EFFECT OF PALM DENSITY AND LEVELS OF NPK FERTILIZERS ON YIELD AND QUALITY OF COCONUT

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "EFFECT OF PALM DENSITY AND LEVELS OF NPK FERTILIZERS ON YIELD AND QUALITY OF COCONUT" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or society.

Vellayani,
December 29, 1978.

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CERTIFICATE

Certified that this thesis entitled "EFFECT OF PALM DENSITY AND LEVELS OF NPK FERTILIZERS ON YIELD AND QUALITY OF COCONUT" is a record of research work done independently by Shri. K.J. Abraham, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

The coconut palm (*Cocos nucifera* L.) is the worlds most extensively cultivated palm. Its cultivation extends over most of the islands and coasts of the tropics. The major coconut growing countries of the world are Philippines, Indonesia, India, Sri Lanka, Malaysia, Thailand, Papua and New Guinea, West Indies, Central and South America and East and West Africa. Of these countries Philippines, Indonesia and India account for 63% of the world area (Bavappa, 1976). The total area of its cultivation in the world is estimated to be 6.488 million hectares (Child, 1974).

India stands third in area and production of coconut in the world with an estimated area of 1.1 million hectares and an employment potential for over 10 million people. Of this, over two thirds of the area and production and confined to West Coast of Kerala (Nelliat *et al*, 1976).

Coconut is one of the most important cash cum food crops of Kerala. The word Kerala itself means "the land of coconuts". It is very much linked with the socio economy of the State.

Even though coconut is being grown for centuries, the per palm yield remains as low as 35 nuts a year (Haridasan, 1977). Among the various factors responsible for this low production, management practices like improper spacing and inadequate nutrition are important.

The spacings adopted in different countries and within the country are varied; 6 to 9 m in India, 2.75 to 14 m in Sri Lanka, 6 to 10 m in West Africa and 10 to 11 m in Indonesia. The square system of planting is widely adopted in India. A spacing ranging from 7.5 to 9.0 m is now recommended by the various agencies like Kerala Agricultural University (K.A.U.), Department of Agriculture and Central Plantation Crops Research Institute (C.P.C.R.I.) (Anon, 1976 b) and Anon, 1972).

It is well accepted that maximum yields can be obtained only if the palms are planted at optimum density. One of the reasons for increasing palm density by cultivators was that the valuation of lands were earlier done on the basis of number of trees and not on yield or area (Menon and Pandalai, 1958). With the advancement of more effective agricultural techniques plant density appears to be an important element in obtaining higher yields. Optimum density depends upon several factors. For a given set of predetermined environments (climate, soil, planting materials etc.) it is necessary to determine the optimal density at which maximum yield can be obtained.

Information on the optimum level of fertilizers required under varying densities of planting is also scarce, the present recommendations (0.50 kg N, 0.32 kg P and 1.2 kg K_2O/palm/year) which are rather arbitrary are based on a few field experiments conducted from time to time at few locations by the K.A.U. and C.P.C.R.I. (Anon, 1976 b and Nelliat et al, 1976).

Marked increases in yield and growth of coconut due to manuring have been reported by many workers (Salgado, 1952, Nuliyar and Nelliat, 1971).

Under these circumstances the present study was initiated with the following objectives.

1. To determine the optimum level of NPK fertilizer mixture to obtain maximum yield under the agro-climatic conditions of Southern Kerala.

2. To determine the optimal palm density to obtain economic yields per unit area.

3. To study the correlation if any of soil and leaf nutrient status and yield for fertilizer recommendations.

4. To study the effect of spacing and manuring on quality of coconuts in terms of copra and oil outturn.

An experiment started at the Coconut Research Sub Station of K.A.U. at Balaramapuram was used in the present study.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Research on coconut started in India in the early part of this centuary with the establishment of four experimental farms, one each at Kasargod and Pillicode (Nileswar I) and two at Nileswar (Nileswar II and III) (Nelliat et al, 1976). The setting up of these different stations was done with a view to initiate organised research in different typical coconut soil types viz. red loam, laterite gravelly, red sandy loam and littoral sand. The first attention of workers was on nursery techniques and management practices like ploughing, weeding and soil moisture conservation measures. The next priorities were on manuring aspects; in the beginning organic manures like oil cakes, guano, ash and green leaf manures were tried. The work done in India and abroad was reviewed by J.S. Patel in his monograph on coconut published in 1938. As a preliminary to regular nutritional studies many attempts were made to estimate quantities of nutrients removed from soil by coconut palms (Pillai, 1919; Jacob and Coyle, 1927; Copelan, 1927; Georgie and Teik, 1932; Eckstein et al, 1937; Patel, 1938; Carvalho, 1947 and Cook, 1950). Pillai and Davis (1963) reviewed literature upto 1958 and presented data of their own and according to them the annual nutrient removal by 175 adult palms in a hectare was 52.2 kg N, 13.0 kg P, 70.9 kg K, 34.3 kg Ca and 12.6 kg Mg. According to Shetty (1978), the corresponding figures, applicable to Tamil Nadu are 95 kg N, 48 kg P and 148 kg K per annum per hectare. Magat (1978) has estimated the annual requirement for a normal bearing palm as 0.68 kg N, 0.29 kg P_2O_5, 1.01 K_2O, 0.90 kg Cl, 0.28 kg Ca and 0.11 kg Mg.

It was in 1934 that a comprehensive fertiliser experiment was initiated in Sri Lanka and continued till 1965. It was probably the first experiment in perennial crops like coconut where Fisherian techniques were adopted. Since 1935 many fertiliser trials have been carried out in many parts of the world including India, West Africa, Pacific Islands and Jamaica. The experiment at Kasargod with no cultivation, cultivation alone and cultivation and manuring, which continued for a long time, gave encouraging results for adopting inorganic manuring.

The Indian Central Coconut Committee was formed in 1945 which took over Kasargod station and co-ordinated research activities in the country. Fertiliser demonstration trials were established and research activities strengthened. In 1958 the available information, till then on coconut culture, were compiled by K.P.V. Menon and K.M. Pandalai in the voluminous book titled "The Coconut Palm - A Monograph". From 1947 onwards a series of research stations were established in different parts of the country to study the nutrient requirements and fertiliser response of coconut under the agroclimatic conditions of each region. These include the stations at Balaramapuram and Kumarakom in Kerala, Veppankulam and Muthupet in Tamil Nadu, Arsikere in Karnataka, Ambajipeta and Rasole in Andhra Pradesh, Ratnagiri (Maharashtra), Sakkigopal and Konark (Orissa) and Mahuva in Gujarat.

The difficulty in conducting fertiliser and spacing experiments in coconut due to the perennial nature of the crop as well as the large requirement of experimental area posed many problems. Soil analysis have been extensively used as a method for predicting crop requirement. During late forties and entire fities, the concept of leaf analysis as an index of crop nutrient status gained momentum. Largely as a result of the pioneering work of the scientists of Institut de Recherches pour les Huiles et Oleagineux (IRHO) in West Africa, foliar analysis have been widely adopted as a diagnostic method in predicting fertiliser requirements of coconut. Of late, several reports have come from India and abroad on soil and leaf analysis.

An attempt has been made here to review the more important literature related to field experiment on nutrition and spacing (palm density) as well as the studies on soil and leaf nutrient status related to some of the cultivated palms with emphasis on coconut. The review has been classified mainly under different headings as mentioned below.

1. Effect of Nutrients(major and minor) and Spacing on Yield and yield components.

2. Effect of Nutrients and Spacing on vegetative Growth characters.

3. Effect of Nutrients and Spacing on Leaf nutrient status.

4. Effect of Nutrients and Spacing on Soil nutrient status.

1. Effect of Nutrients(major and minor) and Spacings on Yield and yield components

1.1 Effect on Yield of nuts.

1.1(a) Nitrogen.

Amongst the production factors, fertilisation is certainly one which brings the quickest yield increase in coconuts. The response of coconut to major nutrients viz. nitrogen, phosphorus and potash has been well recognised. The increases in yield are due to enhanced nutrient absorption and their assimilation for the dry matter production. Nitrogen application is reported to have caused copra yield increase by 8.0% over no fertiliser (Salgado, 1952). Menon and Pandalai (1958) have elaborately dealt with the role of major and minor elements in the nutrition of coconut. They have stated that individually nitrogen, which is a constituent of plant cell and chlorophyll, promotes the development of vegetative parts especially leaves and trunk and these parts in turn account for increase in yield. Nut production increased by 16.9% by application of N (Muliyar and Nelliat, 1971). On the other hand Prudente et al, (1976) observed a reduction in the yield when nitrogent was applied singly over an unfertilised treatment even though N was found to be a limiting factor when applied with KCl.

1.1(b) Phosphorus.

Reports from Sri Lanka (Salgado, 1947) indicated beneficial effects of NP interaction on female flower production which in turn is expected to result in higher yields. Phosphorus though not often a limiting factor is found in all parts of the plant including leaves and seeds and where vigorous cell division takes place and is responsible for efficient root production. (Menon and Pandalai, 1958). Nethsinghe (1963) found response for P, from an experiment in Sri Lanka started in 1935, only after 28 years of P application. On the other hand Muliyar and Nelliat (1971) obtained response to P_2O_5 after eight years of continuous application. Martin and Prioux (1972) have found that application of tripple super phosphate increased nitrogen and magnesium levels in leaves of oil palm and they have concluded that P should be the pivot of fertilizer formulae in that crop. Coomans and Ochs (1976) have suggested an optimum economic dose of 0.7 kg of bicalcic phosphate per tree per year in South Eastern Ivory coast conditions. According to Kamaladevi et al (1978) responses due to P are varied. This is because of the initial fixation of P in unavailable form.

1.1(c) Potassium.

