERTILIZER LEVELS ON MAGNESIUM CONTENT IN LEAF, STEM AND TUBER OF TURMERIC AND SWEET POTATO AS SOLE CROPS

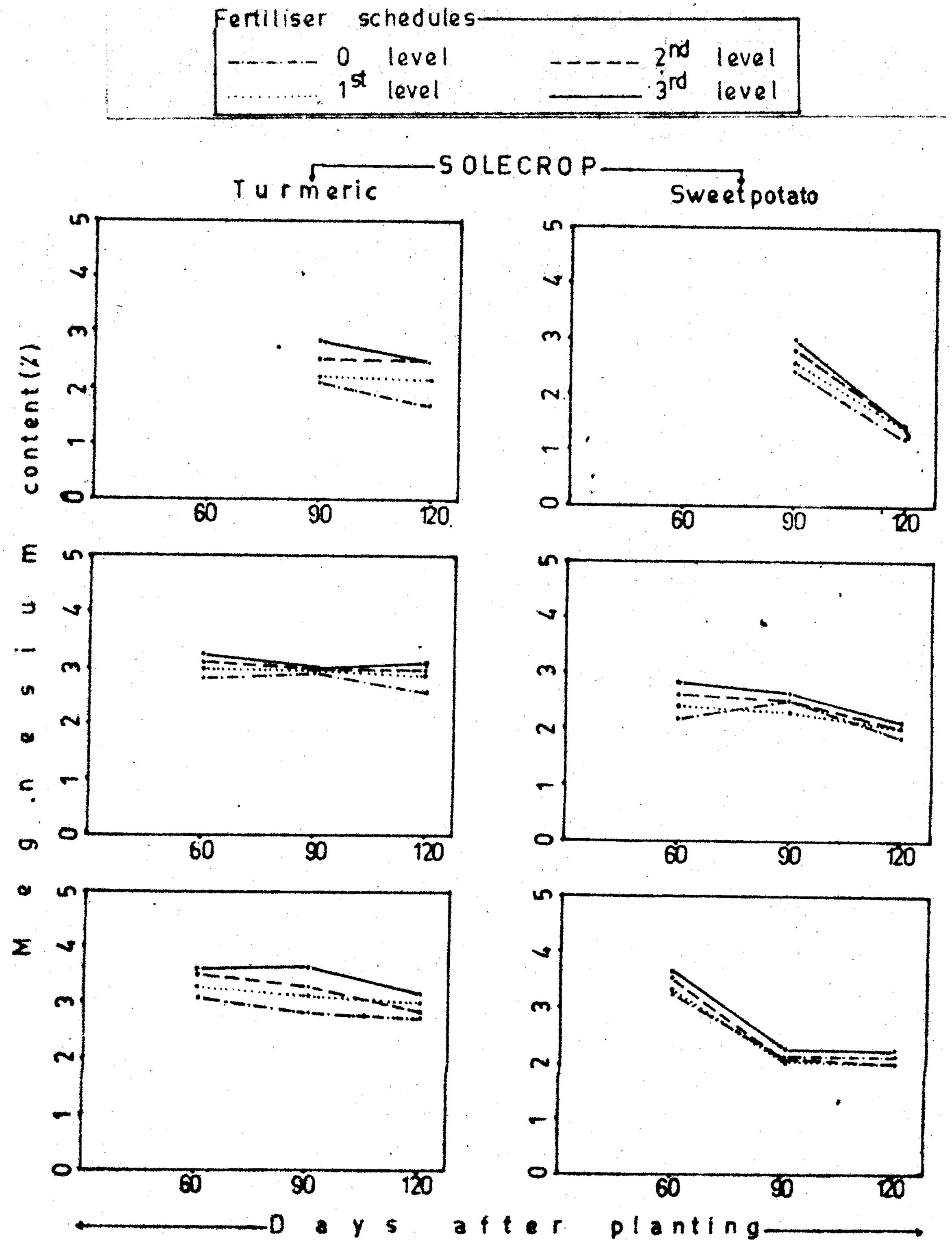

Fertiliser schedules
0 level
1st level
2nd level
3rd level
SOLECROP
Turmeric
Sweet potato
Magnesium content (%)
Days after planting

FIG 12b

magnesium from 2.84 in control at 90 days after planting. The same effect was carried out to 120 days where highest level of fertilizers recorded significantly high value (3.3%) when compared to control (2.7%).

Sweet potato: During 1978-79 at 120 days after planting, the magnesium content of sweet potato leaves was increased with the last two levels of fertilizers significantly. The differences during 1979-80 were negligible. The mean data indicated that increase in fertilizer schedules increased leaf magnesium content of sweet potato leaves.

IV.10.12(a) Effect of fertilizer levels on magnesium content of stems in turmeric and sweet potato grown in arecanut as intercrops

The data on the magnesium content of turmeric and sweet potato stems grown in arecanut in response to varied fertilizer levels are given in Fig.12(a).

Turmeric: Increasing fertilizer levels increased xxxx magnesium content in stems. The highest level of NPK significantly differed with others both during 1978-79 and in the mean values of xxx two years at 120 days after planting. There were no differences during 1979-80. Magnesium content decreased with time as with control from 2.63% to 2.14% and from 3.18% to 2.78% in the highest NPK schedule.

Sweet potato: Fertilizer schedules did not bring about any significant differences in magnesium content of stems at 90 days after planting during 1978-79. At 120 days, all the fertilizer schedules (2.66% to 2.96%) recorded significantly higher magnesium compared to control (1.80%). The effects were carried out to next year also. Mean data showed that fertilizers at the highest level (3.65%) increased magnesium content of stem significantly over control (1.76%) and first level (2.43%).

IV.10.12(b) Effect of fertilizer levels on magnesium content of stems in turmeric and sweet potato as sole crops

The data on magnesium content of turmeric and sweet potato stems as sole crops in response to varied fertilizer levels are presented in Fig.12(b).

Turmeric: There were no differences in magnesium content of stems in turmeric during 1978-79. The differences were significant only at 120 days after plating during 1979-80, where the highest level of fertilizers recorded the maximum magnesium content in stem (3.1%) when compared to control (2.56%). The same trend was observed in the mean data.

Sweet potato: Magnesium content of sweet potato stems did not differ significantly due to varied levels of fertilizers during 1978-79. During the second year, only higher level of fertilizers could establish significant difference with control at 90 days after planting. Mean data showed significant differences both at 90 and 120 days after planting. At 90 days, the highest level of NPK schedule (2.59%) significantly differed with control (2.49%) whereas at 120 days, the last two levels

(2.15% and 2.24%) differed from control (1.82%) significantly.

IV.10.13(a) Effect of fertilizer levels on magnesium content of turmeric and sweet potato tubers grown in arecanut as intercrops

The data on the magnesium content of tubers grown in arecanut in response to varied fertilizer levels are presented in Fig.12(b).

Turmeric: Fertilizer levels brought significant differences in magnesium content of tubers. During 1978-79, at 90 days after planting, all the fertilizer levels recorded significantly higher values of magnesium over the control where during the same period in 1979-80, only the fertilizer level of 140 N, 120 P_2O_5 and 240 K_2O kg/ha was superior to control. However, mean data did not show any significant differences among the treatments.

Sweet potato: Sweet potato tubers did not record any significant differences in magnesium content due to fertilizer treatments in the first year. However, during 1979-80, differences were significant only at 120 days after planting where the higher two levels of fertilizers (1.93% and 2.01%) could significantly increase tuber magnesium content over the control (1.63%) and the lower level of fertilizer (1.60%). Mean data showed that magnesium content of tubers increased in the last two levels of fertilizers (2.56% and 2.76%) when compared to control (1.96%) at 90 days. The differences at 120 days were not statistically significant.

IV.10.13(b) Effect of fertilizer levels on magnesium content of turmeric and sweet potato tubers grown as sole crops

The data on magnesium content of turmeric and sweet potato tubers grown as sole crops in response to varied fertilizer levels are presented in Fig.12(b).

Turmeric: Increasing levels of NPK increased magnesium content of rhizomes. However, the differences were significant only at 120 days after planting during 1978-79, where the control recorded significantly lower value (1.7%) compared to the last higher levels (2.43% and 2.33%). The differences in magnesium content of turmeric were not significant during 1979-80 due to variation in fertilizer schedules. Fertilizer schedules were significantly showed superior to control only at 120 days after planting.

Sweet potato: Though increasing levels of NPK schedules increased tuber magnesium content in sweet potato, they were not statistically significant. The magnesium content in general sharply declined from 2.42% to 1.32% in control and from 2.89% to 1.53% in the highest fertilizer level from 90 to 120 days after planting respectively.

IV.10.14. Effect of fertilizer levels on the calcium content of leaf, stem, rhizomes and tubers of turmeric and sweet potato as sole and intercrops in arecanut

The data on the effect of fertilizers in influencing the calcium content of the leaf, stem and tubers of turmeric and sweet potato have not been presented since there were no positive trends or significant differences in calcium content in most of the treatments.

DISCUSSION

CHAPTER .V

DISCUSSION

Research on intercropping systems with special reference to plantation crops being of recent origin, any discussion on these investigations faces the formidable task of identifying the relevant advances made in the already existing situations of paucity of literature on the one hand and of having to relay and draw upon resources from related disciplines to distil the essence of results on hand on the other. Though intercropping is an age old practice, investigations to maximise utilisation of resources under plantation crops have hardly made any impact and any discussion on these aspects would have to be therefore viewed from these limitations. The results on the current investigation entitled "Interaction of intercrops in maximising utilization of resources in arecanut stands (Areca catechu L.) in the Maidan tracts of Karnataka" presented in the previous chapter are discussed briefly in the context of objectives set out and in relevance to the literature available on the following aspects:

1) Utilisation of light, land and labour sources in an intercropping system in arecanut.

2) Interaction of plant densities of arecanut with intercropping intensities of turmeric and sweet potato-cowpea on the growth and yield attributes of intercrops.

3) Interaction of arecanut plant densities with intercrops

on the growth and yield attributes of arecanut in maximising gross income

4) Effect of fertilizer levels on the growth and yield of intercrops

5) Effect of fertilizer levels on the plant nutrient contents of sole and intercrops.

6) Fertility management of the intercropping system in arecanut on the growth and yield attributes of arecanut and in maximising the nutrient availability and gross income.

V.1. Utilization of light, land and labour resources in an Intercropping system in arecanut

Cropping practices all over the world particularly in the semi-arid tropics are gradually changing in the recent years in order to be able to produce more food crops from the same piece of land in a year. Though the concept of intercropping is an age old practice in Indian farming situations merited for its dependability of return compared with sole cropping, the subject of optimum utilization of light, land and labour resources under intercropping systems has not received adequate and integrated attention from a scientific point of view. This is particularly so in respect of plantation crops where traditional practices accentuated by local demands of farming communities have largely determined the existing intercropping systems. The scope for introducing new crops in the same piece of land where perennial plantation crops are raised and the possibilities to maximise the utilization of light and labour resources at the same time are bright in the coastal and hilly tracts of Karnataka where rainfall is generally adequate and moisture is not that limiting compared to the Maidan tracts. The results obtained from the present investigations draw attention to some of the interesting aspects on this subject which are discussed further.

V.1.1. Light interception as influenced by arecanut plant densities

The results of the present investigations have revealed that the total light interception was affected by the plant densities adapted for raising the arecanut crop. Wider spacings filtered through more light giving scope for introduction of crops in the interspaces. A reduction of total light interception from about 41.8 to 34.1% with the increase in spacings of arecanut crop is an indication of the unutilised light as a resource material in plantation crops. Muralidharan (1980) also indicated that a 14 year old arecanut plantation with a spacing of 2.7m x 2.7m allowed 32.7 to 47.8% of incident light rays to pass down through the canopy depending on the time of the day. He further said that intercropping system utilized less light and nutrients than pure stand of arecanut. The comparison of these values with those of the current investigations show that the per cent incident light that passed through the canopy was found to be greater under Hirehalli conditions of the Maidan parts of Karnataka than that found in the coastal area. Moreover, the readings here were taken just around mid-day in contrast to about three readings taken during the entire day in those observations. This explains how more incident rays of light were observed to pass through arecanut canopy at Hirehalli. The point of interest from the observations of the current investigations is that light resource utilisation needs to be re-examined critically especially when it is brought out that wider spacings allow 64 to 66% of incident light rays to pass through the canopy of arecanut. In this context it may be essential not only optimise the spacings-cum-plant density but also to locate the optimum planting geometry so as to give scope for accommodating intercrops in order to maximise interception of light. In the present investigations, a point of observation is that while altering the plant densities, the planting geometries had also been incidentally modified. For instance, the conventional planting with a spacing of 2.7m x 2.7m and the spacing of 3.6m x 3.6m had both square shape while the closer spacing of 1.8m x 3.6m and the other spacing of 2.7m x 3.6m provided a rectangular shape. These two geometries perhaps facilitated in allowing for a larger part of the day, a greater proportion of incident rays to pass through the arecanut canopy as more of light could seep through in the North-South direction.

Intercrops chosen for these investigations behaved differently in intercepting light received at their canopies and as modified by the planting densities. For instance, wider spacings of 2.7m x 3.6m or 3.6m x 3.6m received 47,000 lux compared to 37,000 lux in other spacings. The intercrop turmeric was found to utilise about 64 to 75% of this light under different densities of arecanut. Sweet potato on the other hand was found to intercept 73 to 78% light received under different planting densities.

An interesting feature about light interception is that light interception seems to improve under an intercropping system with perennial and annual crops as components as in the present investigations than when these two crops are taken as sole crops. This can be inferred from Table.1.1. It is seen that the total light interception by arecanut alone averaged over four plant densities was about 38% and that of the sole crop of turmeric was 30%. Put together the theoritical interception of light would be about 68% while the intercropping system of arecanut and turmeric was actually found to intercept about 78% of total light. Similarly, the total interception of arecanut sweet potato was found to be 82% while the summation of the interception of the two sole crops was only about 63%. Thus there seems to be wider scope for better utilization of light resource under an intercropping system. It is possible that an intercrop offers a better scope for interception and utilization of incoming light because of the growing canopy aided by fertilization and planting geometry and a possible utilization of even the reflected light from the partially white to greyish, white trunks of the arecanut palm which needs confirmation. Such a better utilization of light under intercropping systems than under sole cropping systems was perhaps made possible from spatial use of light at different vertical layers of the component crops of of arecanut with either turmeric or sweet potato-cowpea. This may be regarded as biological complimentarity as interpreted in earlier studies by Willey (1979). In contrast to this, Muralidharan (1980) found that intercrops suffered due to competition for light since only 33 to 48% of the total radiation reached the intercrops thus bringing down economic yields of all intercrops.

V.1.2. Utilization of land resources in arecanut

Interspaces in any plantation crop do generally provide scope for greater utilisation of this land resource for taking intercrops especially when there is adequate light passing down the tall structure of the main crop. In the early stage of the crop, the utilization of floor spaces can be high. In arecanut plantation a spacing of 2.7m x 2.7m has been regarded as optimum under pure stand (Bhat et al., 1972, Anon., 1974, 1976 and 1977). With the roots of arecanut exploiting only 60-75 cm radius from the base of the palm, 69% of the land is estimated to be not effectively utilized by the root system of arecanut (Sannamarappa and Muralidharan, 1982), thus providing scope for better use of this land resource.

The present investigations had one of its objectives as to identify the optimum proportion of intercrops that could be raised under varied planting densities and plant space geometries of arecanut plantation. The spacings of 1.8m x 3.6m and 2.7m x 2.7m had high populations of 1543 and 1371 plants respectively while the spacings of 2.7m x 3.6m and 3.6m x 3.6m had 1028 and 771 plants respectively. The choosing of these plant densities thus provided an opportunity of testing, whether 60-70 per cent of the under-utilized floor spaces as claimed by earlier workers (Bhat and Leela, 1969, 1978 and Sannamarappa and Muralidharan, 1982) can be used through varied intensities of intercrops by first altering the plant densities, which indirectly modified the plant geometries also. It was envisaged that by mere altering plant densities from as low a population as 771 plants/ha on the one extreme and doubling this density to 1543 plants/ha on the other, the scope of testing better utilization of inter floor spaces would be enhanced. Enhancing intercropping intensity especially under wider spacing was also though to be helpful in augmenting the total biomass production and income from the intercropping system as a whole. Muralidharan et al. (1976), Singh and Roy (1977) reported no substantial differences in yield when arecanut was raised under spacings of 1.8m x 3.6m and 2.7m x 3.6m as against the conventional spacing of 2.7m x 2.7m. The present investigations which were planned in the light of these findings, to effectively utilize interspaces and maximise productivity have revealed certain interesting features in respect of land resource use in arecanut as influenced by altering planting densities and testing of two intensities of interconropping of turmeric and sweet potato-cowpea. In pure stands of arecanut, yields of arecanut were proportionately reduced with the reduction in the plant densities from 19331 kg/ha in 1.8m x 3.6m spacing with a plant density of 1543 plants/ha to 9836 kg/ha in 3.6m x 3.6m spacing with 771 plants/ha as seen from the summary table (Table.V.12). It is also seen that increased spacings reduced the yields of arecanut when grown in an intercropping system with turmeric under both the intensities of intercropping from 19921 kg/ha to 12802 kg/ha. Compared to the reduction seen in the pure stands of arecanut, the reductions of arecanut yields under intercropping were minimal and under the spacing of 3.6m x 3.6m there was an yield advantage of about 3000 kg/ha over that of the pure stand. These results are therefore a step further in confirming and re-iterating the fact that both under pure stand as well as under intercropping with turmeric, arecanut needs to be raised under the narrow spacing of 1.8m x 3.6m giving a rectangular shape compared to the square shape of conventional spacing with 2.7m x 2.7m. Perhaps coupled with the advantage of the rectangular shape as well as with the feature of allowing for a larger part of the day a greater proportion of incident rays to pass through the arecanut canopy from the North-South direction, the utilization of the inter floor spaces under this narrow spacing with high plant density was optimum. This can be further examined from the high yields obtained by the intercrop of turmeric both under low (4490 kg/ha) and high

Table V.1.2. Land resource use in arecanut as influenced by altering plant densities and testing two intensities of intercropping of turmeric and sweet potato—cowpea

Arecanut spacing	Cropping system	Arecanut yield (kg/ha)	Turmeric yield (kg/ha)	Total income (Rs./ha)	Arecanut yield (kg/ha)	Sweet potato yield (kg/ha)	Cowpea yield (kg/ha)	Total income (Rs./ha)
2.8 m x 3.6 m	Sole crop	19,331	-	32,867	15,829	-	-	26,909
	Intercrop	19,921	a) 4,490	38,355	12,186	a) 3,227	504	26,519
			b) 6,028	39,893		b) 3,706	794	24,580
2.7 m x 2.7 m	Sole crop	17,320	-	29,444	14,546	-	-	24,728
	Intercrop	16,772	a) 4,239	32,751	19,419	a) 3,458	679	36,422
			b) 5,322	33,834		b) 3,841	788	36,912
2.7 m x 3.6 m	Sole crop	16,776	-	28,519	18,240	-	-	31,008
	Intercrop	14,426	a) 3,578	28,112	17,656	a) 3,931	759	33,864
			b) 5,637	30,161		b) 5,101	840	34,575
3.6 m x 3.6 m	Sole crop	9,836	-	16,721	12,161	-	-	20,673
	Intercrop	12,802	a) 2,747	24,510	9,231	a) 4,301	790	19,782
			b) 3,925	25,688		b) 5,545	891	20,583

a) = 40% intensity

b) = 60% intensity

(6028 kg/ha) intensity. Thus, it was observed that this plant spacing of 1.8m x 3.6m provided a high income of Rs.32,867 and Rs.39,124/ha in pure and intercropped arecanut respectively compared to proportionate reductions in the total income from other spacings ranging from Rs.29,444 to Rs.16,721/ha in pure stands of arecanut and from Rs.33,294/ha to Rs.25,009/ha under the intercropping systems of turmeric.

The picture is altogether different when sweet potato-cowpea combination was taken for intercropping in arecanut. The yields of pure stands of arecanut ranged from 15829 kg/ha with the spacing of 1.8m x 3.6m to 12161 kg/ha with the spacing of 3.6m x 3.6m. Here it is only this last spacing which brought down the yield considerably compared to the proportionate reductions observed with the increasing in spacings. The yield of arecanut when intercropped with the sweet potato-cowpea combination also proved to be different under different spacings. Both the spacings of 1.8m x 3.6m and 3.6m x 3.6m provided the lowest yields of 12186 kg/ha and 9231 kg/ha. The highest yield of arecanut of 19419 kg/ha was obtained with the conventional spacing of 2.7m x 2.7m closely followed by 18240 kg/ha with the spacing of 2.7m x 3.6m. Intercrops of sweet potato and cowpea had a positive trend of increased yields with the increase in the levels of spacings under both the crop intensities. Under 40% intensity, the sweet potato-cowpea yielded 3227 + 504 kg/ha which rose to 4301 + 790 kg/ha at the highest level of spacing. For the 60% intensity, the corresponding figures were 3706 + 794 kg/ha and 5545 + 891 kg/ha respectively. However, the maximum income of Rs.36,912/ha was obtained from arecanut sweet potato-cowpea combination at 60% intensity. Though these intercrops provided high yields, they could not compensate for the yield reduction in the main crop in providing higher income.

The influence from these results is that land resource utilization is perhaps optimum under arecanut turmeric intercropping system, which gave nearly two to three times the income of that obtained from sweet potato-cowpea intercropping. The best combination was the narrow spacing of 1.8m x 3.6m with a rectangular geometry having a high population of the main crop of 1543 palms/ha and 60% of the intercropping intensity of turmeric. It is perhaps possible that this closer planting along with a high intensity of intercropping in this spacing combination-cum-geometry must have brought in beneficial associative effects in the dynamic nature of the soil involving chemical and biological process helping in better utilization of the nutrients. More plant cover in a crop combination (Khanna and Nair,1977) or increased root volume because of crop combinations were found to be helpful in increasing the plant cycling fractions of the nutrients and in reducing the direct loss of nutrients in percolating water (Martin, 1977). It is thus possible that this combination, spacing and geometry of 1.8m x 3.6m with rectangular shape was ideal in utilization of all the land resources inclusive of moisture, nutrient and inter floor spaces in the arecanut turmeric intercropping system.

It is interesting to study the role of intercropping in respect of enhancing the crop intensity index which is a measure of land use efficiency proposed by Manogay et al, (1978). In the current studies on the intercropping system in arecanut, it was found that the CII increased from 0.70 and 0.64 in the sole crops of turmeric and sweet potato-cowpea rotation to 1.28 and 1.29 in the respective intercropping systems in arecanut. This conspicuous positive effect on CII is an indirect indication of better utilization of land resources under intercropping systems. However, just based on CII one cannot determine whether any one particular intercropping system is better than the other as in the present case, as CII merely indicates how best land and time resources are utilized but not how good is the biological efficiency or which system is the most paying enterprise. Therefore, the concept of Land Equivalent Ratios which can assess the biological efficiency of intercropping system as initiated (IRRI,1974) and tested (Willey,1978) were computed for these studies. These ratios for different intercropping systems when managed under varying fertilizer levels indicated that intercropping systems under higher levels of fertilizers always improved the LER. Arecanut-turmeric as well as arecanut-sweet potato intercropping, systems had an LER of about 1.24. With increasing fertilizer levels, LER in arecanut-turmeric ranged from 1.63 to 1.78. In case of arecanut-sweet potato intercropping, the LER marginally declined with the increased doses of fertilizers upto an LER 1.12. However, since sweet potato occupied only a part of the duration of turmeric, cowpea was also taken in rotation with sweet potato to make this combination equivalent in duration to that of turmeric. The LER of this combination in arecanut intercropping under no fertilizers was as high as 1.93. Increasing doses of fertilizers brought down the LER ranging from 1.82 to 1.72. The point of observation is that a high LER of 1.93 was found in arecanut sweet potato-cowpea intercropping system where even no fertilizers were applied. The explanation for this high LER under no fertilizers is to be sought from the fact that all the fertilizer levels upset the very grwoth and yield of sweet potato by tilting the balance more towards vegetative growth. In contrast, the treatment with no fertilizers behaved fairly normally and had a balance in growth between the vegetative and reproductive phases as seen from the tuber to shoot ratio of 1:13 compared to over 1:50 obtained in the fertilized treatments. It is thus significant that the LER which showed an increasing trend with increased fertilizer levels in case of arecanut-turmeric intercropping system should be showing a small declining trend in the arecanut-sweet potato-cowpea combination largely because of excessive vegetative growth under heavy fertilization. The results are indicative of the fact that land resources could be better utilized under the situations viz; i) when intercropping systems in arecanut with either turmeric or sweet potato-cowpea combinations are adapted which nearly double the crop intensity index compared to their sole croppings and ii) when the intercropping systems are judiciously fertilized as in arecanut turmeric-intercropping system where the LER could be raised from 1.24 with no fertilizers to 1.63 to 1.78 under varying fertilizer levels.

V.1.3. Utilisation of labour resources in arecanut

The specific yield advantages in any intercropping system have to be complimented with yet another benefit of labour resource utilization equatably over a long stretch of time so that any saving made on the cost of labour would greatly add to the economic advantage of the farmer. The present investigations have indicated yield advantages and income in arecanut turmeric intercropping system irrespective of fertilizer levels and at a plant density of 1573 palms accommodated in a spacing of 1.8m x 3.6m having a rectangular geometry at 40% intensity of intercropping. A prome into labour resource utilization would throw additional insight into the subject matter.

In the pure stands of arecanut the treatment with narrow spacing of 1.8m x 3.6m effected a saving on the cost of labour by about Rs.828/ha/yr compared to the wider spacing of 3.6m x 3.6m. The data on labour requirements have emphatically indicated that the narrow spacing is optimum in respect of labour utilization. The same spacing was found to be ideally suited in effecting savings on the labour compared to other spacings even in the intercropping system with two differing intercropping intensities. Irrespective of intensities of intercropping, there was a saving of Rs.2,310 on labour expenses on 385 persons at the lowest level of spacing of 1.8m x 3.6m compared to the wider spacing of 3.6m x 3.6m. A similar trend was observed in the arecanut sweet potato-cowpea intercropping system at the same level of spacing with a saving of Rs.1,830 on the labour cost. These data have clearly indicated that from the point of labour utilisation narrower spacing of 1.8m x 3.6m having a rectangular geometry was definitely superior to other combinations. There was a greater saving in labour expenses when the intensity of intercropping was 40%. It was also observed that wider spacings incurred heavy losses not only by way of additional labour requirement but also by lower yields and income accrued from these combinations as observed from the results obtained from these investigations. The labour requirement of the pure stand of arecanut was 763 persons costing Rs 4,578/ha/yr. The total labour requirement of arecanut and turmeric intercropping system irrespective of four levels of fertilizers tried was 723 persons costing Rs.4,338/ha/yr. A similar situation prevailed with arecanut sweet potato-cowpea intercropping. Thus comparing just the pure crop of arecanut with those of the intercropping systems, it was found that there was a saving of Rs.240 and Rs.300/ha/yr effected by cutting down 40 and 50 persons from the labour force in the two intercropping systems of arecanut and turmeric and arecanut and sweet potato-cowpea respectively. Muralidharan (1980) while studying the labour requirement in arecanut intercropping systems under coastal conditions found that the highest labour requirement of 337.3 work days of man/women was for the intercrop turmeric and it was as much as 87.5% of annual labour requirement of arecanut alone. In the present investigation also, it was found that the intercrop of turmeric required a high labour requirement of 205/ha/yr but the cost on labour was effectively cut down through careful management. These results are an indication to the fact that effective utilization of labour can be made by adjustment of plant densities so as to accommodate them in the rectangular geometry and then utilize the inter spaces by proper agronomic management involving fixing of the right intensity of intercrop and of providing the optimum soil moisture and nutrition. It is only the right combination of these under a given locality that can provide the maximum yield advantages and economic returns so that the cost on labour could be manipulated as per the requirement of individual cropping systems.

V.2. Interaction of plant densities of arecanut with intercropping intensities of turmeric and sweet potato-cowpea on the growth and yield attributes of intercrops

In any intercropping system, the main crop is allowed to dominate over the intercrops in all growth and yield aspects so that maximum benefit is obtained from the main crop in addition to whatever supplimental benefits that can be obtained from the intercrops. In this context, the resource facilities provided for the main crop and those provided for the intercrops are bound to interact bringing in steep competition in majaority of cases. In the present investigations the four plant densities of arecanut were found to interact with the intercropping intensities of turmeric and sweet potato-cowpea combinations in influencing the growth and yield attributes which are discussed further.