Potash has a very important role in coconut nutrition viz. it regulates water economy, promotes root development, impairs disease resistance and improves quality of seeds. Many parts of the palm contain high amounts of potash and hence the demand for potash is very high (Menon and Pandalai, 1958). With the above functions the effect of potash on yield increases is evident. A potash dressing of 1.0 to 1.5 kg per tree per year leads to yield being doubled or even tripled (Fremond and Ouvrier, 1971). Muliyar and Nelliat (1971) also found significant response to K from fifth year onwards. Uexkull (1971) has shown that K fertilization increases yield. The yield increased from 23.1 nuts per palm in plots receiving N alone to 76.7 nuts when N and K were applied. Green (1972) found significant interaction between N and K in increasing yield of oil palm though N or K singly did not respond. Uexkull (1972) estimated that the increased copra out turn due to K dfertilisation could be apportioned as 30% to the increase in number of nuts. Child (1974) has suggested K and N as the most likely fertiliser for coconut. According to Coomans and Ochs (1976) K application is indispensible and Mg necessary to obtain full effect of K on yield. In the absence of K the other elements have a nil or depressive effect. Excessive K can induce Mg deficiency and can lead to a fall in yield. Sumbak (1976) based on the results of coconut fertiliser trials in New Guinea has reported economical response to K. Annual yield increments of 0.30 to 0.38 tons per hectare resulted from one to two kg K Cl per palm.

1.1(d) NPK fertilisers.

The response to NPK fertilisers on yield of coconuts has been reported by many workers from very early times. Cook (1932) has given an example in Sri Lanka where, when cultivated and manured plots gave an average 90 nuts per tree, unmanured plots gave only 30 nuts per tree. John (1952) suggested a manurial dose of 0.25 to 0.50 kg N, 0.10 to 0.25 kg P_2O_5 and 0.375 to 0.750 kg K_2O per tree per year. According to Menon and Pandalai (1958), the yield from a regularly cultivated and manured plot at Kasargod was 64 nuts per palm as against a poor yield of 10 nuts from a neglected plot. John and Jacob (1959) found that the application of 0.34 kg N, 0.34 kg P_2O_5 and 0.68 kg K_2O per palm per year resulted in an increase of 35% in nut production over cultivators practice. Muliyar and Nelliat (1971) have reported that in the combined analysis (10 years data), the effect of N, P and K were significant and have suggested the optimum dosage values as N 0.47 kg, P_2O_5 1.0 kg and K_2O 0.89 kg per palm per year. Responses to NPK fertilisation in increasing yield have been reported in other palms also. Green (1972) has reported considerable increase in production (12 to 22%) on account of N, P and K application in oil palm. Rawther and Abraham (1973) obtained three to four times yield increase in NPK applied plots over no manured plots in arecanuts. Markose and Nelliat (1975) have reported an yield increase of 11.7 nuts per palm (coconut) in single application of fertilisers and 17.8 nuts in split application while the increase was only 3.7 nuts in control over pre treatment data. For Venezuela conditions, in general, it is recommended to apply 200-400 g N, 200-400 g P_2O_5 and 500-1000 g K_2O per palm per year (Anon, 1976a). An application of 225 g N, 337 g P and 337 g K per palm per year was found to be the most economical dose for Central Travancore area giving 40 to 50% increased yield over no fertilisation (Anon, 1976b). To obtain higher efficiency of utilisation the annual input of fertilisers viz. 500 g N + 320 g P + 1200 g K has to be applied in two or more split doses

(Nelliat et al, 1976). Prudente et al (1976) basing on the results of an experiment in Davavo has found that nut production was increased by 202%, 127% and 93% by NPK application over plots with N alone, unfertilised plots and NP plots respectively. They also found that KCl with either N or NP gave a mean yield of 23.1 kg copra per palm where as trees without KCl produced only 6.6 kg per palm. Leaf analysis revealed that response was only for N and Cl.

1.1(e) Calcium.

Krishna Marar, . . . (1961) out lined that lime had a definite place in coconut soil management programme in regions where soil acidity was a problem. Epstein (1972) points out that a major function of Ca may be in maintaining cell organisation. Calcium is an essential component of the enzyme, amylase, and is also required as an activator by some enzymes. It is a major component of middle lamella of plant cells and may therefore have effect on the mechanical strength of tissues (Corley, 1976).

1.1(f) Magnesium.

Magnesium is an essential component chlorophyll molecule and its deficiency was found to cause decreased chlorophyll content (Peaslee and Moss, 1966). Coomans and Ochs, (1976) have recommended an optimum economic rate of 0.9 kg Kieserite

(26% M_GO) per tree per year in South East Ivory Coast conditions. According to Corley (1976) Mg is required by even more enzymes than K. Among many systems requiring Mg is that of fatty acid synthesis.

1.1(g) Sodium.

According to Pandalai (1957) the addition of small quantities of common salt to coconut gardens, could if at all, be only of some advantage and never harmful. Application of NaCl to coconut palms is practised from very early times (Menon and Pandalai, 1958). Though sodium is found in plant tissues, it has not been shown to be essential for most plant species (Corley, 1976). In Davavo a dressing of 2 kg NaCl/tree remarkably reduced foliar yellowing caused by nutrient deficiency (Magat, 1978).

1.1(h) Chlorine.

Chlorine was suggested as an essential element in plant nutrition by Nobbe and Siegert (1863). Its deficiency is not observed in any plant and it is presumed that plants take up enough Cl from atmosphere (Johnson et al, 1957). Jacobs and Uexkull (1958) rated Cl as an essential element in small quantities. It is an essential constituent of chloroplasts necessary for photosynthetic activity, but its precise function is not clearly understood (Chonlao, 1970). Mendoza and

Prudente (1972) initially demonstrated the role played by chlorine in the vegetative and reproductive growth of palms. Chlorine is reported to effect absorption of calcium. Brunin et al (1975) reports that the action of Mg is nil in the absence of Cl. Magat et al (1975) have reported from Philippines that the response to KCl application is more likely due to the Cl than the K. According to Magat (1978) chlorine enhances better absorption of P, K, Ca and Mg. The addition of chlorine to the soil through rain water is about 15 - 40 kg/ha/annum.

1.1(i) Sulphur.

Southern (1969) has suggested an application of 2 lb of sulphur per palm once in two years for conditions in Papua and N. Guinea. Ollagnier and Ochs (1972) have reported that sulphur deficiency affects the survival of young plantations. As in chlorine, it seems that anionic nutrition of SO_4 or Cl radical of salts used as fertilisers is important. Sulphur is an essential component of proteins and various coenzymes and sulphur deficiency will tend to cause the same general disruption of metabolisms as N and P deficiency (Corley, 1976). Sumbak (1976) has obtained excellent response to S in the trials conducted in New Guinea. Yield increments of 0.4 to 0.5 tons/ha were obtained by application of 0.8 kg sulphur per tree per year.

1.1(j) Spacing.

Coconuts are planted at different densities in different countries and also there are wide variations within a country. Menon and Pandalai (1958) have cited the different spacings adopted in different countries. Thomson (1968) obtained increase in yields of coconut in Cook islands by thinning of existing stand. According to Whitehead and Smith (1968) every plantation inevitably suffer from tree losses and hence a little higher density over optimum will compensate. In the spacing experiment conducted in Jamaica (Whitehead and Smith, 1968) maximum yield of 4815 nuts/acre was obtained at 22' x 22' spacing which was the lowest spacing tried. Per palm yield of 95.1 nuts per year was obtained at the widest spacing of 35' x 35'. Romney (1972a) is of the view that in the development of more effective agricultural methods, planting density appears to be an important element in precocity and high yields per acre. It is hardly surprising that reports of successful spacing experiments cannot be found in literature (Smith, 1972). He has stated that maximum yields can be obtained only if the palms are planted within an optimal density range. According to him fertile soils can support more palms per acre. He has also cited another view that palms in fertile soils grow larger and hence less density is advisable. On the results of the spacing experiments conducted in Jamaica, he supports the earlier view by Patel and others that 25' on the triangle is the best spacing for Jamaican Talls and 17 - 18' for Malayan Dwarfs. Ramachandran et al (1973) reported that the system with high density of planting have given consistently lower yields/ha in oil palm. The maximum yield of nuts/acre (above 10,000) was obtained with a palm density of 145 to 160/acre in an experiment in Jamaic (Anon, 1974). According to Child (1974) the concensus of opinion among experience planters in Sri Lanka was that planting density should not exceed 160/ha on the worst soil and 140 on the best. Muhammad et al (1974) have recommended a spacing of 9.1 m x 9.1 m based on the results of a spacing cum manurial experiment at Veppankulam where there was 70% increase in yield in plots with lowest density over plots with highest density in the 8th year of planting. While a stand of 250 palms/ha (based on return per rupee invested) has been arrived at as best from the spacing trials at Pilicode, a spacing of 7.5 m x 7.5 m (178 palms/ha) demonstrated its superiority at Balaramapuram. (Anon, 1976c).

1.2 Copra per nut.

The effect of potassium on the out-turn of copra has been pointed out by many workers. Salgado (1952) reporting on the results of Sri Lanka experiments has shown 39% increase in copra yield due to K application. John and Jacob

(1959) found that fertilisation resulted in an increase of 44% in copra production over cultivators practice. Muliyar and Nelliat (1971) have also held that N has little effect, P has some beneficial effect and K has very beneficial effect on copra out turn per tree. Ollagnier and Ochs (1971) reported that weight of copra/nut was double in plots receiving KCl than plots without KCl as response to chlorine. Magat et al (1975) have reported that KCl application had increased copra/tree in Philippines and the net profit was more by 60%. Markose and Nelliat (1975) have also reported increase in copra out turn by fertilisation.

1.3 Percent oil in copra.

Menon and Pandalai (1958) have cited that when oil percent of copra from NPK Ca applied plots was 64.30%, it was only 56.77% in plots with green manure only. Smith (1968) found that there was no difference in oil percentage (72.5%) in copra with fertilised and unfertilised plots in the same variety. Fields with higher palm density tend to have lower oil percentage as also in sites where higher yields of nuts are obtained. Muliyar and Nelliat (1971) did not find much difference in oil content due to N, P or K treatments. Romney (1972) reporting the results of four fertiliser experiments in Boston, Pleasant Hill etc. did not find any significant difference in oil content of copra due to application of P or any other fertiliser except that there was effect for P in one year which later disappeared. Corley (1973) did not find difference in oil to bunch ratio in oil palm due to fertilisation. But Ollagnier (1973) found in Colombia that the correction of Cl deficiency leads to an increase in oil.