V.2.1. Growth attributes of intercrops as influenced by plant densities of arecanut and intercropping intensities

Leaf production in turmeric was not affected either due to planting densities of arecanut or due to intercropping intensities. In sweet potato, 2.7m x 2.7m spacing at 60% intercropping intensity produced 174 leaves compared to 151 leaves at the same spacing but with 40% intercropping intensity. Cowpea fared best with 287 leaves per plant at this spacing of arecanut. Interactions showed that at the same intensity of 40% intercropping, 2.7m x 2.7m spacing was superior to 1.8m x 3.6m.

The leaf area of turmeric increased with increasing intercropping intensities. The spacing of 2.7m x 2.7m with 40% intensity gave the maximum leaf area of 1.57 $m^2/0.25\ m^2$. Generally, 40% intensity recorded higher leaf area. Sweet potato also fared well with 40% intercropping. Higher spacings of 2.7m x 3.6m and 3.6m x 3.6m with 40% intercropping intensity produced higher leaf area of 2.35 and 2.44 $m^2/0.25\ m^2$ than other spacings.

Tillering and branching in intercrops were not affected by plant densities and intercropping intensities. In turmeric, tiller production was high at 3.6m x 3.6m when the intercropping intensity was 60% or when the spacing was 2.7m x 2.7m at 40% intensity. Wider spacings tended to increase the branching both in sweet potato and cowpea, leading to greater vegetative growth.

In turmeric, high biomass production was seen at a spacing of 1.8m x 3.6m and at 60% intercropping intensity. In sweet potato, wider spacings and 60% intercropping intensity provided high biomass. At 40% intensity, 2.7m x 3.6m spacing produced 13374 kg/ha compared to 9266 kg/ha at 1.8m x 3.6m spacing.

Intercrops fared well under an arecanut spacing of either 2.7m x 2.7m or 3.6m x 3.6m in producing higher number of leaves, leaf area and tillers. The intercropping intensity of 40% seemed to be good for these attributes. While biomass production increased with 1.8m x 3.6m spacing with 60% intensity in turmeric and at wider spacings in case of sweet potato.

V.2.2. Yield attributes of intercrops as influenced by plant densities of arecanut and intercropping intensities

In general, number of tubers in turmeric increased from 12.3 to 20.8 per plant from first to second year of experimentation indicating the possible residual benefits from fertilisation in the first year being carried over to second year. Both intercrops did not respond to either the planting densities of arecanut or to intercropping intensities. Volume and weight of tubers in turmeric decreased and it increased in sweet potato with the increasing in spacings. Tuber weight in intercrops increased with increased spacings. In sweet potato, it ranged from 321 to 471 g. Intercropping intensity at 40% was good at higher level of spacing. Turmeric yields decreased with wider spacings of arecanut from 5279 kg to 3336 kg/ha while sweet potato gave higher yields at 3.6m x 3.6m spacing of arecanut compared to 1.8m x 3.6m. Cowpea gave higher yields at wider spacings and at 60% intensity. The test weight of cowpea seeds increased at 40% intensity under wider spacings.

These discussions indicate that intercrops turmeric and sweet potato behaved differently in yield attributes in response to planting densities of arecanut and intercropping intensities. In turmeric, volume of tubers decreased with the increased spacings, while the weight and yield of turmeric increased with narrower spacings. Intercropping intensities of 60% was good for high yields. In sweet potati, wider spacings were found to be optimum in enhancing yield attributes and yields. Under wider spacings, weight and yield of tubers were higher at 40% and 60% intensities respectively. Cowpea yielded better with wider spacings but had a higher test weight at 40% intercropping intensity.

The salient features of these results indicate that spacings of either 2.7m x 2.7m or 3.6m x 3.6m were ideal for enhancing growth attributes in all the three intercrops, while biomass production of turmeric was best under 1.8m x 3.6m spacing. Increased level of spacings enhanced the yield attributes in sweet potato and cowpea, while the weight and yields of turmeric were higher with lower spacings. The response to intercropping intensities depended on the spacings provided. Better response to wider spacings in growth and yield attributes particularly in sweet potato might be because of better utilization of light and other resources. Earlier studies on mere spacings have indicated that wider spacings are as good as narrower spacings for arecanut (Muralidharan et al., (1976) and Singh and Roy (1977). Since the present research attempted to study the effect of spacings on intercropping intensities as well as on arecanut's performance there have been no real comparisons between earlier and present studies.

V.3. Interaction of arecanut planting densities with intercrops on the growth and yield attributes of arecanut in maximising gross income

Spacings not only affect the planting densities but may also affect the plant geometries thus bringing in changes in the total environment both in the above ground surface for light and other growth factors to interact with the plant community and in the inter floor spaces of the rowed crops for nutrients and other soil growth factors to interact with the plant environment. Arecanut being a plantation crop having a tall structure and requiring wide spacings naturally affords greater ease and convenience for any modification in its environment by either merely altering the spacings or by modifying planting geometries so that the interspaces created may be very well utilized by suitable intercrops with the light intensities to interact positively with the main crop resulting in maximising productivity and gross income.

V.3.1. Growth attributes of arecanut as influenced by planting densities of arecanut and intercropping intensities

The growth attributes of main crop of arecanut as influenced by planting densities of arecanut and intercropping intensities are discussed briefly. Muralidharan (1980) found that the growth rate of arecanut was reduced in the intercropping bringing in reduction in elongation and girth of the trunk. However, in the present investigation it was found that internodal length and girth of the arecanut palm at the last exposed node was not affected by either plant spacings or intercropping intensities during the experimental period. The girth at the last exposed node was enhanced with a spacing of either 3.6m x 3.6m or 2.7m x 2.7m in the post experimental period. Bunch production was not affected by any treatment combinations in any of the years of observations. Wider spacings and 40% intensity had slightly higher number of bunches of 3.3 compared to all other treatments which ranged from 3.0 to 3.1 in the post-experimental period. These discussions in general indicated that growth attributes of arecanut were unaffected by plant densities and intercropping intensities.

V.3.2. Yield attributes of arecanut as influenced by plant densities of arecanut and intercropping intensities

The number of nuts per palm were higher under 2.7m x 3.6m (807) and 3.6m x 3.6m (877) over the lower spacings (523 and 655 nuts) in one year. In the post experimental period also 2.7m x 3.6m spacing provided higher number of nuts (913) compared to 1.8m x 3.6m spacing. Turmeric as an intercrop (1035) and at 40% intensity (1021) provided higher number of nuts as well as yields. Arecanut yield was maximum both in the pre-experimental (157 q/ha) and experimental period (188 q/ha) under the narrower spacing of 1.8m x 3.6m. In the pre experimental period 2.7m x 2.7m (157 q/ha) and 2.7m x 3.6m (147 q/ha) spacings also gave high yields which were superior to higher are still to be studied. The question turns to be hard when one considers the varied complex situations of intercropping such as geometries of these combinations, the intercropping intensities and the rooting habits of the components in relation to nutrient uptake and utilization.

V.4.1. *Growth attributes in intercrops as influenced by fertilizer levels*

The growth attributes of intercrops turmeric and sweet potato as influenced by fertilizer levels indicated a few features in the course of study which are discussed further. Tiller and leaf area production in turmeric were found to be marginally influenced with the increase in fertilizer levels. A level of 140 N, 120 P_2O_5 and 240 K_2O kg/ha favoured significantly higher tiller production and LAR than in control in the intercrop. The same level as well as the lower level of 70 N, 60 P_2O_5 and 120 K_2O kg/ha enhanced the number of functional leaves both in inter and sole crops. Higher doses tended to increase leaf area in the intercrop. This lower dose of 70 N, 60 P_2O_5 and 120 K_2O kg/ha is the recommended practice in Karnataka (Anon., 1978) while in Kerala the recommendations is 30 N, 30 P_2O_5 and 60 K_2O kg/ha (Anon., 1978). Turmeric responds to heavy manuring in some locations. According to Rao et al. (1979) 25 t of cattle manure or compost and 63 kg N/ha as oil cake was found to be optimum. However, they recommended 189 N, 63 P_2O_5 and 126 K_2O kg/ha for high yields in Andhra Pradesh. Nair (1964) reported that N and K_2O had significant effect on plant height, tiller production and yield while the response to phosphate was rather negligible. In the results presented, the growth attributes like tiller production, number of functional leaves produced, the leaf area and NAR were partially influenced by fertilizers confirming the need for fertilizer recommendations for turmeric and that the recommended dose for Karnataka holds good as far as response to fertilizers by way of growth attributes are considered. With regard to biomass production, a dose of 140 N, 120 P_2O_5 and 240 K_2O kg/ha was found to produce 10,400 kg/ha compared to 8,000 kg/ha produced by the lower dose in one year. An important observation to be made is however, on the negligible differences in the mean biomass production over two years data between the intercropped turmeric (8738 kg/ha) and the sole crop (8828 kg/ha) as also between different fertilizer levels. This must be because of the fact that fertilizers brought down both the LAR and RGLR values indicating that they did not have much impact on the growth aspects. Muralidharan (1980) however, found that intercrop turmeric produced between one third to half of its sole crop biomass. This observation was under a spacing of 2.7m x 2.7m with recommended fertilizers while the current observations were under varying fertilizer levels. That there were no differences between sole and intercrops of turmeric in biomass production is an indication that either light, land and other resources for intercrop were not wanting or that sole crop did not fare well beyond a certain limit.

It would therefore be interesting to compare these growth aspects with those of yield attributes to infer the effects of fertilizers on the total performance of intercrop turmeric.

Sweet potato is one of the intercrops being raised under plantation crops especially in humid tropics. However, the crops' requirements of fertilizers especially under semi dry tracts and under intercropping situations are not known.

Growth attributes such as branching, number of functional leaves and leaf area of sweet potato were not consistently influenced by fertiliser levels. In sole crop, branching was good at 70 N, 50 P_2O_5 and 70 K_2O kg/ha and functional leaves, leaf area and shoot weight at 140 N, 100 P_2O_5 and 140 K_2O kg/ha The LAR, NAR, RGR and RLGR as well as biomass production were not greatly influenced by fertilizer levels though the highest fertilizer level of 240 N, 150 P_2O_5 and 210 K_2O kg/ha recorded 29260 kg/ha compared to 26553 kg/ha by control in sole crop. Generally, the NAR and RLGR values in sole crop were higher by two to three times in intercrop. Mean values indicated that sole crop fare better than intercrop in respect of branching 21.96 and 15.69), functional leaves (233.4 and 190.7), leaf area (12.75 and 10.95 cm^2) shoot weight (623 and 522 q/ha in 1979-80) and biomass production (20411 and 14240 kg/ha). Thus from the point of fertilizer recommendations, a dose of 70 N, 50 P_2O_5 and 70 K_2O kg/ha or double this dose may serve well in providing optimum expression of growth attributes.

V.4.2. Yield attributes of intercrops as influenced by fertilizer levels

Among the yield attributes, the number of tubers produced by turmeric was found to be least affected by raising the crop either as an intercrop in arecanut or as a sole crop. The crop was not influenced by fertiliser levels too. Levels of fertilizers had no significant effect in tuberisation also in the intercrop turmeric while the sole crop responded either to 70 N, 60 P_2O_5 and 120 K_2O kg/ha or double this dose. The volume of tubers was higher in sole crop (1478 ml) than in intercrop (1141 ml), so also the weight of tubers being more in sole crop (1.57 kg) than in intercrop (1.22 kg) and with fertiliser dose of 140 N, 120 P_2O_5 and 240 K_2O kg/ha (1.97 kg). Yield of turmeric was not influenced by fertilisers during 1978-79 when intercrops provided on an average 2955 kg/ha compared to 6991 kg/ha obtained from sole crops. During the next year, the respective yields for inter and sole crops were 1947 kg and 7483 kg with the highest yield of 10233 kg/ha obtained from sole crop with no fertilizers. The mean data of two years also gave the same result of control (8500 kg) being superior to the highest level of fertilizers (5900 kg). In general, sole crop of turmeric provided nearly three times the yield of intercrop.

Yield attributes thus far observed present a contrasting picture in some aspects in comparison with the growth attributes presented earlier. While growth of turmeric was responsive upto a level of 70 N, 60 P_2O_5 and 120 K_2O kg/ha or double this dose in respect of tiller, leaf number, leaf area, NAR,

KMMR

RLGR and biomass production. Practically no differences between sole and intercrops in the biomass production, yield attributes and yield of turmeric showed an inconsistent behaviour to fertility levels. There was no response from the crop in respect of the number of tubers. The volume and weight of tubers were more in sole crop and they responded upto 70 N, 60 P2O5 and 120 K2O kg/ha or double this dose. The yield of the crop was not greatly influenced by fertilizers. Indeed, highest level of fertilizers brought down the yields partioularly in sole crops. These observations tend to project the thought that fertilizers in modest quantities were helpful in improving most of the growth attributes and some yield attributes of turmeric but were not evidently effective in enhancing yields. It is to be expected that either both above and below soil environments were not condusive in the reproductive phase of the crop or that transfer of nutrients from vegetative to reproductive parts did not take place in the right proportions. This must be particularly so in intercropping situations where light from above and nutrients from soil as well as from photosynthetic processes must have been limiting at some critical growth periods of crop especially during the later reproductive stages thus limiting the yield potentials inspite of heavy doses of fertilizers. This explains why the yields of intercrop turmeric were restricted by about three times compared to the yields of sole crop inspite of the fact that biomass production exhibited no tangible differences between intercrops and sole crops. Again a point of observation is that LAR values in intercrop was higher about three times than its sole crop. Perhaps this is an indication of high rate of leaf production leding to high vegetative growth reaching to the level of sole crop thus brining no differences in the biomass production between the inter and sole crops. It is thus obvious that vegetative growth was not hampered in intercropping situations but yields were greatly reduced. Muralidharan (1980) revealed that biomass enhanced by intercropping. Actual productivity of any sole crop was less than ten per cent of its potential productivity.

Sweet potato did not respond to fertilization in respect to number and volume of tuber produced. The weight of tubers was, however, adversely affected when sweet potato was raised as an intercrop (0.36 kg) in arecanut than when grown alone as a sole crop (2.62 kg). A fertilizer level of 140 N, 100 P_2O_5 and 140 K_2O kg/ha was about the dose for these characters. The yield of sweet potato when raised as an intercrop was adversely affected by fertilizer application by bringing down the yields from 4066 kg/ha with no fertilizers to 1331 to 1239 kg/ha with fertilizer levels tried. The sole crop did not show any definite response or adverse effect with fertilizer application.

These results on the growth and yield attributes of sweet potato seem to suggest that a low dose of fertilizers of 70 N, 50 P_2O_5 and 70 K_2O kg/ha or double this dose might be helpful in providing good expression of growth attributes while higher doses tend to adversely bring down the yields. With an ability to utilize the resources better, sole crop gave better expression of growth attributes perhaps at the expense of yield by over-vegetative phase and development. The adverse response of this intercrop to fertilizer application is again a pointer to the hypothesis that resources of light, soil and nutrients were not utilized well by the crop and perhaps the transfer of nutrients from vegetative parts to reproductive parts was improper and inadequate. There is also a possibility of not locating the ideal combination of fertilizers with the limited combinations tried in the current studies. For instance, Urio and Kasseb (1973) while obtaining highest yield of 42.7 t/ha with 150 N/ha alone, found that tuber yields decreased with combined applications of 25 or 50 kg P_2O_5/ha and 150 kg/ha. Togari (1950) observed that heavy N decreased yield of sweet potato and P did not affect its yield. Miller and Covington (1962) found no advantages with higher fertilizer dose of 100 kg N and 83 kg K_2O/ha. Thus, the present studies are more or less in conformity with these findings with perhaps a minimum dose of 70 N, 50 P_2O_5 and 70 K_2O kg/ha being sufficient to enhance growth attributes as well as yield of sweet potato. Among the legumes which fit into any intercropping system in field crops Maidan of Karnataka, cowpea stands as the most singular popular crop. With this in view and also to accommodate a short duration crop after the harvest of sweet potato having duration of five months so as to bring the total duration of these two crops

to about eight months which would be equivalent to that of the other intercrop selected viz., turmeric, cowpea was chosen for intercropping in these investigations. However, cowpea was also not influenced by the residual effect of fertilizers applied to the previous intercrop of sweet potato. The intercrop of cowpea produced an yield of 1438 kg/ha while sole crop yielded 2169 kg/ha irrespective of the fertilizer levels tried for the sweet potato crop. The residual effect of fertilizers was not seen either in the pod weight or 1000 grain weight of cowpea. The pod weight in the intercrop was 1964 kg/ha while it was 2873 kg/ha in sole crop. The 1000 grain weight was about 96 and 106 g in these two systems respectively. Fertilizers having had no marked influence on the yield attributes of previous crop of sweet potato itself, these yield attributes of cowpea seem to suggest that the nutrients available from soil as well as from applied fertilizers were all either exhausted or not made available adequately to the cropping system as a whole at the critical periods of requirement. Perhaps, the best explanation is that the previous crop of sweet potato has utilised most of the applied nutrients though these were not expressed through yield attributes but were seen to be manifested in the vegetative growth. This can be studied from the tuber to shoot ratio of sweet potato crop which was markedly influenced by the fertilizer levels adapted especially in the intercropping system where this ratio increased abnormally from 1:13 to 1:54 with the increase in fertilizer levels. In sole crop, though fertilizer levels did not bring such high proportionate increase in tuber to shoot ratios, a point for observation is that these were all above 1:3 indicating conversion of nutrients more for the vegetative growth. Yet, another aspect is that cowpea having been not directly manured at least as a starter dose of 10 N, 20 P_2O_5 and 10 K_2O kg/ha as recommended by University of Agricultural Sciences (Anon., 1982a) cowpea must not have responded to the residual fertilizer level of the previous crop.

V.5. Effect of fertilizer levels on the plant nutrient contents of sole and intercrops

Plant nutrition plays an important role in the expression of growth and yield of any crop. The sole and intercrops of turmeric and sweet potato in the present investigations when examined critically for their nutrient contents revealed that the fertilizer levels tried were not effective in influencing the yield of these intercrops to the desired extent. It is probable that the response was not that favourable because of 1) the initially medium to high native fertility of the experimental plots, 2) the fertilizer levels tried were rather high with that lower level having been started at 70 N, 60 P_2O_5 and 120 K_2O kg/ha for turmeric and 70 N, 50 P_2O_5 and 70 K_2O kg/ha for sweet potato-cowpea, 3) the fertilizer combinations were not to the actual proportionate requirements of the intercrops at their critical growth phases and 4) the high doses of fertilizers could only affect the growth attributes leading to higher vegetative growth rather than providing a balance between the vegetative and reproductive growth. In the present studies the fertilizer having been started at higher doses must not have given any response. The actual recommendation of fertilizer dose for turmeric sfor Kerala is 30 N, 30 P_2O_5 and 60 K_2O kg/ha (Anon.,1978). Heavy manuring to sweet potato is reported to drastically reduce the yield (Togari, 1950). While relating these with the plant nutrition aspects with the current studies only marginal. Only marginal differences were observed in the plant nutrient contents of the sole and intercrops in many instances. During the peak periods of the growth of sole and intercrops except for phosphorus content in a few instances the nitrogen and potash contents of all the plant parts analysed showed an increasing trend with the increasing fertilizer levels (Appendix II). Besidès, an interesting observation is that the magnesium content in general was found to raise sharply with the increase in fertilizer levels. For instance in the intercrop of sweet potato, magnesium content increased from 1.76% to 3.65% with higher dose of fertilizers. It is well known that higher magnesium content would lead to greater chlorophyll accumulation and such a situation would arise if light is not adequate as in an intercropping system. Phorphorus and potassium are both known to be highly essential in the right proportions for the reproductive growth and manifestation of yield and yield attributes of crops. In the present studies an inadequacy of phosphorus in the plant parts perhaps due to poor uptake of the element by the plant in contrast to the high uptake and accumulation of magnesium must have lead to an imbalance in nutrition of the plants leading to a better expression of the growth attributes rather than yield attributes. These aspects of plant nutrition need further critical examination through crop log studies to elucidate the fertilizer requirement of the crop in relation to the native fertility of the soil and the fertilizer doses to be provided.

V.6. <u>Fertility management of the intercropping system in arecanut on the growth and yield attributes of arecanut and in maximising the nutrient availability and income</u>

Management of the intercropping system in an arecanut plantation in respect of fertility of soil, growth and yield of the main crop and in maximising gross returns from the whole system itself involves considerable efforts in choosing the right intercrops, growing them in right intensities with appropriate agronomic practices and in meeting the combined demand as well as individual demands for resources such as light, land, moisture, nutrients, labour and capital. In the present investigations, initially, fertility evaluation was undertaken followed by routine soil tests in an effort to assess not only the inherent soil nutrient supplying capacity but also to determine the behaviour of main and intercrops to added fertilizers and to assess the final fertility status of the soil.

V.6.1. <u>Growth attributes of arecanut as influenced by varying fertilizer levels to the intercrops</u>

The growth attributes of arecanut palm such as height of the palm, girth and internodal length were found to be only marginally influenced by varying levels of fertilizers treatments. The palm height ranged from 6.35 m to 7.89 m with increasing levels of fertilizers showing the tendency of increased heights. The girth and internodal length of arecanut palm also exhibited marginal increase with the increasing levels of fertilizers. These observations tend to lead to the theme that some improvements in growth attributes of arecanut palm is possible due to the application of fertilizers to the intercrops besides supplying 100 N, 40 P_2O_5 and 140 K_2O g/palm. The effects perhaps could be measured with greater distinction in the long run with arecanut being a perennial crop.

V.6.2. Yield attributes of arecanut as influenced by varying fertilizer levels to the intercrops

Bunch production increased from pre-experimental period to experimental period from 3.13 to 4.3 and 2.73 to 3.99 in the turmeric and sweet potato-cowpea intercropped plots respectively indicating the beneficial role of fertilizers. The highest dose of 210 N, 180 P_2O_5 and 360 K_2O kg/ha to turmeric provided 4.44 bunches per palm in arecanut. Post experimental data showed a marginal decline in bunch production. The number of nuts produced per palm during the pre-experimental period was 824 and 545 respectively from the turmeric and sweet potato combinations. The respective figures for the experimental period were 1224 and 870, indicating that fertilization to turmeric and sweet potato did enhance the number of nuts produced by arecanut. The post experimental period showed a declining trend. A dose of 70 N, 60 P_2O_5 and 120 K_2O kg/ha for turmeric provided a highest number of nuts of 1472 per palm during the experimental period.

Interesting observations have been made in respect of response of arecanut crop to varied levels of fertilizers applied to the intercrops of turmeric and sweet potato. Fertilization to the intercrops in general was found to augment the production of nuts in arecanut by 25 to 50 per cent, with fertilization to turmeric exhibiting a conspicuous influence. During the experimental period, pure crop of arecanut produced an yield of 18,506 kg/ha while turmeric without fertilizers produced 19,239 kg/ha. All the fertilized treatments in case of turmeric produced significantly higher yields ranging from 26,087 to 30570 kg/ha. A dose of 70 N, 60 P_2O_5 and 120 K_2O kg/ha provided the highest yield both during experimental and post-experimental period. Fertilization to sweet potato did not have so much impact as to enhance the yield significantly over no fertilized plots or that of pure arecanut crop. From these, it can be inferred that while turmeric as an intercrop was beneficial to the main crop of arecanut by way of allowing better absorption and utilization of nutrients supplied to it, the sweet potato did not provide this benefit to the main crop. Perhaps, the nutrient supplied to this crop was exhausted for its own growth especially for vegetative development as seen from earlier discussions. These investigations clearly demonstrate that intercropping in arecanut is is not only feasible but is also beneficial to the main crop of arecanut if agronomic management is taken care of specially in respect of providing adequate nutrients both to the main as well as intercrops. For instance, significant adverse effects were observed when banana was intercropped with arecanut (Sannamarappa and Muralidharan, 1982) and that intercropping with banana did not bring any beneficial effects to arecanut (Roy, 1974, Nagaraja,1974 and Bhandary,1974). However, it was observed when six intercrops viz., turmeric, ginger, sweet potato, dioscorea, elephant foot yam and chicory were raised in arecanut, at Hirehalli under Maidan tracts of Karnataka, no significant differences in yields of arecanut were observed because of intercropping though many of them provided benefits in other aspects (Anon., 1982). Muralidharan (1980) reported that competition indices for nutrients were above unity in arecanut indicating that nutrients were not limiting for growth of arecanut. All these reports are indicative of the problem that fertilization was not taken care of adequately as these studies were conducted just under normal low doses of fertilizers while the current investigations could be regarded to have provided adequate fertilizers for better growth and yield expression of not only the intercrops but also of the main crop of areanut.

V.6.3. Nutrient uptake by arecanut crop as influenced by soil nutrition and varying fertilizer levels to the intercrops

Soil analysis prior to the experimental period indicated that there were no significant changes among the treatments for the characters like pH of the soil, available nitrogen, potassium and calcium content in the soil. The upper layer of 0 - 25 cm was found to generally contain higher amounts of nitrogen and potassium content while calcium content was higher in the lower layer of 25 - 50 cm soil depth. During the experimental period in 1980 the pH of the soil ranged from 6.00 to 6.33 in different treatments while the range was between 5.86 to 6.43 prior to the start of the experiment in 1978, indicating that there was not much of difference in pH over a period of two years. The data on the available nitrogen in soil indicated a very marginal increase in its content from pre to post experimental period with higher accumulation of nitrogen in the lower layer of 25 to 50 cm depth of soil. The potassium content showed a marginal declining trend in the top layer of 0 - 25 cm depth of soil content particularly under sweet potato intercrop from the pre to post-experimental period indicating a small but considerable uptake of this nutrient by sweet potato. In case of calcium content, there were minor fluctuations in the values between the years with 1979 showing lower values of calcium. Muralidharan (1980) found that leaf nutrient status of intercrops remained less than those of respective sole crops due to their poor biomass productivity under arecanut. Nutrients were not limited in mixed stands. In contrast to these insignificant changes in the soil nutrition aspect the plant nutrition as observed from the analysis of arecanut leaf indicated certain interesting features. In case of fertiliser levels in turmeric the nitrogen content of arecanut leaf gradually increased from 2.35% with no fertilizers to 2.48% and 2.47% at the higher levels of fertilizers, a trend similar to the yields obtained in arecanut. In case of sweet potato, it is significant that 2.57% nitrogen was recorded with no fertilizers compared to 3.2% to 3.4% found in other treatments. Incidentaly the yield of sweet potato was highest in this treatment without fertilizers. The phosphorus content of arecanut leaf was found to be 0.170% and 0.167% in the two higher doses in turmeric compared to 0.157% in control indicating a better uptake of phosphorus under higher levels of fertilizers applied to intercrops. Phosphorus content of arecanut leaf was higher both in control as well as in the highest dose of fertilisers to the intercropped sweet potato compared to the other two doses. The potassium content in arecanut leaf was higher in control as well as the highest levels of fertilizers in both the intercropping systems. Incidentaly the highest yield obtained by sweet potato must have been due to not only the higher uptake of nitrogen but also a higher uptake of both phosphorus and potassium as is seen from these observations. These results though cannot give a positive trend in many instances on the uptake and utilization of nutrients supplied to the intercrops, have still indicated that arecanut could forage into the soil zone where intercrops were raised and that it could supplement to its own nutrition from the fertilized plots of intercrops. This indicates the beneficial role of intercropping in arecanut plantation by way of maximising nutrient uptake by the main crop. Muralidharan (1980) also reported that competition indices for nutrients were above unity in arecanut indicating that nutrients were not limiting for growth of arecanut.