1.4 Weight and volume of nuts:

Whitehead and Smith (1968) said that nut size decreased with increased plant density. Smith (1969) stated that neither N nor K influenced nut size, though P did influence. Muliyar and Nelliat (1971) have reported that N adversely affected all the nut characters viz. weight and volume of whole nut, and weight and volume of husked nut while K improved the characters and P had negligible effect. Uexkull (1971) found that nut size and weight decreased rapidly in the absence of K. Weight of husk decreased with an increase in N level (Nelliat, 1973). Uexkull (1972) estimated that the increased copra out turn due to K fertilisation could be apportioned as 70% to the increase in nut size.

1.5 Female flowers.

It has been generally observed that fertiliser application enhances the female flower production as well as the setting percentage. Salgado (1947) found that female flower production increased by 15% from N application and NP interaction had a positive effect. K_2O application of 0.68 kg/tree increased setting % by 35% over no application of K. Based on the observation on a number trees at Nileshwar-1 and Kasaragod, Menon and Pandalai (1958) have stated that on an average, good yielding palms produced 151, medium yielders 120 and poor yielders 41 female flowers per annum. They have also stated that poor yielders reponded well to manuring (33.3% increase) while good yielders produced only 6.5% more flowers. Beneficial effect of N was seen in the increased production of bunches ranging from 11.7% to 12.8% and female flowers between 20% to 40% (Anon, 1967). Whitehead and Smith (1968) found that the number of set nuts increased from closest to the widest spacing. A large part of the increased nut count per palm at the wider spacing, was due to greater number of set nuts/bunch rather than to an increase in the number of bunches. Smith (1969) has reported that K application improves flower setting. Reports from Jamaica also support the role of N in increased female flower production (Anon, 1970). Smith (1972) found that at high densities though flower production per inflorescence was high, setting was less. Child (1974) has reported that NaCl dossings can significantly increase the number of inflorescences, number of female flowers per tree (19% increase) and number of nuts (13%). Markose and Nelliat (1975) have reported that annual single application of fertilisers resulted in high production of female flowers.

2. Effect of Nutrients and Spacing on Vegetative Growth Characters

2.1. Early bearing:

Salgado (1952) reported that in the palms receiving K_9 the first fruits were observed five years after planting while it took eight years for the unmanured palms to come to bearing. According to Smith (1969) K application improves the ability of the palms to carry fruit. Smith (1972) quoting an experiment in Jamaica has stated that palms spaced at 33' square (40 palms/acre) are slow to come to bearing as compared to palms spaced closer. Cooke (1954) reported that proper manuring of seedlings will promote early bearing and high yields. Muhammad et al (1974) have stated that the pre-flowering period of coconut is reduced from 84 months in unfertilised plots to 68 in plots receiving fertilisers. Similarly, in the eight year old plantation when only 11 out of 18 palms in unfertilised plots produced nuts, 17 palms under fertilised conditions reached fruiting stage during the same period. Differential spacings were not found to have influenced earliness in bearing.

2.2. Height and Girth of palms.

According to Patel (1938), cultivation and manuring and better soil conditions favour the production of taller stems. Close planting is also reported to favour taller stems. Whitehead and Smith (1968) found that palm density did not significantly influence the height of palms. According to them Girth of stem is influenced among other factors by fertility of the soil. Studies in Jamaica showed that application of N increased trunk growth (Anon, 1970). Fremond and Ouvrier (1971) have recorded that absence of K application for initial seven years of planting had produced smaller trees. (height as well as girth). Muhammed et al (1974) found that height and girth of palms (1.70 m and 68.00 cm respectively) wereless in unmanured plots as compared to manured plots (2.21 m and 72.00 cm).

2.3. Leaves.

In a coconut palm, the first set of 10 - 12 oldest leaves are of very little value to the tree having past their prime (Sampson, 1923). According to Patel (1938) the number of leaves in a group of trees vary from 22 to 35/tree. He has further reported that manuring and cultivation had beneficial effect on the production of leaves, on fertile soil the rate of production is much more. Manuring has resulted in the production of larger leaves. He has also stated that trees having greater rate of production of leaves in general give better yield than others. Davis(1954) has recorded that the average length of leaves was between 4.5 to 6.0 m which varies according fertility. He has stated that on an average there will be 200-250 leaflets in a leaf of an average coconut palm. Menon and Pandalai (1958) have stated that there will be 30 to 40 opened leaves in adult healthy trees. According to Fremond and Cuvrier (1971), absence of K application for initial seven years of planting produces trees with less number of leaves, less length for limb of fronds, less index of vigour, less weight of leaflets, and the total number of leaves produced since planting was also less. Uexkull (1971) based on the results of experiments in Philippines has also reported that potash application caused increased number of fronds. Muhammed et al (1974) did not find any effect on vegetative characters on account of differential spacing viz. 6.1 m^2, 7.6 m^2 and 9.1 m^2 tried in an experiment at Veppankulam. But manuring was reported to have increased the number of functioning leaves (20.67) over no manuring (18.22 leaves).

2.4 Leaf Area and Light infilteration

Uexkull (1971) has found that in Philippines, K application enhanced the leaf area and improved the leaf angle which resulted in better utilisation of sun light. Corley (1973) has stated that crop growth rate increased with LAI in oil palm. NAR and DMP decreases with increases in LAI. Nair and Balakrishnan (1976) studying on light interception in a coconut-cocoa mix have observed that only 44% of the sun light was intercepted by a pure stand of coconut plantation aged 16 years and planted at a density of 178 per hectare.

3. Effect of Nutrition and Spacing on Leaf nutrient status.

Extensive work has been done in India and abroad on the leaf nutrient status in coconut and critical levels of these nutrients in leaves have been arrived at by many workers.

Pillai and Davis (1963) studying on the removal of nutrients from soil by coconut palms have reported that the foliar nutrient content of a healthy West Coast Tall palm to be 1.40% N, 0.16% P and 1.00% K on dry matter basis. Prevot and Ollagnier (1963) suggested the critical levels (in 14th leaf) as 1.80% N, 0.10% P and 0.45% K. Fremond <u>et al</u> (1966) on reviewing the results of 20 years research on coconut carried out by IRHO in different countries fixed the critical levels of foliar N, P, K, Ca and Mg as 1.8 to 2.0, 0.12, 0.8 to 1.0, 0.5 and 0.3 per 100 respectively on dry matter basis. Reports from Sri Lanka (Anon, 1969) indicated critical levels of N (1.98%), P (0.13%) and K (0.87%). Southern (1969) suggested a critical level of 150 ppm for S in the 9-14 leaf of coconut. According to Ollagnier and Ochs (1972) the critical level of leaf sulphur lies between 0.20 and 0.23%. Magat (1976) has quoted foliar critical levels of Na, Cl and S (apart from other nutrients) as 0.4%, 0.5 to 0.6% and 0.2% respectively.

Bachy (1963) has cited that for optimal growth and yield, the sum of K, Ca and Mg should be 2.7% of the dry weight and 67 to 70% of this should be K. Fremond et al (1966) found the same leaf P level in poor and high yielding groups of palms. Smith (1968) obtained significant correlation between per cent oil and foliar K as well as per cent oil and foliar Mg in Malayan Dwarf. The antagonism between K and Mg is to be expected but not the effect of leaf level of these nutrients in oil%. Smith (1969) suggested an N K ratio of 2.25 where foliar level of N was less than the critical level of 1.8%. Kanapathy (1971) could not establish any relationship between yield and nutrient status of different yield groups. Kamala Devi et al (1973) found a significant increase in the leaf N content (1.4% to 1.55%) due to fertilisation. (1 kg N, 1 kg P and 1 kg K/palm) but it did not reach the critical level of 1.8% suggested by IRHO. The P status in leaf was near to critical level. The leaf status of K was very low in unfertilised plots. The Ca level in leaf did not show much variation while there was significant variation in the case of Mg between medium and high level of fertilisation. Thomas (1973) from his obervations on low and high yielding groups of coconut palms in Tanzania has found that

1. high yielding palms recorded higher N level in leaf than low yielding group, however both were less than the critical level of 1.8 to 2.0%;

2. the results of P level in leaf varied, however it was higher than the critical level of 0.12%;

3. Foliar K was high in low yielding group of palms and K levels in low as well as high yielding groups were higher than the critical level;

4. high yielding groups had higher foliar Ca but lower than the critical level of 0.5%; and

5. the foliar Mg was high in low yielding group.

Ramanandan and Pillai (1974) have reported that foliar N and K were significantly higher in manured plots as compared to unmanured plots, leaf P and Mg were less in manured plots and leaf Ca did not show any significant difference. Increased N K status of leaves was reflected in the higher yield of 67 nuts/palm in manured plots as against 39 nuts in unmanured plots. Magat et al (1975) have reported that the yield and copra increase due to varying KCl applications (0 to 3.3 Kg/tree) are in close positive relationships with Cl content of leaves and with negative relationship with the K content.

4. Effect of Nutrition and Spacing on soil nutrient status.

Sankaranarayanan *et al* (1958) have reported that coconut palms can with stand soil salinity upto 0.6%. Nethsinghe (1962) found that after six months of application of fertilizers, there was little difference in available N and K contents of soil between fertilised and unfertilised plots. It was seen that continued application of fertilizers to young palms had improved the available nutrient status of the top 50 cm of the soil, the higher level having superior effect (Anon, 1972). Nelliat *et al* (1972) quoted by Nelliat (1973) reported that the continued application of fertilisers had little effect on soil organic carbon and available N, but there was considerable build up of available P and K in the soil. Thomas (1973) based on his comparison on high yielding and low yielding groups of coconut palms in Tanzania has reported that

1. N in soil was little higher in high yielding group;
2. Low yielding group grew in soil with greater available P;
3. K was higher in soils of high yielding group;
4. there was no difference for Ca; and
5. Mg was higher in soils of low yielding group.