V.6.4. Income from arecanut as influenced by varying fertilizer levels to the intercrops

In the final assessment of an investigation of the present agronomic nature the income from the crops would be the deciding factor to accept and recommend any improved practice that may arise out of it. The nature of the problem becomes emphatic if fertilizer schedules are involved since they are a costly input. These investigations have indicated that turmeric when intercropped with arecanut was a better crop than sweet potato-cowpea combination in influencing the income of the main crop of arecanut. Irrespective of the fertilizer levels tried for the intercrops, it was found that the arecanut turmeric intercropping system provided an income of Rs.44,124/ha from the produce of the main crop arecanut alone compared to Rs 34,491/ha obtained from arecanut out of the arecanut sweet potato-cowpea combination. There was a maximisation of income of Rs 50,797/ha from the main crop arecanut when it was intercropped with turmeric which was fertilized at a level of 70 N, 60 P_2O_5 and 120 K_2O/kg/ha. The level was also found to be optimum in providing high yields and could be regarded for general recommendation for practice. A comparison of these results with these obtained by Muralidharan (1980) indicates a high profitability of arecanut turmeric intercropping as tried out in this study with a suitable fertilizer schedule. He obtained maximum incomes ranging from Rs.18,500 to Rs.19,198 from arecanut when intercropped with paddy+ragi+groundnut, ginger+chilly, or with banana. It is thus seen that turmeric as an intercrop in arecanut has bright scope under Maidan tracts of Karnataka in providing higher incomes in the main crop of arecanut.

V.6.5. Income from intercrops as influenced by varying fertilizer levels to the intercrops

Varying levels of fertilisers to intercrop turmeric did not bring any variation in the income obtained from turmeric as an intercrop (Rs.2,457 to Rs.2,137) whereas the sole crop of turmeric provided Rs.8,500 even without fertilizers. The fertilised plots gave lower incomes (Rs.7,283 to Rs.5,917) with greater negative effects with the higher fertilizer doses.

Income from sweet potato-cowpea rotation either as intercrop or as sole crop recorded nearly two fold increase over that of turmeric with highest income of Rs.6,378 realised even without fertilizers. The income was Rs.4,455 at the first level of fertilizers. However, Muralidharan (1980) obtained highest net return of Rs 4,524/ha/yr from intercrop of banana followed by Rs.3,934/ha/yr from ginger and the net returns obtained by turmeric was less than Rs.1,000/ha/yr. A net return of Rs.13,334/ha was obtained from the sole crop of ginger followed by turmeric Rs.9,455/ha.

Those results indicate that the income from sweet potato-cowpea was high. The reasons for this are to be sought not from the corresponding yields obtained from different intercrops (as sweet potato was found to provide the least yield advantages over the intercrop of turmeric) but from the prevailing market rates for produce. Turmeric which was being marketed at Rs.6/kg of produce during the pre-experimental period fell sharply in its market rate to Rs.1/kg. Sweet potato was sold during the period at Rs.00-40/kg. Cowpea which never fetched beyond one rupee per kg earlier, was found to be sold at Rs.3/kg. Thus, though the yields of turmeric were high, the income realised from it was poor during the experimental period while cowpea boosted the income from sweet potato-cowpea combination though the intercrop sweet potato was a great disadvantages in pulling down both in yield and income. These discussions tend point out that sweet potato could be althogether deleted from the intercropping system with arecanut and that cowpea could be taken up soon after turmeric in February in order to gain still higher incomes from the intercrops.

The discussions so far made on the fertility management aspects of the intercropping system in effecting improvements in growth, yield and income of the main crop of arecanut and in maximising utilization of fertilizers applied to the system as a whole have thus revealed that it is beneficial to take an intercrop of turmeric and that intercrop turmeric should be separately and adequately fertilized at the rate of 70 N, 60 P_2O_5 and 120 K_2O kg/ha.

V.6.6. Income from the intercropping systems of arecanut as influenced by varying fertilizer levels to the inter crops

A clear picture of advantage from any set of treatments in an intercropping system cannot be obtained without studying the gross income from the intercropping system as a whole. In these studies, it was found that gross income was higher under arecanut-turmeric intercropping (Rs.46,540) than that obtained under arecanut sweet potato-cowpea intercropping system (Rs. 39,481) irrespective of fertilizer levels tried. A maximum of Rs.53,260/ha was obtained in the arecanut-turmeric intercropping system with a fertilizer dose of 70 N, 60 P_2O_5 and 120 K_2O kg/ha. Muralidharan (1980) obtained maximum incomes of Rs.31,540 and Rs.28,757 with intercropping systems of arecanut with ginger and chilly and arecanut with banana respectively while arecanut with turmeric and cowpea provided only Rs.21,564.

The discussions made in V.6.4 and V.6.5 indicated that intercropping in arecanut with turmeric was beneficial from the point of income from the main crop arecanut and that intercropping in arecanut with sweet potato-cowpea was high from the angle of income from the intercrops. However, it was pointed that sweet potato did not fare well in providing high yields though this combination of sweet potato-cowpea as intercrops in arecanut provided high incomes through their combined yields and high market price for cowpea. Looking at the combined incomes from main and intercrops, it is clear that arecanut-turmeric intercropping is viable with higher incomes and that it could be recommended for general practice.

The possibilites of raising either banana or cacao in arecanut to enhance the combined income of the cropping system as a whole was tried in earlier studies. Sannamarappa and Mralidharan (1982) reported that banana was found to be a profitable intercrop in arecanut fetching Rs.4,048. Similar results obtained elsewhere (Muralidharan and Nayar,1979). Arecanut - cacao combination was reported to fetch Rs.18,049/ha (Bhat,1970). The gross income from the intercropping systems tried in the present study far exceeds the incomes reported from those other studies. These differences are partly because of fluctuations in market prices and largely because of high yields obtained in the present study thus pointing out that arecanut-turmeric intercropping could be tried out on a large scale.

V.6.7. Cost benefit ratio relationships as influenced by plant densities of arecanut and intensities of intercropping

It is interesting to observe that wider spacings in both intercropping systems of turmeric and sweet potato-cowpea in arecanut brought down the cost benefit ratio. The narrow spacing of only 1.8m x 3.6m had a ratio of 2.3 in turmeric and 2.50 in sweet potato-cowpea, irrespective of the level of intercropping intensities. Except in turmeric 60% intercropping intensity was found to provide a marginally lower cost benefit ratio under each plant density. These data suggest that though higher yields could be obtained in some combinations, when considering the cost benefit ratio, the narrower spacing of 1.8m x 3.6m with a high population density seems to be a must to benefit the farmer under intercropping systems of turmeric and sweet potato-cowpea in arecanut. This point is made emphatic further when we consider the results of investigations on ten intercropping systems involving 19 crops under coastal conditions of Karnataka (Muralidharan,1980). These studies have revealed that the highest cost benefit ratio was obtained with groundnut (1.78) followed by banana (1.67) under a spacing of 2.7m x 2.7m for the main crop of arecanut. The current investigation are therefore indicative of the fact that a narrower spacing of 1.8m x 3.6m is the only answer in raising the cost benefit ratio to as high as 2.6 and 2.4 in turmeric and sweet potato-cowpea respectively under this spacing.

A discussion on the cost benefit ratio of the sole crops in comparison with intercrops of turmeric and sweet potato-cowpea reveal some interesting features. While the sole crop of turmeric (3.0) was found to have a cost benefit ratio value of three times that of the intercrop (1.04), the cost benefit ratio of sole crop of sweet potato-cowpea was found to be higher (8.97) than that of sole crop of turmeric by nearly three times and it was higher than that of its intercrops (3.89) by about two times, irrespective of fertilizer levels. Higher levels of fertilizers brought down the cost benefit ratio indicating that additional benefits were not forthcoming by way of yield and income by additional doses of fertilizers. In the sweet potato-cowpea combination, it was observed that it is cowpea, which provided such high cost benefit ratio by higher yields as well as higher market rates as discussed earlier. In studies of ten intercropping systems, Muralidharan (1980) found that intercrop turmeric had a cost benefit ratio of 1.45 and sweet potato had a ratio of 0.51. In the current studies, these ratios were lower in turmeric because of the large scale reduction in the market prices of turmeric fetching down to Rs.1/- only per kilogram as against Rs.3-75 in those studies, though the yields were to the tune of 2416 kg/ha in the current studies irrespective of fertilizer levels while the yields obtained by Muralidharan were only 1541 kg/ha. In current studies, sweet potato-cowpea combination gave very high cost benefit ratio because of high returns from cowpea as discussed earlier.

V.7. Results of extension value

V.7.1. The present investigation has brought out the findings that intercropping in arecanut is a viable and feasible practice that could be adapted by farmers all over in the Maidan tracts of Karnataka also.

V.7.2. A planting density of 1543 plants/ha with a narrow spacing of 1.8m x 3.6m providing a rectangular geometry provides optimum conditions for maximum utilization of resources of light floor spaces for nutrients and moisture and labour. This is a practice which can be of immense value from the extension point of view.

V.7.3. Turmeric as an intercrop in arecanut with 40% intercropping intensity with a fertilizer schedule of 70 N, 60 P2O5 and

and 120 K_2O kg/ha is a practice which can be recommended for general cultivation till the right combination of fertilizer levels are fixed through further experimentation.

V.8. Future line of work

V.8.1. Interaction of plant densities of the main crop arecanut with intercropping intensities needs to be examined further with respect to modifying the plant geometry so as to maximise the utilization of resources. A closer spacing might be still advantageous. Intercropping intensities have to be readjusted as per plant densities/plant geometries.

V.8.2. Fertilizer responses of the intercrops in the present study were inconsistent. A critical approach in research is needed to identify critical stages of crop growth when limitations are imposed either in making available all resources to both the main crop and intercrops or in bringing competitive or complementary effects of the component crops. Crop log studies are therefore warranted to study all aspects of nutrition of the entire intercropping system.

V.8.3. Studies to fix the optimum dose of each nutrients in combination with other nutrients should be undertaken for intercrops on a priority basis so as to maximise the productivity of the entire intercropping system. It is also necessary to study the micro-nutrient requirements of the main and intercrops since arecanut is a perennial crop.

V.8.4. A thorough assessment of suitable intercrops and their sequence of intercropping in arecanut isneeded for maidan tracts of Karnataka. This should be based on not only enhanced utilization of rèsources and higher yields but also on monetary returns as governed by market prices for the produce. For instance, turmeric in the first eight months followed by a short crop of cowpea in February-March might be highly remunerative intercropping system in arecanut.

V.8.5. Intercrops might also be tested for their high biomass production to be partially or entirely used for fodder purposes. Growing legumes and fodder legumes, grasses and othersx which are fairly shade tolerant at some stages or all stages of their growth have to be identified.

SUMMARY

CHAPTER .VI

SUMMARY

Studies were made on the "Interaction of intercrops in maximising utilization of resources in arecanut stands (*Areca catechu* L.) in the Maidan tracts of Karnataka". These studies were carried out at the Central Plantation Crops Research Institute, Hirehalli, Tumkur District, Karnataka representing Maidan tract as well as a tank bed farming situation. Two experiments were undertaken in the existing arecanut gardens during 1978-79 and 1979-80 with research materials and data gathered both in the pre and post experimental period of two years each, thus covering a total period of six years for drawing inferences and making this summary.

The first experiment was framed in order to investigate the interaction of planting densities and plant space geometries of arecanut with the intercropping intensities on light interception, land and labour utilization and in maximising yields and incomes of the intercropping system as a whole. The experiment was entitled "Interaction of plant densities and plant space geometries of arecanut with intercropping intensities of turmeric, sweet potato and cowpea on the growth and yield attributes of arecanut and intercrops and in maximising utilization of resources". This was conducted in an already existing 17 year old arecanut garden with the already existing four plant spacings-cum-geometries in a split-split plot design with three replications.

The treatments of this experiment consisted of four plant densities-cum-plant geometries viz., i) 1.8m x 3.6m with rectangular plant geometry having 1543 plants/ha, ii) 2.7m x 2.7m with square geometry having 1371 plants/ha, iii) 2.7m x 3.6m with rectangular plant geometry having 1028 plants/ha and iv) 3.6m x 3.6m with square geometry having 771 plants/ha and two intercrops of turmeric and sweet potato-cowpea and with two intercropping intensities viz., 40% and 60%.

The second experiment was envisaged to optimise the fertilizer requirements of intercrops and to explore the possibilities of maximising the productivity of the intercropping system through exploitation of available resources. The title of the experiment was "Effect of four fertilizer levels on the intercrops of turmeric and sweet potato-cowpea in arecanut on the growth and yield attributes of main and intercrops in maximising productivity and utilization of resources". This experiment was conducted on a 15 year old arecanut garden in a randomised block design with three replications.

The treatments of this experiment consisted of four levels of fertilizers each for the two intercrops viz., 1) control with no fertilizer and 2), 3) and 4) with multiples of 70 N, 60 P_2O_5 and 120 K_2O kg/ha respectively for turmeric and 1) control with no fertilizers and 2), 3) and 4) with 70 N, 50 P_2O_5 and 70 K_2O kg/ha respectively for sweet potato

The sole crops required for this experiment were raised in the open field adjacent to the intercropping experiment under replicated plots to compare them with the intercropping system.

The salient features of these experiments coupled with highlights of research results obtained are presented further.

1. Light intercepted by arecanut ranged from 35.4 to 40.1 10^3 lux under the four varied plant densities. Narrower spacing of 1.8m x 3.6m intercepted 41.9% and 39.4% of light while the wider spacing intercepted 36.2% and 34.1%. Thus narrower spacing utilised more light and allowed 58% to 61% of incident light to pass through the arecanut canopy compare to 64% to 66% of light passed through by wider spacings.

2. Turmeric as an intercrop received around 37,000 lux under the spacing of 1.8m x 3.6m and 2.7m x 2.7m and around 47,000 lux in the wider spacings. The light interception by this intercrop ranged from 75% under narrower spacing to 64% under the wider spacing. Similarly sweet potato intercepted 78% to 73% of the incident light.

3. The effects of planting densities of arecanut on total light interception were not distinct. It was estimated that the intercropping system of arecanut turmeric intercepted 78% of incident light while arecanut sweet potato intercepted 82% and the arecanut cowpea intercepted 75%.

4. Growth attributes of intercrops were not greatly influenced by either plant densities of arecanut or by intercropping intensities. However, it was observed that wider spacings encouraged better tillers/branch production in intercrops. In 2.7m x 2.7m spacing, sweet potato produced 174 leaves at 60% intercropping intensity and cowpea produced 287 leaves/plant. Leaf area of turmeric increased with increased intercropping intensity. In sweet potato, 40% intercropping intensity at wider spacing produced higher leaf area 2.35 and 2.44 m^2/0.25 m^2. Biomass production was higher at 1.8m x 3.6m at 60% intercropping intensity in turmeric, while wider spacing at 60% intercropping intensity was ideal for high biomass production in sweet potato.