Ramanandan and Pillai (1974) have reported from their studies on the effect of fertilisation on soil nutrient content that there was no difference in N content between fertilised and unfertilised plots. P and K was higher in unmanured and cultivated plots. They also found that Ca content was more and Mg content was less in manured plots. Kamaladevi et al (1975) have found that the pH of unfertilised plots was 5.1 and that of fertilised plots as 4.3 in red sandy loam soils of Kasaragod. Wahid et al (1975) have observed that P level in soil and leaf was unaffected by discontinuance of application of phosphatic fertiliser in an year in a plantation where P application was regular. Fotyma (1978) found that P accumulated in soil as a result of regular fertilisation is taken up by the plants in the course of time to come.

M A T E R I A L S A N D M E T H O D S

MATERIALS AND METHODS

The results presented in this thesis were collected from a spacing cum manurial experiment on West Coast Tall palms in progress at the Coconut Research Sub-Station, Balaramapuram of the Kerala Agricultural University. The Station is located at Kattachalkuzhy, 3.2 km south of Balaramapuram (08°20' N latitude and 76°57' E longitude) on the Balaramapuram - Vizhinjam road in the Neyyattinkara Taluk of Trivandrum District in Kerala State. The soil is typical red loam (Vellayani series). The annual rain fall varies from 1200 - 1800 mm (Appendix 1). The mean maximum temperature ranges from 29°C to 34°C. The spacing cum manurial experiment utilised for the studies is located in the Block B of the Experiment Station Farm. The pre-experiment soil analysis data are pH 5.3, N (organic carbon) 0.24%, P 2.0 kg/ha, K traces and soluble salts 0.01 milli mhos/cm. Summer water table is 30 m deep. The experiment was initiated in June, 1964 using relatively homogeneous West Coast Tall coconut seedlings. One year old seedlings were planted in 0.9 m^3 pits. The land was previously under a coconut plantation. All the trees were removed before the seedlings were planted. There are no records available of the management practices or yield of the earlier plantations.

The experiment was designed to determine the optimum spacing at different levels of fertilizer application. Three levels of spacing and three NPK levels were included in the experiment.

Design: Randomised Block

No. of replications: Three.

Treatments: Spacing.

Symbols	Spacing	No. of palms per plot.	Plot size	Plant Density (No. of palms/ha)
S_0	5.0 m x 5.0 m	5 x 5	25.0 m x 25.0 m	400
S_1	7.5 m x 7.5 m	3 x 3	22.5 m x 22.5 m	178
S_2	10.0 m x 10.0 m	2 x 2	20.0 m x 20.0 m	100

Fertilizer levels

Symbols	g/tree/year		
	N	P	K
M_0	0	0	0
M_1	340	225	450
M_2	680	450	900
Source of nutrients	Ammonium sulphate	Single super-phosphate.	Muriate of Potash.

Treatment combinations:

1.	S_0 M_0	2.	S_0 M_1	3.	S_0 M_2
4.	S_1 M_0	5.	S_1 M_1	6.	S_1 M_2
7.	S_2 M_0	8.	S_2 M_1	9.	S_2 M_2

Border rows: Common border row for the plots.

(Fig. 1)

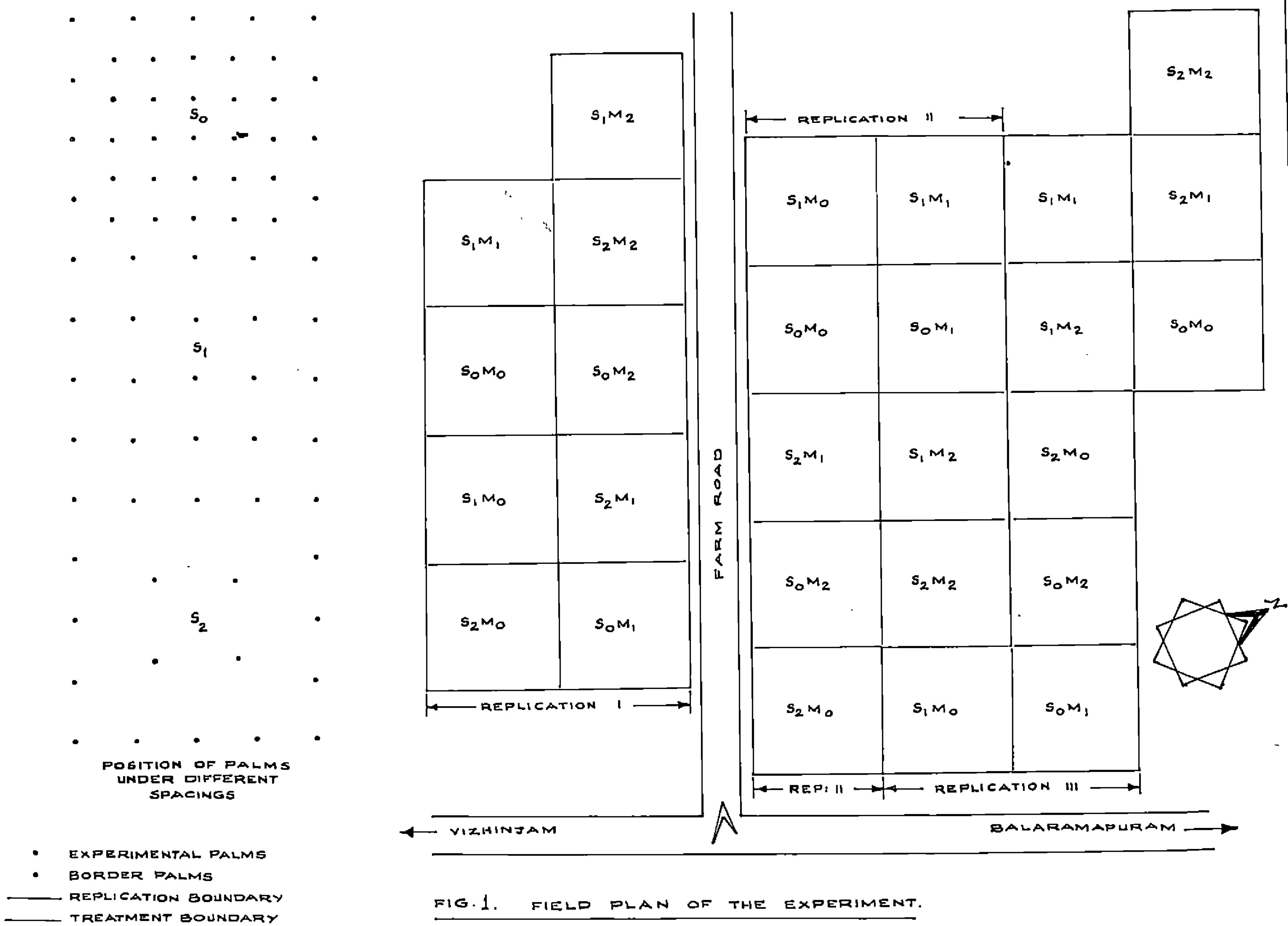

FIG. 1. FIELD PLAN OF THE EXPERIMENT.

The fertilisers were applied annually in one dose in trenches of 45.0 cm width and 22.5 cm depth around the trunk at a distance of 1.0 m. During the first year 1/3 of the full dose and during second year 2/3 of the full dose were given. From third year onwards, full dose was applied annually in September.

A. Observations and Chemical Analysis.

The data wherever used under (1) yield and yield components and (2) vegetative growth characters for the individual years 1972, 1973, 1974 and 1975 were obtained from the original records of the Experimental station.

1. Yield and Yield Components

1.1 Yield of nuts.

Yields of individual palms were recorded from six bi-monthly harvests (from February, 1976 to December, 1976). Yield per hectares was computed from the above data.

1.2 Copra per nut.

Four nuts were selected at random from each plot (where nuts were available) at the time of harvest in April, 1977. Copra was prepared by sundrying of the kernal for four days to about 6% moisture content and copra weight was recorded in grams. The same nuts were used for all the nut characters mentioned below.

1.3 Percent oil in copra.

The copra from each plot was sampled to about 50 g., oven dried at 60°C for 16 hours and sub sampled to 10 g. (Romney, 1972 b) and the oil content of copra was estimated by ether extraction method. (Anon, 1971).

1.4 Weight and volume of nuts.

1.4(a) Weight of whole nuts.

All the nuts with husk from each plot were weighed on the same day of harvest and the weight expressed in grams.

1.4(b) Volume of whole nuts.

All the nuts with husk were individually immersed, using a strong needle, in a can filled with water and fitted with a sprout near the top and the displaced water flowing out through the sprout was measured to determine the volume in cc.

1.4(c) Weight and volume of husked nuts.

The nuts were dehusked and weight and volume were determined.

1.4(d) Ratio of weight of husked nuts and whole nuts.

This was determined from the data collected under 1.4(c) and 1.4(a) above.

1.4(e) Ratio of weight of copra and husked nuts.

This was calculated from the data from 1.2 and 1.4(c) mentioned above.

1.5 Female flowers.

1.5(a) Production of female flowers.

Number of female flowers were recorded by counting the number of female flower scars on the rachis after harvests and adding to this figure the number of nuts harvested.

1.5(b) Setting percentage.

Setting percentage was calculated as

$$\frac{\text{Number of nuts harvested}}{\text{Number of female flowers}} \times 100$$

2. Vegetative Growth Characters

2.1 Number of Bearing palms.

The number of bearing palms per plot, at 12th year of planting ie. 1976, was obtained from the yield data and the percentage calculated as

$$\frac{\text{Number of yielding palms per plot}}{\text{Number of surviving palms}} \times 100$$

2.2 Height and girth of palm.

2.2(a) Height.

The height of all the palms were measured from the base of the crown to the ground level and the same expressed in meters.

2.2(b) Girth.

The girth of trunk of all individual palms was measured just below the crown (ie. just below the oldest leaf) and recorded in cm.

2.3 Leaves.

2.3(a) Total number of leaves produced.

Total number of leaves produced from planting was recorded in January, 1977 from the tagging made in the last opened leaf during the previous observations and adding to this, the number of new leaves standing above the tagged leaf.