5. Intercrops behaved differently in yield attributes in response to plant densities of arecanut and intercropping intensities. In turmeric, volume and weight of tubers and yield increased with narrower spacings while in sweet potato wider spacings were optimum in enhancing yield attributes and yields. Turmeric and sweet potato responded to 60% intensity (5228 kg/ha and 4549 kg/ha compared to 3764 kg/ha and 3743 kg/ha at 40% respectively). Cowpea yielded better with wider spacings but had a higher test weight at 40% intercropping intensity.

6. The gross income realised in the arecanut turmeric intercropping was Rs.4,498/ha compared to sweet potato-cowpea intercropping with Rs.3,930/ha. Planting densities did not bring

significant variation in gross income which ranged from Rs.4,303 under narrew spacing to Rs.3,916 in wider spacing. Increased intensity increased the gross income from intercrops. A maximum income of Rs.4,770 was realied at 60% intercropping intensity.

7. The girth of the palm, where sweet potato was grown was higher (53.3 cm) than when turmeric was grown (48.5 cm). The internodal length was not affected by any of the treatments. Bunch production showed an increasing tend with the increasing in spacings of arecanut in the post experimental period. Wider spacings of 2.7m x 3.6m and 3.6m x 3.6m significantly increased the number of nuts/palm (807 and 877 nuts) over the other two lower spacings (523 and 655 nuts). Intercropping with turmeric produced 932 nuts while sweet potato-cowpea intercropping provided 764 nuts.

8. Pre-experimental data indicated high yields of 147 to 157 q/ha of arecanut with the first three spacings compared to 98 q/ha with the wider spacigg of 3.6m x 3.6m. During the experimental period, the first two lower spacings gave 188 and 186 q/ha compared to 162 and 168 q/ha with wider spacings. Nearly 18 to 20% increase was observed in the arecanut production between pre and post experimental period under various arecanut spacings. Intercropping intensities did not change the yields. These results indicated that though growth attributes were marginally influenced by plant densities and intercropping intensities, the yields of arecanut were reduced with wider spacings.

A spacing of 1.8m x 3.6m with a population 1543 plants/ha providing a rectangular plant geometry with turmeric as intercrop and under 40% intensity of intercrop appeared to be optimum for maximising productivity in arecanut in the intercropping system.

9. In pure stands of arecanut, the results revealed that there were yield reductions from 19331 kg/ha with 1.8m x 3.6m (1543 plants/ha) to 9836 kg/ha in 3.6m x 3.6m (771 plants/ha). In the intercropping system also increased spacing reduced the yields of arecanut from 19905 kg/ha to 12802 kg/ha. Compared to the reductions seen in the pure stands of arecanut, the reduction of arecanut yields under intercropping were minimal. These results indicated that with a change in planting densities/plant space geometry against the conventional spacing of 2.7m x 2.7m with a square shape, the spacing of 1.8m x 3.6m with a x rectangular shape of planting geometry allowed for a longer part of the day a greater proportion of incident light to pass through the arecanut canopy from the North-South direction. This made the utilization of inter floor spaces under this narrow spacing with high plant density to be optimum. This spacing geometry also provided high incomes of Rs.32,867 and Rs.39,124/ha in pure and intercropped arecanut, respectively.

10. Land resources utilization was optimum under arecanut-turmeric intercropping system which gave nearly two to three times the income that obtained from arecanut-sweet potato-cowpea intercropping system.

11. The crop intensity index increased from 0.70 and 0.64 in the sole crops of turmeric and sweet potato-cowpea rotation to 1.28 to 1.29 in the respective intercropping systems in arecanut indicating better utilization of land resources under intercropping systems. These intercropping systems had an LER of about 1.24.

12. A narrow spacing of 1.8m x 3.6m resulted in a saving on the cost of labour by about Rs.828/ha/yr in the pure stand of arecanut while in the intercropping system with turmeric there was a saving of Rs.2,310/ha/yr. Similar trend was observed in arecanut and sweet potato-cowpea combination. Wider spacing incurred heavy losses not only by way of additional labour requirement but also by lower yield and income. In the fertilizer experiment there was a saving on the cost of labour by about Rs.240 and Rs.300/ha/yr in the two intercropping systems.

13. The growth patterns of the intercrops as influenced by fertilizer levels indicated a maximum production of 14 to 17 leaves in turmeric under varied fertilizer levels by about 120 days while sweet potato produced maximum leves and branches by about 60 days only with the highest level producing 333 leaves per plant. On an average of two years, in turmeric, the first and second levels of fertilizers produced significantly higher number of leaves over the control. The LAR and tiller production were high in intercrop turmeric (4.6) at 140 N, 120 P_2O_5 and 240 K_2O kg/ha. The pattern of biomass production varied

between sole and intercrops of turmeric. Sole crop reached high values of 175 q/m^2 by 120 days. Intercrop took 150 to 180 days to reach peak values of biomass production under varied fertilizer treatments. In contrast, sweet potato had high values of biomass production by about 90 days only. Intercrop turmeric produced increased biomass with the increase in levels of fertilizers ranging from 8713 kg/ha to 9206 kg/ha. Sole crop also produced the same. In general, growth attributes inclusive of NAR, RLGR and biomass production were favourably increased with 70 N, 60 P_2O_5 and 120 K_2O kg/ha or at the next higher dose in case of turmeric.

14. In sweet potato growth attributes of branching, number of leaves, leaf area, LAR, NAR, RGR and RLGR were not consistently influenced by fertilizer levels. In sole crop, branching was good at 70 N, 50 P_2O_5 and 70 K_2O kg/ha and functional leaves, leaf area and shoot weight of 754 q/ha, at the next level. Sole crop expressed growth attributes better than intercrop. The NAR and RLGR values were higher by two to three times in sole crop than in intercrop. The mean biomass production for inter and sole crops under varied fertilizer levels ranged from 13760 to 16093 kg/ha and 26553 to 29260 kg/ha respectively.

15. Both turmeric and sweet potato did not respond to fertilization in respect of the number of tubers produced. Tuberisation in intercrop turmeric was good at the first two levels. The weight of tubers in the intercrop sweet potato was adversely

affected (0.36 kg/plant) than when it was taken as a sole crop (2.62 kg/plant). Fertilizer level of 140 N, 100 P_2O_5 and 140 K_2O kg/ha was good for all these yield attributes in this crop.

16. The tuber to shoot weight ratio in sweet potato tremendously increased in the intercrop (1:41) compared to sole crop (1:34) indicating that sweet potato exhibited high tendency to putforth a greater amount of vegetative growth than reproductive growth under an intercropping situation. Fertilizers also favoured vegetative growth rather than reproductive growth as seen from the fact that this ratio was increased from 1:13 in the control to 1:54 at the highest level of fertilizer.

17. The yield of intercrop turmeric was not influenced by fertilizer in the first year while the lower doses were favourable in the second year. The yields of sole crop too were favourable under lower levels of fertilizers with control giving maximum yields in the second year and the average of two years. The mean yields ranged from 2437 kg/ha in intercrop to 8500 kg/ha in sole crop of turmeric with no fertilizers. These were found to decline to 2317 kg/ha and 5900 kg/ha with the highest level of fertilizers.

Intercrop sweet potato was adversely affected by fertilizers with yields decreasing from 4066 kg/ha with no fertilizers to 1331 to 1239 kg/ha with fertilizer levels tried. Sole crop had no definite response to fertilizers with yields ranging from 14782 to 18082 kg/ha.

18. Cowpea grown after sweet potato in the intercropping system was not influenced by residual effect of fertilizers applied to the previous intercrop. Intercrop cowpea yielded 1438 kg/ha while sole crop 2169 kg/ha irrespective of residual fertilizer levels. Pod weight and 1000 grain weight were also not influenced by fertilizer levels indicating that nutrients available were exhausted by the previous crop itself.

19. The plant nutrition aspects revealed that there appeared to be an imbalance in the uptake and accumulation of nutrients in the intercrops with the levels of fertilizers tried. A higher proportion of magnesium content and lower proportion of phosphorus was found to result in luxurious vegetative growth especially of sweet potato resulting in poor expression of yield attributes. This lead to an unfavourable response by both the intercrops for the high levels of fertilizers tried.

20. The growth attributes of height and girth and internodal length of arecanut palm were marginally influenced by fertilizers. Increasing levels of fertilizer showed a tendency of increased heights from 6.4 to 7.4 metres. A girth of about 48 cm was observed with the highest level of fertilizer compared to 44 to 45 cm in control.

21. Bunch production increased from pre-experimental period

to experimental period from 3.1 to 4.1 and 2.7 to 3.9 in the turmeric and sweet potato-cowpea intercropped plots respectively, indicating the beneficial role of fertilizer levels. Highest dose of fertiliser benefitted the post experimental period also. Fertilization to turmeric effected in producing 1224 nuts while sweet potato effected in producing 1870 nuts. A dose of 70 N, 60 P_2O_5 and 120 K_2O kg/ha was optimum for turmeric in this respect.

22. Pure crop of arecanut produced an yield of 18506 kg/ha. Arecanut under turmeric intercrop without fertilizers produced 19239 kg/ha. Fertilizer levels enhanced yields from 26087 kg/ha to 30570 kg/ha. A dose of 70 N, 60 P_2O_5 and 120 K_2O kg/ha provided highest yield both in experimental and post experimental period. Fertilization to sweet potato did not have any influence on the yield of the main crop.

23. The income obtained from the produce of the main crop of arecanut alone was higher at Rs.44,124/ha in the arecanut turmeric intercropping system than with the arecanut sweet potato-cowpea intercropping which gave an income of Rs.34,491/ha. Maximization of income to Rs.50,977/ha from arecanut was found when turmeric was fertilized at 70 N, 60 P_2O_5 and 120 K_2O kg/ha.

24. Income from intercrop turmeric indicated that a negligible range from Rs.24,57[illegible]/ha to Rs.~~2,317~~ 2197 were realised with varied fertilizer levels whereas sole crop of turmeric provided Rs.8,500 even without fertilizers. Higher levels of fertilizers had a

negative effect on the income of turmeric. Income from sweet potato-cowpea rotation either as an intercrop or as a sole crop increased by two times to that of turmeric. Highest income of Rs.6,378/ha was realised even without fertilizers. Fertilizers at the first level brought the income from this combination under intercropping to Rs 4,455/ha. Income from sole crop in this combination ranged from Rs.11,758 to Rs.14,081/ha under different fertility levels. High incomes of intercrop arecanut sweet potato-cowpea as against the one of arecanut turmeric was found to be not as an outcome of the performance of sweet potato but as a result of marked sharp decline in market prices for the turmeric produce and marked income for the price of cowpea.

25. A clear of picture of advantage of the intercropping system was seen with arecanut turmeric intercropping providing Rs.46,546/ha compared to Rs.39,491/ha received from arecanut xx sweet potato-cowpea intercropping system. Fertilizer dose of 70 N, 60 P_2O_5 and 120 K_2O kg/ha for the former system was found to maximise the income to Rs 53,260/ha. This dose could be regarded as optimum for fertilization to intercrop of turmeric in maximising growth and yield of components crops and the gross income of entire intercropping system.

26. A comparison of economic yields of sole and intercrops in arecanut on an equal area basis indicated that irrespective of fertilizer levels the sole crops of turmeric (6566 kg/ha) sweet potato (17069 kg/ha) cowpea (2166 kg/ha) yielded higher compared

to their respective intercrops (2445, 1970 and 1439 kg/ha). The reduction in the yield in the intercrops was maximum in sweet potato with 88% and minimum with cowpea with 33%. Turmeric recorded 62% reduction in yield when grown as intercrop compared to sole crop on an equal area basis. Economic yields were high in the arecanut turmeric intercropping system which provided 44,124 kg/ha. This yield was 26% higher over the combined yields of the respective combination of sole crops. Arecanut sweet potato-cowpea intercropping provided only a marginal (5%) yield advantage over the respective sole crops.

27. The narrow spacing of 1.8m x 3.6m had a cost benefit ratio of 2.5 in turmeric and 2.3 in sweet potato-cowpea combination as intercrops in contrast to cost benefit ratio of 8.97 and 3.89 as sole crop respectively.

28. From these studies it could be concluded that it is highly advantageous to take an intercrop of turmeric in arecanut. An intercropping intensity of 40% with a fertilizer schedule of 70 N, 60 P_2O_5 and 120 K_2O kg/ha having a plant population of 1543 areca palms/ha with a narrow spacing of 1.8m x 3.6m providing a rectangular geometry is beneficial to the farmer.

REFERENCES

Abraham, P., 1956, Spices as intercrops in coconut and arecanut gardens. Arecanut J., 7(3):56-58.

Agarwal, R.C. and Heady, E.C., 1970, Prospects and problems of multiple cropping. In. National Seminar on Multiple Cropping, May,1970. New Delhi, India.

Aiyadurai, S.G., 1966, A review of research on spices and cashewnut in India. Regional Office (Spices and Cashewnut) Indian Council of Agricultural Research, Ernakulam, pp.228.

Aiyer, A.K.Y.N., 1949, Mixed cropping in India. Indian J. Agric. Sci. 19(4):439-543.

Allen, L.H. Jr. Sinclair, T.R. and Lemon, E.R., 1976, Radiation and microclimate relationships in multiple cropping systems. In. Multiple Cropping (ASA Special Publication Number 27).pp.171-200. Am. Soc. Agron. Madison, Wisconsin.

Andrews, D.J. and Kassam, A.H., 1976, The importance of multiple cropping in increasing world food supplies. In. Multiple Cropping (ASA Special Publication Number 27).pp.1-10. Am. Soc. Agron. Madison, Wisconsin.

Anon., 1974, Central Plantation Crops Research Institute, Annual Report for 1973, Kasaragod, India. pp.24-28

Anon., 1976(a), Determination of optimum spacing for arecanut and NPK manurial experiment. In. CPCRI Ann. Rept. for 1975. pp.73-74. Central Plantation Crops Research Institute, Kasaragod, India.

Anon., 1976(b), Package of Practices. Pub. Directorate of Extension Education, K.A.U. Mannuthy. pp.128.

Anon., 1977(a), Cultivation practices for vegetables. University of Agricultural Sciences,State Department of Horticulture and Indian Institute of Horticulture Research,Bangalore. pp.68-71.

Anon., 1977(b), Central Plantation Crops Research Institute, Ann. Rept. for 1976, Kasaragod, India. pp.31-34.

Anon., 1978, Package of practices for arecanut, Pamphlet No.2E. Central Plantation Crops Research Institute, Kasaragod, Kerala, India.pp.4.