2.3(b) Number of functioning leaves.

This was recorded by actually counting the standing leaves on the crown (excluding dried leaves if any) in January 1977 observation.

2.3(c) Rate of production of leaves.

The number of leaves produced above the tagged leaf of January 1976 observations were counted in January, 1977 to obtain the rate of production of leaves.

2.3(d) Total length.

The oldest functioning leaf from each tree was cut down and its total length measured taking care that the length of any portion of petiole adhering to the trunk was not excluded. The length is expressed in cm.

2.3(e) Length of petiole.

This was measured as above(2.3(d)) from the same leaf.

2.3(f) Length of leaf blade.

The length of leaflet bearing portion was also recorded from the same leaf under 2.3(d).

2.3(g) Breadth of leaves.

Each leaf was put flat on the ground and the maximum breadth from the tip of one leaflet to the tip of another leaflet on the opposite side was recorded in cm.

2.3.(h) Number of leaflets.

The number of leaflets on one side of the leaf was counted and recorded.

2.3(i) Length of leaflets.

The longest leaflet on the leaf vide (2.3(d))was measured in cm.

2.3(j) Breadth of leaflets.

The breadth at the maximum point of the leaflet was recorded in cm.

2.4 Leaf area and light infilteration.

2.4(a) Leaf area index.

The area of a leaf was calculated using the formulae $Y = 3.5459 + 0.3596 X$ where $X = l \times b$ or length of leaf blade in m $\times$ maximum breadth of the leaf in m (Anon, 1977). LAI was calculated as $\frac{Y \times \text{mean number of leaves/palm}}{\text{Area occupied by a palm}}$.

2.4(b) Light infilteration.

The intensity of light falling on the ground was measured in Lux using a portable lux meter. The recordings were made five times a day at two hour intervals starting from 08.00 hours and ending at 16.00 hours on eight days (partially cloudy and bright days) during October 1976 to March 1977. To sample the levels of light intensity on the ground, three points were fixed in each plot, one at the centre of the plot, second at the middle of two adjacent palms in N S row and third on the E W row and the mean of the three readings was taken as intensity for that plot at the stipulated time. The maximum intensity which the instrument could record was 30,000 lux and at instances where the intensity was above this range, the values were taken as 30,000 lux for the purpose of calculation (Nair and Balakrishnan, 1976).

3. Leaf Nutrient Status

Foliar analysis for diagnostic purposes are particularly useful for perennial crops since they are relatively slow growing. With this in view, leaf samples were collected in the last week of February, 1977. Four trees were selected at random from each plot for selection of leaf. The sampling leaf was fixed as $\frac{n}{2} + 1$, where 'n' is the total number of leaves on the crown at the time of sampling (Menon and Pandalai, 1958). Five leaflets from either side of the middle portion of the sampling leaf were removed. Only the central 10 cm portion of each leaflet was utilised for chemical analysis after discarding the mid rib and 2 mm portion of the outer edge (Fremond et al, 1966). The samples were wiped with absorbent cotton and dried in a hot air oven at 70°C to a constant weight. The samples were then cut to small pieces and powdered. The samples (9 treatments x 3 replications) were digested using a 1:2 perchloric acid - nitric acid mixture (Jackson, 1967) for estimation of all the nutrients mentioned below except for nitrogen and chlorine. All the values are expressed in percentage on dry matter basis.

3.1 Nitrogen.

Total nitrogen was estimated by micro Kjeldhal method (Jackson, 1967).

3.2 Phosphorus.

Total phosphorus was estimated colorimetrically by the Ammonium Vanadomolbdate method using a Spectronic 20.

3.3. Potassium.

Total potassium content was determined in the acid extract using an EEL flame photometer.

3.4 Calcium.

Calcium was determined in the diacid extract by atomic absorption spectro photometry using a Var. Techt. Atomic Absorption Spectro photometer.

3.5 Magnesium.

The method used for calcium was adopted.

3.6 Sodium.

Sodium was determined in the diacid extract with an EEL flame photometer.

3.7 Chlorine.

The content of chlorine was estimated after ashing the sample with lime by Husband and Coddens method (Piper, 1966).

3.8 Sulphur.

This was estimated in diacid extract calorimetrically using a Klett Summerson calorimeter.

4. Soil Nutrient Status

From each plot composite soil examples from the basins of four palms selected at random (the same trees selected for leaf samples) were taken 1.25 m away from the trunk during February 1977. Samples were separately collected for four depths viz. 0.25 cm, 25 - 50 cm, 50 - 75 cm and 75 - 100 cm using a 5 cm (diameter) soil auger. The samples were air dried, cleaned by passing through a 2 mm sieve and approximately 200 g sample was finally taken adopting quartering method. The 108 samples (9 treatments x 3 replications x 4 depths) were analysed for the following information.

4.1 Soil Reaction.

pH was determined in 1:2.5 soil water ratio using a Beckman pH meter.

4.2 Organic carbon.

Estimated calorimetrically by chromic acid method using a Klett Summerson calorimeter (Perur et al, 1973) and expressed in percentage.

4.3 Nitrogen.

Total nitrogen in per cent was estimated by macro Kjeldhal method (Jackson, 1967).

4.4 Phosphorus.

Available Phosphorus (ppm) was estimated colorimetrically in Bray I extract using Klett Summerson colorimeter (Wilde et al, 1972).

4.5 Potassium.

Available potash content was estimated in neutral normal ammonium acetate extract with the help of an EEL flame photometer and expressed in ppm (Porur et al, 1973).

4.6 Calcium.

Calcium was estimated in neutral normal ammonium acetate extract (Porur, et al, 1973) using a Var. Techt. Atomic Absorption spectro photometer. The values are expressed in me/100 g soil.

4.7 Magnesium.

The method described for calcium above was adopted.

B. Statistical Analysis

The data were analysed statistically by applying the technique of analysis of variance for Randomised Block Design. (Snedecor and Cochran, 1967).

The analysis for all nut characters (1.2 to 1.4 referred above) were restricted to a 6 x 3 RBD ignoring zero level of manuring (M_0) since data from a number of plots were missing due to non-availability of nuts at the time of harvest in April, 1977 when sampling was done.

The following abbreviations have been used in the column for 'source' in the ANOVA.

S - Spacing.
M - Manuring.
Y - Year.
T - Treatment.

R E S U L T S

RESULTS

1. Yield and Yield Components

1.1 Yield of nuts.

The yield data for five consecutive years from 1972 to 1976 and the mean data for the five years are presented in Table 1 and Fig 2 and their analysis of variance in Appendix II.

The yield was significantly increased by manuring. The yields per palm were highest in plots receiving 680 g N, 450 g P_2O_5 and 900 g K_2O per palm (M_2 level) at all spacings. With no manuring the yields were practically none. The mean yields for the five years also show similar results.

At the closest spacing of 5.0m x 5.0m (S_0 level) the response to manuring was minimum. When the spacing increased to 7.5 m x 7.5 m (S_1) and 10.0m x 10.0m (S_2), M_2 level had produced higher yields than M_1 which was also superior to M_0. The pooled results also reveal the same trend.

The interaction of spacing and manuring was significant individually in all the years as well as in the pooled analysis. The effect of spacing was more apparent at higher levels of fertilization only because at M_0 level, yield was practically none in all the years. At M_1 level, plots with 10.0 m x

Table 1.

Yield of nuts per palm for the years 1972 to 1976 and the mean for five years.

Treatments	1972	1973	1974	1975	1976	Mean
$S_0 M_0$	0.0	0.6	0.2	0.0	0.6	0.3
$S_0 M_1$	3.8	8.1	6.0	12.8	9.8	8.1
$S_0 M_2$	10.7	14.8	11.2	19.2	18.6	14.9
$S_1 M_0$	0.0	0.0	1.7	2.0	0.6	0.9
$S_1 M_1$	32.3	39.1	29.4	44.6	32.8	35.6
$S_1 M_2$	34.0	49.2	40.8	66.2	46.4	47.3
$S_2 M_0$	0.0	4.4	0.0	0.0	0.1	0.9
$S_2 M_1$	38.2	47.6	42.4	52.0	29.2	41.9
$S_2 M_2$	56.0	65.8	47.6	72.0	60.8	60.4
S_0	4.8	7.8	5.8	10.7	9.7	7.8
S_1	22.1	29.4	24.0	37.6	26.6	27.9
S_2	31.4	39.3	30.0	41.3	30.0	34.4
M_0	0.0	1.7	0.6	0.7	0.4	0.7
M_1	24.8	31.6	25.9	36.5	23.9	28.5
M_2	33.6	43.3	33.2	52.5	41.9	40.9
General mean	19.4	25.5	19.9	29.9	22.1	23.4
C V%	45.2	43.9	37.9	35.3	31.9	37.5
CD for levels of S or M	8.78	11.12	7.56	10.53	7.05	3.85
CD for combination	15.20	19.38	13.09	18.25	12.20	6.66

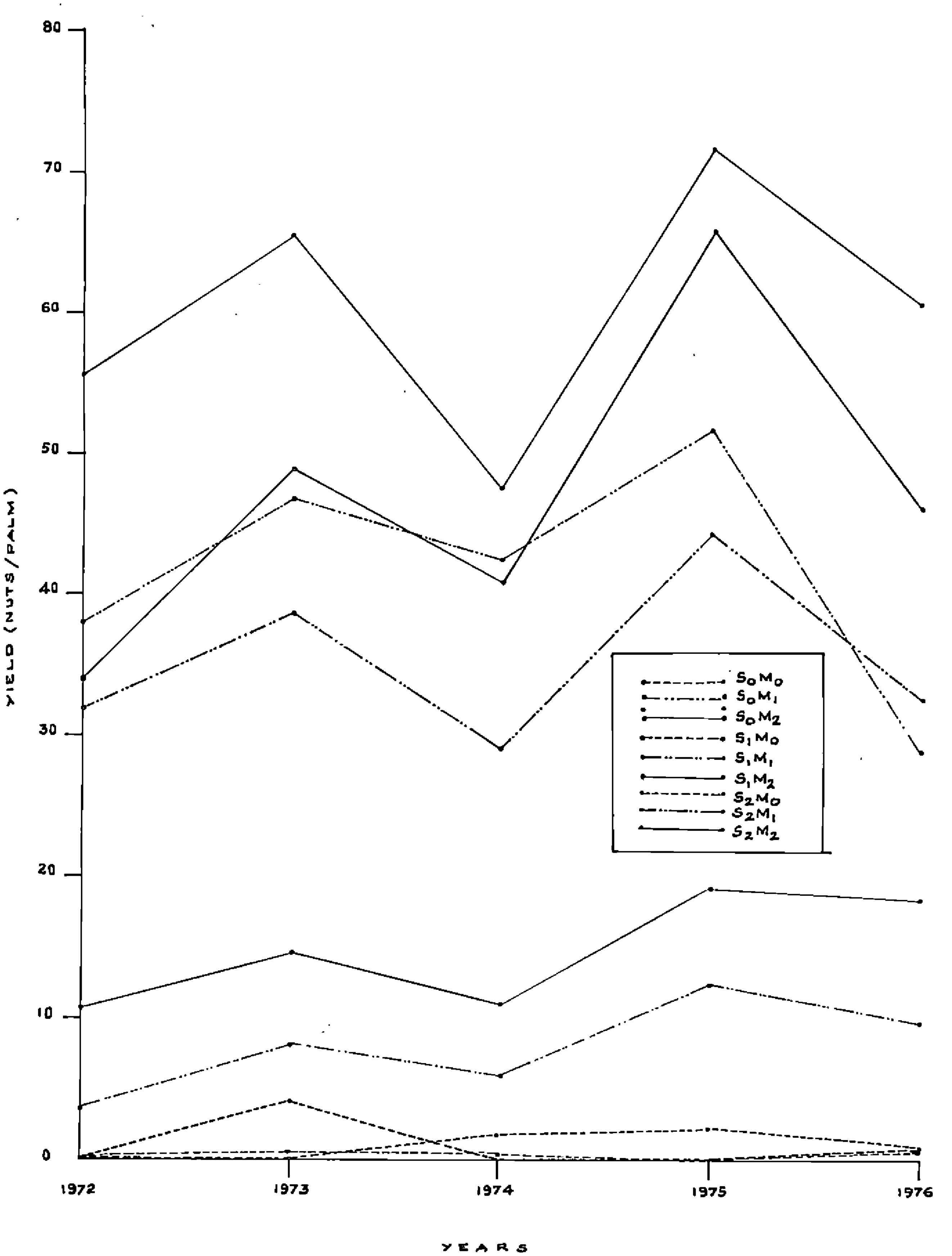

FIG. 2. EFFECT OF PALM DENSITY AND LEVELS OF NPK FERTILISERS ON YIELD OF NUTS PER PALM.

10.0 m (S_2) and 7.5 m x 7.5 m (S_1) spacing had higher number of nuts per palm than lowest spacing of 5.0 m x 5.0 m (S_0). At M_2 level (680 g N, 450 g P_2O_5 and 900 g K_2O) yield was the highest at the S_2 spacing then at S_1. The above trend holds good for all the five years. S_2 M_2 combination had given the highest yield in all the years. The interaction, treatment x year, was non significant.

The yield trend for the five years indicate that the yield has not yet stabilised and also the alternate low and high bearing over the years.

In interpreting the effect of spacing on yield, however, it is necessary to take into account the total yield per unit area to determine the optimum density to maximise returns. Computed yields per hectare are presented in Table 2 and the analysis of variance in Appendix III.

Contrary to the results of per palm yields, the interaction between spacing and manuring was not significant in any of the years though it was the other case in the pooled analysis. Generally the effect of spacing on yield was in the order $S_1 > S_0 > S_2$ in the later two years and in the order $S_1 > S_2 > S_0$ in earlier years. The latter trend holds good in the pooled data. The yields/hectare were the highest at a spacing of 7.5 m x 7.5 m, though the yields per palm were

Table 2.

Yield of nuts per ha. for the years 1972 to 1976 and the mean for five years.

Treatments	1972	1973	1974	1975	1976	Mean
$S_0 M_0$	0	220	67	0	259	109
$S_0 M_1$	1506	3231	2401	5121	3902	3232
$S_0 M_2$	4270	5937	4486	7667	7453	5963
$S_1 M_0$	0	7	303	362	110	156
$S_1 M_1$	5738	6937	5218	7931	5821	6329
$S_1 M_2$	6042	8737	7249	11771	8255	8411
$S_2 M_0$	0	444	0	0	8	90
$S_2 M_1$	3817	4758	4242	5200	2917	4187
$S_2 M_2$	5600	6575	4758	7200	6075	6042
S_0	1925	3129	2318	4263	3871	3101
S_1	3927	5227	4257	6688	4729	4965
S_2	3139	3926	3000	4133	3000	3440
M_0	0	224	123	121	126	118
M_1	3687	4975	3954	6084	4213	4583
M_2	5304	7093	5498	8879	7261	6805
General mean	2997	4096	3192	5028	3867	3835
C.V %	38.0	33.3	27.5	23.5	28.3	29.8
CD for levels of S or M	1139.7	1364.7	877.5	1181.3	1093.5	650.6
CD for combination	1974.0	2363.6	1519.8	2046.0	1894.0	1126.9

significantly higher at 10.0 m x 10.0 m at the M_1 and M_2 levels because plant density was higher at S_1 (178/ha) than at S_2 (100/ha).

1.2 Copra per nut.

The copra content per nut was determined only once (Table 3 and Appendix IV). The nuts were harvested in April 1977 and sampling was done from the above. However no nuts could be harvested at this time from several M_0 (no fertilizers) plots. Hence the analysis of variance was restricted to 6 x 3 RBD. (See 1.2 and B, Materials and Methods). The effect of spacing was highly significant ie. at very high density (400 per ha) the copra yield (152 g) was lower than at lower densities (168 g at S_1 as well as at S_2). However there was no difference in the yield of copra between S_1 and S_2 spacings and therefore the copra yield per ha would be maximum with a spacing of 7.5 m x 7.5 m (S_1) because yields of nut per hectare were maximum at this spacing. At S_1 and S_2 levels of spacing, no significant effect of manuring was evident, even though there was an increase of 9% due to M_2 level over M_1 level at S_0 spacing. The mean weight of copra (mean of four plots) was 128 g/nut in M_0 plots.

There was no significant correlation between yield of nuts and mean copra per nut (r = 0.7153).

Table 3.

Mean weight of copra per nut (g).

	M_1	M_2	Mean
S_0	145.3	158.3	151.8
S_1	168.7	167.7	168.2
S_2	169.0	166.7	167.8
Mean	161.0	164.2	162.6

CV % 4.9

CD for levels of S 10.19

CD for combination 14.41

Table 4.

Mean per cent oil in copra

	M_1	M_2	Mean
S_0	69.87	68.95	69.41
S_1	69.77	66.57	68.17
S_2	70.15	64.66	67.41
Mean	69.93	66.73	68.33

CV % 1.4

CD for levels of S 1.264

CD for combination 1.788

CD for levels of M 1.032

1.3 Percent Oil in copra

The data on oil percent of copra samples collected in April, 1977 are presented in Table 4 (AOV results are presented in Appendix V). The correlation between yield of nuts per palm and oil content in copra is plotted in Fig.3. The main effects as well as interaction of spacing and manuring were significant. The effect of manuring was manifest in plots with lesser densities viz. S_1 and S_2. The oil content decreased with increased level of manuring at both S_1 and S_2 spacing. The effect of spacing was evident only at the higher level of manuring. The oil content was lower in plots with wider spacing. This can be explained by the negative correlation between yield of nuts per palm and the oil content ($r = -0.8813$). The yields per palm were higher at S_2 spacing than at S_1 at M_2 level. There was no significant correlation between copra/nut and oil percentage ($r = -0.316$).

1.4 Weight and volume of nuts.

1.4(a) Weight of whole nuts.

The data on mean weight of nuts and analysis of variance table are presented in Table 5 and Appendix VI respectively. The mean weight per nut was significantly lower at higher palm density (S_0) in spite of the lower yields per palm at close spacing (S_0). Neither the main effect of manuring nor

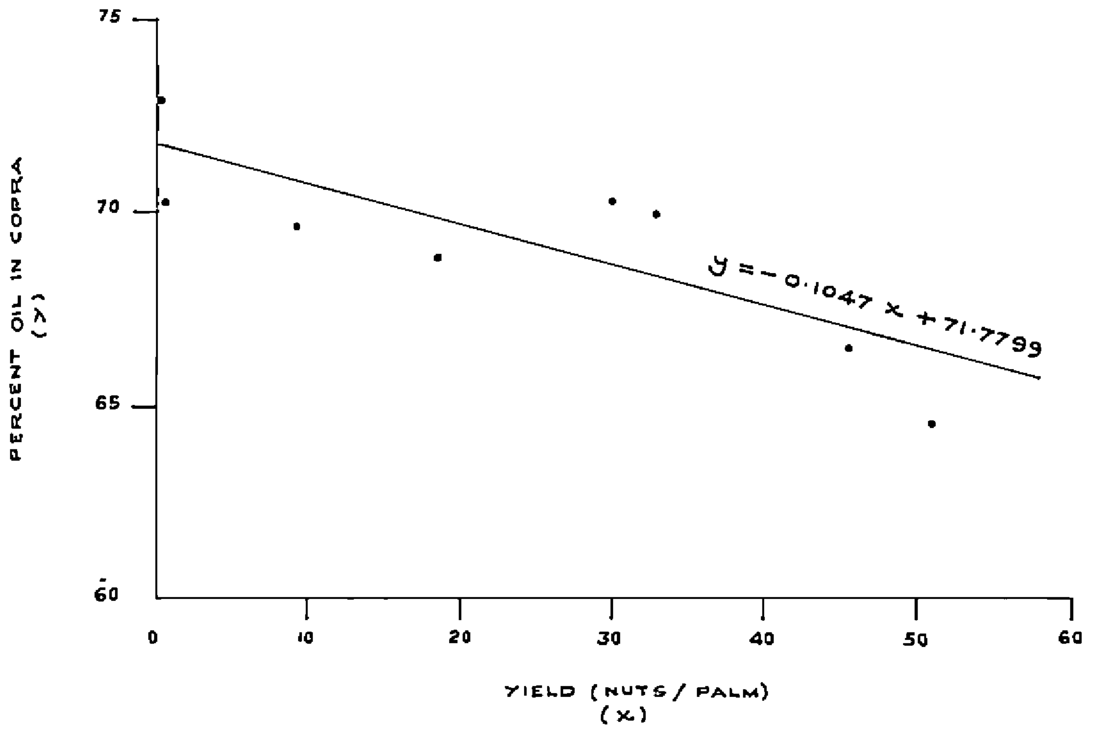

FIG. 3. RELATIONSHIP BETWEEN OIL PERCENT IN COPRA AND YIELD OF NUTS.