Anon., 1979, NPK Manurial experiment. In. Central Plantation Crops Research Institute, Annual Report, 1978.pp. 86-89. CPCRI,Kasaragod, Kerala, India.

Anon., 1982, Package of Practices for High Yields. University of Agricultural Sciences and Department of Agriculture, Bangalore.pp.107.

Bains, K.S., 1967, Effect of applied nutrients on soil fertility, Chemical composition and yield of field beans. Indian J. Agron., 12(2):200-206.

Bains, S.S., 1968, Relay cropping can win race of increased production. Indian Fmg., 18(2):9-10.

Bains, S.S. and Sadaphal, M.N., 1971, Fertilizer application in a multiple cropping system. Fertilizer News, 16(5): 16-18.

Baldwin, J.P. and Tinker, P.B., 1972, A method of estimating the lengths and spatial patterns of two interpenetrating root systems. Plant and Soil, 37:309-312.

Bassham, J.A., 1977, Increasing crop production through more controlled photosynthesis. Science, 197(4304):630-638.

Bavappa, K.V.A., 1951, Some common intercrops in an arecanut garden. Indian Central Arecanut Committee Bullet., 2(2):16-17.

Bederkar, V.K. and Joshi, V.K., 1954, Studies on the agronomy of Gaorani cotton. II.Rotation. Indian Cot. Grow. Rev. 8(1):57-71.

Beets, W.C., 1978, Multiple cropping systems reviewed. Span 21(3):114-116.

Begg, J.E., 1965, High photosynthetic efficiency in a low latitude environment. Nature. 205(4975):1025-1026.

*Bennema, J., 1975, Soil resources of the tropics with reference to the well drained soils of the Brazilian Amazon Forest Region. In. Ecophysiology of Tropical Crops (Alvim, P.T.,ed.) Volume 1, pp.1-47,Published by the Communication Division of CEPLAC, Bahia, Brazil.

Beste, C.E., 1976, Co-cropping sweet corn and soybeans. Hort. Sci. 11(3):236-238.

Bhandary, D.K., 1974, Study of inter and associated crops in arecanut gardens of the "Malnad" tract of Karnataka. Arecanut and Spices Bullet., 5(3):76-77.

Bhat, K.S., 1974, Intensified inter/mixed cropping in areca garden - the need of the day. Arecanut and Spices Bullet., 5(3):67-69.

Bhat, K.S., 1978, Agronomic research in arecanut - a review. Journal of Plantation Crops, 6(2):67-80.

Bhat, K.S., 1979, Mixed cropping in arecanut.pp.35-38. Central Plantation Crops Research Institute, Kasaragod,Kerala.

Bhat, K.S. and Bavappa, K.V.A., 1972, Cacao under palms. In. Wastee, R.L. and Earp, D.A.ed., Cacao and coconuts in Malaysia. Proc. of the Conference held in Kuala Lumpur, 1971. The Incorporated Society of Planters, Kaula Lumpur, Malaysia.

Bhat, K.S. and Khader, K.B.A., 1970, Inter and mixed cropping in arecanut gardens. Indian Fmg., 20(5):35.

Bhat, K.S. and Leela, M., 1968, Cultural requirements of arecanut. Indian Fmg. 18(4):8-9.

Bhat, K.S. and Leela, M., 1969. The effect of density of planting on the distribution of arecanut roots. Tropical Agric., 46(1):55-61.

Biswas, C.R., Sekhon, G.S. and Singh, R., 1977. Accumulation and decline of available phosphorus and potassium in a soil under multiple cropping. J. Indian Soc. Soil Sci., 25(1):23-27.

Black, J.N., 1958. Competion between plants of different initial seed sizes in swards of subterranian clover. Aust. J. Agric. Res., 9: 299-318.

Blackmen, G.E. and Black, J.N., 1959. Physiological and ecological studies in the analysis of plant environment. XII. The role of light factor in limiting growth. Ann. Bol. N.S.23:131-145.

Boardman, N.K., 1977. Comparative photosynthesis of sun and shade plants. Ann. Rev. Plant Physiol., 28:355-377.

Boffey, T.B. and Veevers, A., 1977. Balanced designs for two component competition experiments. Euphytica, 26: 581-584.

Borhamme, R., Grancher, C.V., Chartier, M. and Artis, P. 1977. Utilisation of solar energy by a crop of Vigna sinensis. 4. Effect of age and light intensity on the photosynthetic potential of cotyledanary leaves. Annales Agronomiques. 28:159-169 (Crop Phys. Abs., 5(2):103,1979)

Bramha, R.N., 1974. In North-Bengal banana is a paying intercrop in areca gardens. Arecanut and Spices Bulletin. 5: 80-81.

Bray, R.H., 1954. A nutrient mobility concept of soi-plant relationships. Soil Sci., 78(1):9-22.

Brown, K.W. and Rosenberg, N.J., 1970. Effect of wind breaks and soil water potential on stomatal diffusion resistance and photosynthetic rate of sugar beets (Beeta vulgaris). Agron. J., 62:4-8.

Cochran, W.G. and Cox, G.M., 1965, Experimental designs. Asia Publishing House, Bombay, Modern Asia II Edn.IV. Print. pp.106-116, 293-304.

Coleman, L.C. and Rao, U.M.K., 1918, The cultivation of the areca palm in Mysore, Department of Agriculture, Mysore State, Bangalore. pp.32.

Crookston and Kent, R., 1976, Intercropping - A new version of and old idea. Crops and Soils, 28(9):7-9.

Crookston, R.K., Treharne, K.J., Ludford, P. and Ozbum, J.L., 1975, Response of beans to shading. Crop Sci., 15(3): 412-416.

Donald, C.M., 1958, The interaction of competition for light and for nutrients. Aust. J. Agric. Res. 9:421-435.

Donald, C.M., 1963, Competition among crop and pasture plants. Adv. Agron. 15:1-118.

Duncan, W.G. and Ohlrogge, A.J.,1958, Principles of nutrient uptake from fertiliser bands. II. Root development in the band. Agron. J., 50:605-608.

Duncan, W.G., Williams, W.A. and Loomis, R.S., 1967, Tassels and the productivity of maize crop. Science,7(1): 37-39.

Dunham, R.J. and Nye, P.H., 1974, The influence of soil water content on the uptake of ions by roots. 1. Chloride uptake and concentration gradient in soil. J. Appl. Ecol. 11:581-595.

Evans, L.T., 1978, The influence of radiation before and after anthesis on grain yield and its components. [illegible] Field Crops Research. 1:5-59.

Fischer, K.S. and Wilson, G.L., 1975, Studies of grain production in *Sorghum bicolor* (L.Moench) V. Effect of planting density on growth and yield. *Aust. J. Agric. Res.* **26**(1):31-41.

Freyman, S. and Venkateswarlu, J., 1977, Intercropping on rainfed soils of the Dacan Plateau, India. *Canadian J. Plant Sci.*, **57**(3):697-705.

Gautam, O.P. and Dastane, N.G., 1970, Agronomic Practices and water use patterns for higher crop yields. *New Vistas in Crop Yields* (Agricultural Year Book), Indian Council of Agricultural Research, New-Delhi.

Geiger, D.R. and Batey, J., 1967, Translocation of ^{14}C in sugar beet during darkness. *Plant Physiol.*, **42**:1743-1749.

Harper, J.L., 1961, Approaches to the study of plant competition. *Mechanisms in Biological Competition*, pp.1-39. Sump. Soc. Expt. Biol.(Proceedings).

*Hart, R.G., 1974, The design and Evaluation of a Bean, Corn and Mainoc Polyculture Cropping System for the Humid Tropics. Ph.D. Dissertation, University of Florida, pp.158 (*Diss. Abstr.* 341:75-79).

Ho, C.T., Su, N.R., Tang, C.N. and Sheng, C.Y., 1967, Studies on correlation of soil and plant potassium with response of sweet potato to added potash in *Chiayi Prefecture. Soil and Fertilizers in Taiwan*, 32-47

Iyengar, B.N., 1954, Manuring of the areca palm. *Arecanut Bulletin.* **5**:162-166.

IRRI., 1974, International Rice Research Institute, 1974, *Annual Report for 1973*. RRI, Losbonos, Phillippines.

Jackson, M.L., 1973, *Soil Chemical Analysis*. Second Ed. Prentice Hall, New Delhi. pp.498.

Kasanga, H. and Monsi, M., 1954. On the light transmission of leaves. Japanese J. Bot., 14:304-324.

Khanna, P.K. and Nair, P.K.R., 1977. Evaluation of fertiliser practices for coconuts under pure and mixed cropping systems in the west cost of India. Conference on Classification and Management of Tropical Soils (Proceedings) Malayasian Soc. Soil Sci., Kaula Lumpur.

Krishnamurthy, K., Bomme Gowda, A.,Rajashekara, B.G. Jagannath, M.K. Raghunatha, G. Venugopal, N. Jayaram, G. and Ramachandra Prasad, T.V., 1973. Investigations on the structure of yield in cereals (Maize and Sorghum). Final Technical Report of the PL.480 of Agricultural Sciences, Bangalore.

Kumaraswamy, A.S. and Hosmani, M.M., 1978. Intercropping in Varalakshmi cotton. Mysore J. Agric. Sci., 12:212-216.

Kvet, J., Ondok, J.P. Necas, J. and Jarvis, P.G., 1971. Methods of growth analysis. In. Plant Photosynthetic Production (Manual of Methods), (Sestak, Z. Catsky, J and Jarivis, P.G., ed.), pp.343-413: Dr. W.Junk, N.V. Publishers. The Hague.

Lakhani, D.A., 1976. A crop physiological study of mixtures of Sunflower and Fodder radish. Ph.D. Thesis, Reading University, England, pp.171.

Loomis, R.S., Williams, W.A. and Hall, A.E., 1971. Agricultural productivity. Ann. Rev. Plant Physiol., 22:431-468.

Mahapatra, I.C., Leeuwrik, D.M., Singh, N.K. and Dayanand, 1973. Green revolution through multiple cropping in India. Agri. Mect.in Asia Spring: 37-42.

Mann, H.S., 1968. Manuring of pulse crops. Indian Fmg. 17(11): 7-8.

Martin, J.K., 1977, The chemical nature of ^{14}C labelled organic matter released into soil from growing wheat roots. In. Soil Organic Matter Studies, pp.197-203. Vol.1, International Atomic Energy Agency, Vianna.

Menon, K.S. and Nayar, T.V.R., 1978, Effect of intercropping with tuber crops in root(wilt) affected coconut garden. In. Prog. PLACROSYM.1. PLACROSYM Standing Committe, Kasaragod, India pp.416-424.

Menogay, M.R., Hubbell, J.M. and William, R.S., 1978, Crop intensity index: A research method of measuring land use in multiple cropping, Hort. Science, 13(1):8-11.

Miller, C.H. and Covington, H.M., 1962, Mineral nutrition studies with sweet potatoes during a three year period. Tech. Bull. North Caiolina Agricultural Service(USA) No.273: pp.24.

Mohopatra, A.R., 1977, Soil fertility research in arecanut : A review. Journal of Plantation Crops, 5(2):114-120.

Moss, D.N., 1976, Studies on incresing photosynthesis in crop plants. In. CO2 metabolism and plant productivity (Burris, R.H. and Black, CC. eds.).pp.31-41., University Park Press, Baltimore.

Moss, D.N. and Stinston, H.T., 1961, Differential response of corn hybrids to shade. Crop. Sci. 1:416-418.

Muralidharan, A., 1980, Biomass productivity, plant interactions and economics of intercropping in arecanut. Ph.D.Thesis, Department of Agronomy, University of Agricultural Sciences, Bangalore. PP. 79-187.

Muralidharan, A., Nagaraja, B. Nair, M.A. Harishukumar, P. Sannamarappa, M. and Yadukumar, N., 1976, Cultural-cum-spacing trials. In. CPCRI Ann. Report. 1975, pp. 76-77, CPCRI, Kasaragod, India.

Murata, Y., 1969, Physiological response to nitrogen in plants. In. Physiological aspects of crop yield (Eastin, J.D., Haskins, F.A., Sullivan, C.Y. and Van Bavel, C.H.M. eds.).pp.235-259, Am. Soc. Agron. Madson, USA.

Nagaraya, B., 1974, Intercropping in arecanut gardens of Maidan areas of Karnataka. Arecanut and Spices Bullet. 5(3): 78-79.

Nagaraja, B. and Bhat, K.S., 1977, Inter and mixed cropping trials. a. Arecanut and banana. In. CPCRI. Ann. Rept. 1976, pp:92-93. CPCRI, Kasaragod, India.

√ Nair, P.K.C., 1964, Investigation on turmeric in relation to NPK fertilizers and rhizosphere bacterial population. M.Sc. (Agri) Thesis, Kerala Agricultural University, Trivandrum.

Nair, P.K.R., 1978, Intensive multiple cropping with coconuts in India - Principles, Programmes and Prospectus. D.Sc. Agr. Dissertation, University of Gottingen.

Nair, P.K.R. and Balakrishnan, T.K., 1976, Pattern of light interception by canopies in a coconut + cacao crop combination. Indian J. Agric. Sci. 46:433-462.

Nair, S.K. and Rao, N.S.S., 1977,a, Microbiology of the root regional of coconut and cacao under mixed cropping. Plant and Soil, 46:511-519.

Nair, P.K.R. and Verghese, 1976, Crop diversification in coconut plantations. Indian Fmg. 25(11):17-21.

Nair, P.K.R., Varma, R. Nelliat, E.V. and Bavappa, K.V.A., 1975, Beneficial effects of crop combination of coconut and cacao. Indian J. Agric. Sci. 45(3):165-171.

Nair, K.P.P., Patel, U.K. Sing, R.P. and Kaushik, M.K., 1979, Evaludation of legume intercropping in conservation of fertilizer nitrogen in maize culture. J. of Agric. Sci. 93:189-194.

Nambiar, K.K., 1949, A survey of arecanut crop in Indian Union. Indian Central Arecanut Committee, Calicut.pp.74.

Nambiar, P.K.V., 1970, Grow pepper on arecanut palms. Arecanut and Spices Bulletin., 2(1):1-2.

Nelliat, E.V., 1973, Multiple cropping or multistoreyed cropping in plantation crops. J. Plant. Crop., 1(Suppl.):204.

Nelliat, E.V., 1979, Multistoreyed cropping in multiple cropping in coconut and arecanut gardens. Central Plantation Crops Research Institute,Kasaragod, India pp.39-41.

Nelliat, E.V., Bavappa, K.V.A. and Nair, P.K.R., 1974, Multistoreyed cropping. A new dimension in multiple cropping for coconut plantations. Wold Crops., 26:262-266.

Nelliat, E.V., 1976, Garden land management. Indian Fmg. 25(11): 6.

Nichiporovich, A.A., 1954, Photosynthesis and the theory of obtaining high crop yields, by A.A. Nichiporovich. Field Crop Abst., 13(3):169-175, 1960.

Oritani, T., 1978, Studies on nitrogen metabolism in crop plants 15. The effect of light intensity and TIBA on the photosynthetic capacity and nitrogen metabolism in two contrasting varieties of soybean plants. Japanese J. Crop Sci., 47(1):124-132. (Crop Physiol. Abst. 5(4) 254 (2217)(1979).

Osiru, D.S.O. and Willey., 1977, Studies on mixtures of dwarf sorghum and beans. J. Agric. Sci. Camb. 99:531-540.

Pendleton, J.W. and Seif, R.D., 1962, Role of height in corn competition. Crop Sci., 2(2):154-156.

Pepper, G.E. and Prime, G.M., 1972, Low light intensity effects on ~~the~~ grain sorghum at different stages of growth. Crop Sci., 12(5):590-593.

Power, J.P., Willis, W.O., Grunes, D.L. and Reichman, G.A., 1947, Effect of soil temperature, phosphorus, and plant age on growth analysis of barley. Agron. J., 59(3):231-234.

Rajput, S.G., Patil, V.K., Warke, D.C., Ballal, A.L. and Gunjkar, S.N., 1980, Effect of nitrogen and spacing on the yield of turmeric rhizomes. Proc. National Seminar on Ginger and Turmeric, Calicut. pp. 83-85.

Rao, V.T., 1965, Curing and processing of turmeric in Andhra Pradesh with special reference to Duggirake. Spices Bull., 4(1):91-96.

Rao, R.M., Reddy, R.K. and Subbarayudu, M., 1975, Promising turmeric types of Andhra Pradesh. Indian Spices. 12(2):2-5.

Roy, A.R., 1974, Intercropping in arecanut gardens of North Eastern Region of India. A brief review of the work done. Arecanut and Spices Bullet., 5(3):82-85.

Sadanandan, A.K., 1974, Raise intercrops in arecanut plantation for higher returns. Arecanut and Spices Bullet. 5(3):70-72.

Sannamarappa, M. and Muralidharan, A., 1982, Multiple cropping in arecanut. The Arecanut Palm. Central Plantation Crops Research Institute,Kasaragod,India.pp. 133-146.

Scott, L.E., Bouwkamp, J.C., 1974, Seasonal mineral accumulation by the sweet potato. Hort. Sci. 9(3):233-235.

Shantharam. M.V. and Rangaswami, G., 1967, A comparison of the rhizosphere microflora of mixed crops. Mysore J. Agric. Sci. 1:7-12.

Singh, P.M., 1973. Effect of different levels of light intensity on vegetative growth of rice under controlled environment. Rice., 22:97-103.

Singh, M. and Roy, A.K., 1977. Cultural cum spacing trials. In. CPCRI Ann. Rept., 1976. pp.79. CPCRI,Kasaragod, India.

Stanford, G., Legg, J.D. and Smith, S.J., 1973. Soil nitrogen availability evaluations based on nitrogen mineralisation potentials of soil and uptake of lebelled and unlebelled nitrogen by plants. Plant and Soil., 39:113-124.

Stino, K.R. and Lashin, M.E., 1953. Effect of fertilizer on the yield and vegetative growth of sweet potatoes. Proc. Ameri. Soc. Horti. Sci. 61:367-372.

Subbaiah, B.V. and Asija, C.L., 1956. A rapid procedure for the estimation of available nitrogen in soils. Curr. Sci. 25:259-260.

*Sugawara, T., 1938. Comparative studies on the water culture in sweet potatoes with special reference to the concentration of potash salts. Nippon Dosyo-Hiryo Gaku Zassi., 12:154-160.

Sundaramurthy, S., 1950. Arecanut plantations in Ceylon. The Bulletin., 1(6):1-6.

Szeiz, G., 1975. Solar radiation in crop canopies. J. Appl Ecol., 12:1117-1156.

Tarhalkar, P.P. and Rao, N.G.P., 1975. Changing concepts and practices of cropping systems. Indian Fmg., 25(3): 3-7.

Togari, Y., 1950. Studies on the tuberous - root formation of sweet potatoes. National Agri. Exp. Sta. Bult., 68:1-96. Japan.

Trenbath, B.R., 1973, Neighbour effects in the genus avena 1. Comparison of crop species. J. Appl. Ecol. 10: 379-400.

Trenbath, B.R., 1974, Biomass productivity of mixtures. Adv. Agron. 26:177-210.

Trenbath, B.R., 1975, Diversity or be damned. Ecologist. 5(3):76-83.

Trenbath, B.R., 1976, Plant interactions in mixed crop communities. In. Multiple Cropping (ASA Special Publication Number 24) pp.129-169. American Soc. Agron. Madison.

Trenbath, B.R., 1978, Models and the interpretation of mixture experiments. In. Plant Relations in Pastures (Wilson, J.R., ed.),pp.145-162. CSIRO, Melbourne.

Trenbath, B.R., 1979, Light use efficiency of crops and the potential for improvement through intercropping. In. Proceedings of International Workshop on Intercropping, Hyderabad,India, Patancheru, Hyderabad, India, ICRISAT (1981).pp.14-154.

Tsuno, Y., 1975, Fertilization - Sweet potato nutrient physiology and cultivation. Int. Potash Inst. Berne. pp. 12-13.

Tsuno, Y. and Fujise, K., 1965, Studies on the dry matter production of sweet potato. Bull. Nat. Inst. Agri. Sci. (Japan).D-13:1-131.

Tyagi, C.S., Prasad, R.S. and Lodhi, G.P., 1982, Seed production Technology for Cowpeas. Indian Fmg. pp.15-16.

Uriyo, A.P., Kesseba, A., 1973, Effect of fertilizer levels on the yield of sweet potato tubers. Beitrage zur Tropichen Land (3):299-302.

Urs., V.Y.B., 1977, Effect of incidental solar radiation on photosynthetic rate, growth and yield attributes in rice genotypes. M.Sc.(Agri). Thesis, Department of Crop Physiology, University of Agricultural Sciences, Bangalore.

Varghese, P.T., Nair, P.K.A., Nelliat, E.V., Ramaverma.and Gopalasundaram, P., 1978, Intercropping with tuber crops in coconut garden. Proceedings of the First Annual Symposium on Plantation Crops.pp.399-415.

Velappan, E. and Paulose, T.T., 1974, Present position of the arecanut in India. Arecanut and Spices Bulletin. 6(2):24-28.

Wang,H.Y 1975, Response of sweet potato to fertiliser application. Tech. Bull. ASPAC Food and Fertiliser Technology Centre. p.21:41.

Wardlaw, I.F., 1976, Asimilate movement in Lolium and Sorghum leaves. 1. Irradiance effect on photosynthate, export and distribution of assimilates. Aust. J. Pl. Physiol. 3:377-387.

Warmer, T.M., 1963, The effect of soil moisture, nitrogen fertilization and some meteorological factors on stomatal aperture of Coffea arabica. L. Am. Bt.,29(116):523-539.

Whittaker, R.H., 1975, Communities and Ecosystems., 2nd Edn. Macmillan Publishing Co., Inc., New York.pp.385.

Willey, R.W., 1979, Intercropping - its importance and research needs. Field crop Abstracts. 32(12):1-10 and 73-85.

Willey, R.W. and Osiru, D.S.O., 1972, Studies on mixtures of

Watson, D.J. 1952. The physiological basis of variation in yield. Adv. Agron. 4, 101 - 145.

Willey, R.W. and Roberts, E.H., 1976, Mixed cropping in *Solar Energy in Agriculture*. Joint International Solar Energy Society Conference (Proceedings), University of Reading, England.

Williams, W.A., 1963, Competion for light between annual species of *Trifolium* during the vegetative phase *Ecology*.44:475-485.

* Original article not seen

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APPENDICES

APPENDIX .I. METEOROLOGICAL DATA
a) RAINFALL

Months	Rainfall (mm)					Rainfall (days)				
	Normal*	I yr (78-79)	Deviation	II yr (79-80)	Deviation	Normal*	I yr. (78-79)	Deviation	II yr (79-80)	Deviation
April	47.2	38.0	- 9.2	39.0	- 8.2	3.6	6.0	2.4	2.0	- 1.6
May	151.8	109.6	-42.2	69.9	-81.9	9.5	5.0	-4.5	3.0	- 6.5
June	69.9	35.9	-34.0	126.7	56.8	8.3	12.0	3.7	8.0	- 0.3
July	111.2	125.1	13.9	118.9	7.7	10.2	14.0	3.8	6.0	- 4.2
August	81.7	109.8	28.1	63.1	-18.6	13.4	12.0	-1.4	6.0	- 7.4
September	177.8	224.6	46.8	875.5	97.7	11.5	9.0	-2.5	13.0	1.5
October	192.3	167.8	-24.5	223.8	31.5	10.5	10.0	-0.5	3.0	- 7.5
November	42.1	39.2	- 2.9	58.8	16.7	4.0	2.0	-2.0	7.0	3.0
December	6.2	34.4	28.2	0.0	-6.2	0.6	3.0	2.4	0.0	- 0.6
January	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	0.1	89.2	89.1	0.0	-0.1	0.6	4.0	3.4	0.0	-0.6
March	0.4	14.0	13.6	18.2	17.8	3.9	1.0	-2.9	2.0	- 1.9
Total	880.7	987.6	106.9	993.9	113.2	76.1	78.0	1.9	50.0	26.1

* Average for five years

APPENDIX .I. METEOROLOGICAL DATA

b) MAXIMUM AND MINIMUM TEMPERATURE

Months	Maximum temperature (°C)					Minimum temperature (°C)				
	Normal*	I yr. (78–79)	Deviation	II yr. (79–80)	Deviation	Normal*	I Yr. (78–79)	Deviation	II yr. (79–80)	Deviation
April	35.5	36.0	0.5	35.0	-0.5	16.7	18.0	1.3	19.0	2.3
May	34.5	35.5	1.0	35.5	1.0	17.5	16.0	-1.5	16.5	-1.0
June	31.1	32.0	0.9	34.0	2.9	18.4	15.0	-3.4	19.0	0.6
July	29.9	28.0	-1.9	30.0	0.1	18.6	18.0	-0.6	18.5	-0.1
August	29.0	28.5	00.5	31.0	2.0	18.4	18.0	-0.4	19.0	0.6
September	30.3	29.5	-0.8	30.5	0.2	18.0	17.0	-1.0	19.0	1.0
October	30.1	30.5	0.4	30.5	0.4	14.8	16.5	1.7	16.0	1.2
November	29.2	29.0	-0.2	28.5	-0.7	12.1	11.5	-0.6	17.0	4.9
December	29.7	26.5	-3.2	28.5	-1.2	10.0	10.5	0.5	16.5	6.5
January	30.0	29.5	-0.5	29.5	-0.5	9.5	14.0	4.5	13.0	3.5
February	32.8	31.0	-1.8	33.0	0.2	12.6	17.0	4.4	15.0	2.4
March	33.9	34.5	0.6	34.5	0.6	14.0	16.0	2.0	13.0	-1.0

* Average for five years

APPENDIX .I. METEOROLOGICAL DATA

C) BRIGHT SUNSHINE HOURS

Month	Bright sunshine (h/day)				
	Normal*	I year (78–79)	Deviation	II year (79–80)	Deviation
April	9.7	10.5	0.8	9.2	- 0.5
May	9.2	9.3	0.1	8.5	- 0.7
June	7.7	4.7	- 3.0	6.7	- 1.0
July	5.3	4.6	- 0.7	4.7	- 0.6
August	5.1	4.6	- 0.5	5.8	0.7
September	6.2	5.4	- 0.8	5.5	- 0.7
October	7.3	8.4	1.1	8.5	1.2
November	6.6	8.4	1.8	5.7	- 0.9
December	9.6	5.6	- 4.0	6.5	- 3.1
January	10.1	9.9	- 0.2	9.8	- 0.3
February	8.9	9.2	0.3	10.1	1.2
March	10.1	9.0	- 1.1	8.2	- 1.9

* Average for five years

APPENDIX .II.

Effect of fertiliser levels on the plant nutrient contents of sole and intercrops of turmeric and sweet potato during their peak periods of growth

Nutrient (%)	Crop	Range of nutrients in per cent between control and higher lvels of fertiliser					
		Leaf		Stem		Tuber	
		Sole crop	Intercrop	Sole Crop	Intercrop	Sole crop	Intercrop
Nitrogen	Turmeric	2.19 - 3.44	2.05 - 3.78	1.02 - 3.15	1.07 - 3.45	1.21 - 1.82	1.07 - 1.82
Nitrogen	Sweet potato	2.18 - 4.15	2.99 - 5.10	0.98 - 2.51	1.30 - 3.35	0.98 - 1.86	0.98 - 1.86
Phosphorus	Turmeric	0.15 - 0.26	0.12 - 0.32	0.17 - 0.38	0.14 - 0.25	0.16 - 0.26	0.15 - 0.28
Phosphorus	Sweet potato	0.12 - 0.35	0.12 - 0.33	0.12 - 0.34	0.12 - 0.34	0.17 - 0.35	0.10 - 0.22
Potassium	Turmeric	2.50 - 6.00	3.00 - 5.75	2.26 - 8.07	2.56 - 6.15	2.23 - 3.53	2.10 - 3.16
Potassium	Sweet potato	2.03 - 5.00	3.03 - 4.20	2.00 - 6.28	2.90 - 5.00	2.00 - 3.76	1.50 - 2.20
Magnesium	Turmeric	2.26 - 3.96	2.28 - 3.08	2.56 - 3.52	1.63 - 3.43	1.70 - 3.10	1.66 - 3.63
	Sweet potato	1.40 - 3.66	1.66 - 3.41	1.71 - 3.15	1.73 - 3.05	1.13 - 3.16	1.10 - 3.16