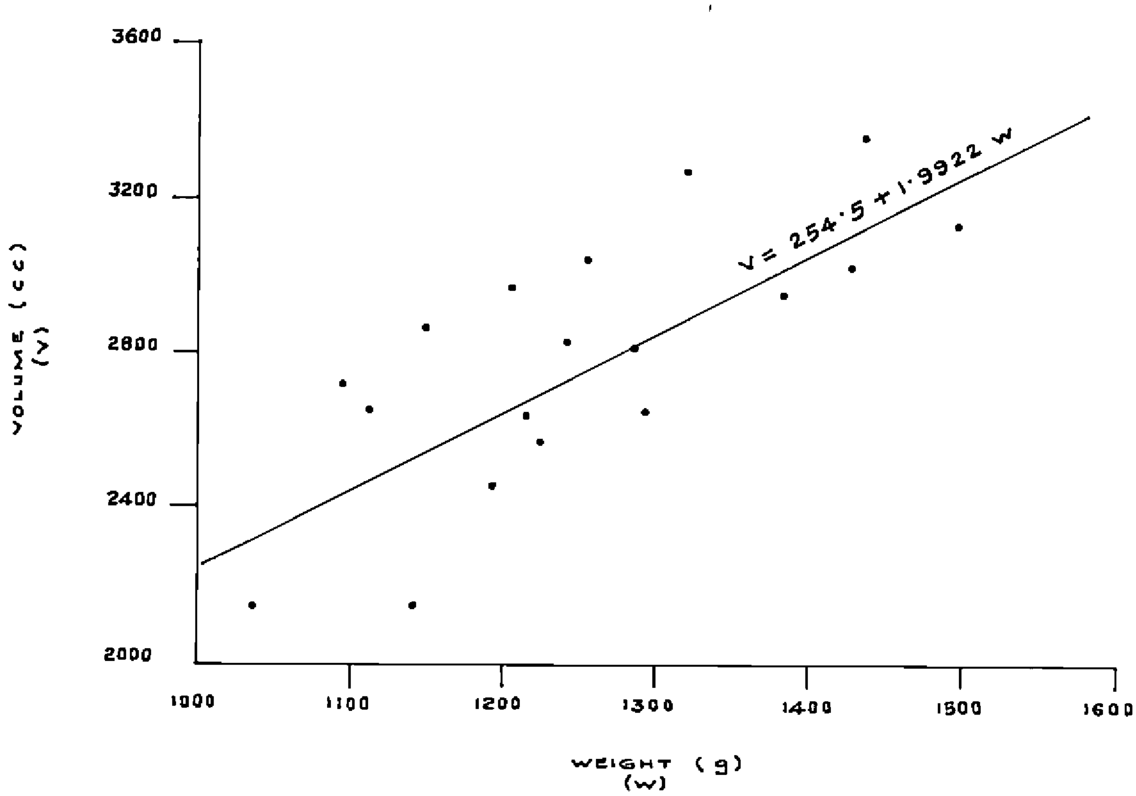

FIG. 4. RELATIONSHIP BETWEEN VOLUME AND WEIGHT OF WHOLE NUTS.

Table 5.

Mean weight of whole nuts (g).

	M_1	M_2	Mean
S_0	1179	1146	1162
S_1	1372	1247	1309
S_2	1324	1241	1283
Mean	1292	1211	1251

CV %	7.2
CD för levels of S	115.3
CD for combination	163.1

Table 6.

Mean volume of whole nuts (cc)

	M_1	M_2	Mean
S_0	2516	2438	2477
S_1	3075	2956	3015
S_2	3103	2750	2927
Mean	2898	2714	2806

CV %	8.0
CD for levels of S	287.2
CD for combination	406.2

S x M interaction was significant. The mean weight per nut from available data in M_0 plots was 1166 g only.

1.4(b) Volume of whole nuts.

The results (Table 6 and Appendix VII) are similar to the weight of nuts described above. The correlation coefficient between weight and volume of whole nuts was found to be r = 0.7511 (Fig. 4).

1.4(c) Weight and volume of husked nuts.

Effect of spacing on volume alone was significant (Table 7 and Appendix VIII). The results revealed that higher the palm density, lesser the volume of the nuts. The same trend was seen in the case of weight of nuts also. The weight and volume of husked nuts also were found to be positively correlated (Fig. 5).

1.4(d) Ratio of weight of husked and whole nuts.

The data on ratio of weight of husked nut and that of whole nut are presented in Table 8 and the ANOVA tables in Appendix IX.

The ratio was higher at closer spacing (S_0) than at S_1 and S_2. Manuring at the higher levels of M_2 increased the ratio. The S x M interaction was not found to be significant.

Table 7

Mean weight and volume of husked nuts

	Weight (g)			Volume (cc)		
	M_1	M_2	Mean	M_1	M_2	Mean
S_0	492.3	510.7	501.5	520.7	509.0	514.9
S_1	507.7	522.7	515.2	570.7	553.7	562.2
S_2	537.3	528.0	532.6	603.0	556.3	579.7
Mean	512.4	520.5	516.5	564.8	539.7	552.2
CV %		6.4			7.2	
CD for levels of S					51.37	
CD for combination:					72.65	

Table 8

Ratio of weight of husked nuts and whole nuts.

	M_1	M_2	Mean
S_0	0.4169	0.4457	0.4313
S_1	0.3702	0.4190	0.3946
S_2	0.3810	0.4270	0.4040
Mean	0.3894	0.4306	0.4100
CV %		4.6	
CD for levels of S		0.02442	
CD for levels of M		0.01994	
CD for combination		0.03454	

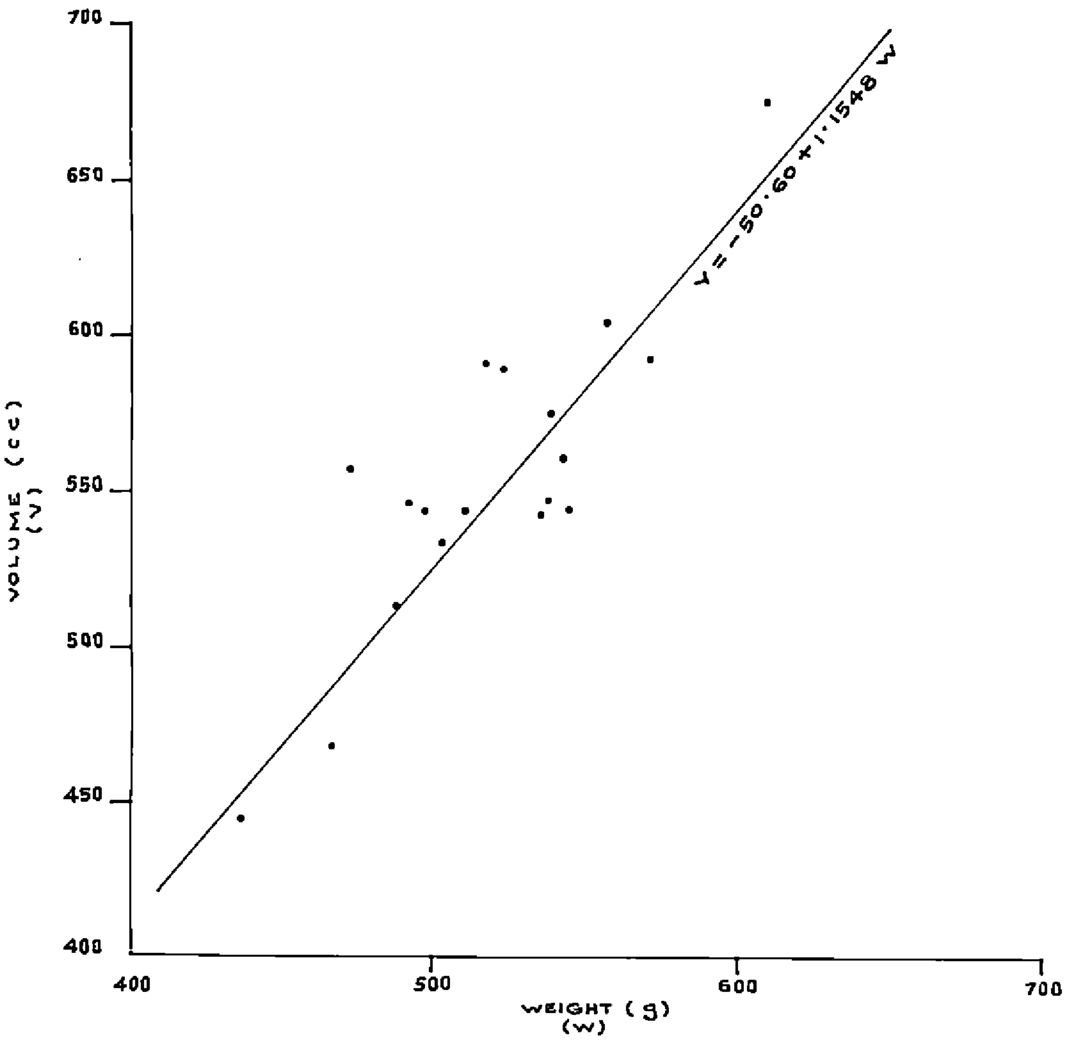

FIG. 5. RELATIONSHIP BETWEEN VOLUME AND WEIGHT OF HUSKED NUTS.

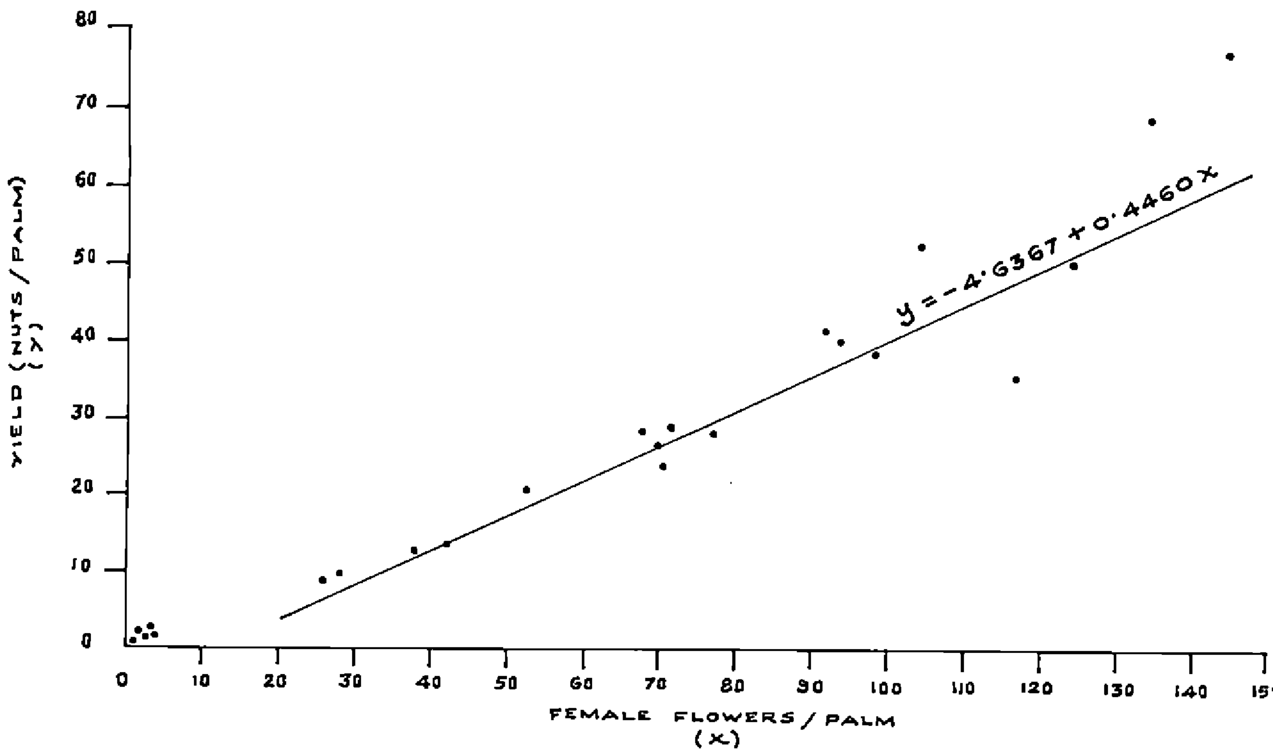

FIG. 6. RELATIONSHIP BETWEEN YIELD OF NUTS AND FEMALE FLOWER PRODUCTION.

1.4(e) Ratio of weight of copra and husked nuts.

The mean data and ANOVA table (Table 9 and Appendix X respectively) revealed that neither the main effects nor their interaction had any effect on the ratio.

1.5 Female flowers.

1.5(a) Production of female flowers.

The data on female flower production per palm for five consecutive years from 1972 to 1976 and the mean data for five years are presented in Table 10 and their analysis of variance in Appendix XI.

As in the case of yield of nuts, both the main effects of spacing and manuring and their interaction were significant. Manuring has highly influenced the production of female flowers. The highest production was at M_2 level (680 g N, 450 g P_2O_5 and 900 g K_2O) followed by M_1 and the production was practically none in plots receiving no fertilizers. In general and in the pooled analysis, M_2 level was consistently and significantly superior to M_1 level which was also significantly superior to M_0 level.

When spacing is taken into consideration, wider the spacing, more was the production. For individual years, in general $S_2 = S_1 > S_0$ and in the pooled analysis $S_2 > S_1 > S_0$.

Table 9

Ratio of weight of copra and husked nut

	M_1	M_2	Mean
S_0	0.2961	0.3106	0.3034
S_1	0.3338	0.3212	0.3275
S_2	0.3169	0.3163	0.3161
Mean	0.3156	0.3160	0.3158

Table 10.

Female flowers per palm for individual years 1972 - 1976 and the mean for five years.

	1972	1973	1974	1975	1976	Mean
$S_0 M_0$	0.0	1.9	0.5	0.0	2.0	0.9
$S_0 M_1$	13.8	25.9	16.3	45.5	32.0	26.7
$S_0 M_2$	32.7	46.7	35.3	62.1	54.0	46.2
$S_1 M_0$	0.0	0.2	6.9	6.4	2.5	3.2
$S_1 M_1$	91.0	97.6	63.6	129.2	77.1	91.7
$S_1 M_2$	136.8	124.0	86.3	145.4	107.6	120.0
$S_2 M_0$	0.0	10.9	0.0	0.7	0.2	2.3
$S_2 M_1$	117.7	152.9	82.0	155.3	88.2	119.2
$S_2 M_2$	153.6	187.7	106.3	161.7	126.3	147.1
S_0	15.5	24.8	17.3	35.9	29.3	24.6
S_1	76.0	73.9	52.3	93.7	62.4	71.6
S_2	90.4	117.1	62.8	105.9	71.5	89.5
M_0	0.0	4.3	2.4	2.4	1.5	2.1
M_1	74.2	92.1	54.0	110.0	65.7	79.2
M_2	107.7	119.5	75.9	123.0	96.0	104.4
General mean	60.6	72.0	44.1	78.5	54.4	61.9
C.V%	32.8	43.6	33.7	32.6	24.9	35.7
CD for levels of S or M	19.86	31.37	14.85	25.61	13.54	9.27
CD for combination	34.40	54.34	25.73	44.35	23.45	16.06

The interaction of S x M was significant in all the years as well as in the combined analysis. The effect of spacing was not at all seen in plots receiving no fertilizers. But when the palms were fertilised either at M_1 or M_2 level, wider spacing (S_1 and S_2) had produced significantly more flowers than the closest spacing. Similarly during 1972 to 1974 the effect of manuring was evident only when the palms were spaced wider (S_1 and S_2). But in the pooled analysis, the effect of manuring was evident in closer spacing also. S_2M_2 combination gave the highest yield of flowers followed by S_2 M_1 and S_1 M_2 in all the years. There was a highly significant positive correlation ($r = 0.9704$) between yield and female flower production (Fig. 6).

1.5(b) Setting percentage

The data on percent flower set for the consecutive years 1972 to 1976 and the mean for five years are given in Table 11 and the statistical analysis in Appendix XII.

In all the years the effect of manuring was highly significant. The percent set was high in fertilized plots as compared to non-fertilized plots. The interaction of spacing and manuring was significant in three years viz. 1972, 1974 and 1975. At all levels of spacing, manuring had increased the set. At M_0 level, spacing did not affect the set, but

Table 11.

Per cent female flower set for the years 1972 to 1976 and the mean for five years.

Treatments	1972	1973	1974	1975	1976	Mean
S_0 M_0	0.00	18.79	11.76	0.00	22.27	10.56
S_0 M_1	26.06	30.73	34.18	27.20	30.55	29.74
S_0 M_2	32.38	31.49	32.48	30.76	34.28	32.38
S_1 M_0	0.00	5.55	8.29	25.19	23.61	12.53
S_1 M_1	35.10	40.19	44.81	34.51	42.25	39.37
S_1 M_2	24.82	40.83	48.86	45.52	43.35	40.68
S_2 M_0	0.00	13.60	0.00	0.00	16.67	6.05
S_2 M_1	31.70	30.65	50.57	31.82	33.75	35.70
S_2 M_2	35.54	35.10	50.88	44.81	47.16	42.70
S_0	19.48	27.00	26.14	19.32	29.03	24.19
S_1	19.97	28.86	33.99	35.07	36.40	30.86
S_2	22.41	26.45	33.82	25.54	32.53	28.15
M_0	0.00	12.65	6.68	8.40	20.85	9.71
M_1	30.95	33.86	43.19	31.18	35.52	34.94
M_2	30.91	35.81	44.07	40.36	41.60	38.55
General mean	20.62	27.44	31.31	26.65	32.65	27.73
CV %	13.5	42.1	25.3	14.6	39.0	31.5
CD for levels of S or M	2.789	11.534	7.914	3.896	12.731	4.879
CD for combination	4.831	19.979	13.708	6.749	22.050	8.450

at M_1 and M_2 level of fertilizers, the set was higher in S_1 and S_2 plots than in S_0 plots.

In the combined analysis, the main effects of spacing and manuring were significant. Fertilisation as well as wider spacings (S_1 and S_2 levels) had increased the per cent set of female flowers.

2. Vegetative Growth Characters.

2.1. Number of bearing palms.

A larger percentage of palms had come to bearing by the 12th year (1976) in plots receiving fertilizers than in unfertilized plots (Ref. Table 12 and Appendix XIII). Spacing had no effect on earliness of bearing. The effect of manuring was highly significant over no manuring (M_0) where as manuring at M_1 and M_2 level did not show any significant difference.

2.2 Height and girth of palms.

2.2(a) Height.

The mean height of palms measured in December, 1976 (12 years after transplanting) is furnished in Table 13, Fig. 7 and its ANOVA in Appendix XIV. Manuring alone had a significant effect on the height. The palms in plots receiving fertilizers (M_2 and M_1) were taller than palms in

Table 12.

Per cent of bearing palms per plot at 12th year of planting (after angular transformation)

	M_0	M_1	M_2	Mean
S_0	10.95	66.89	70.19	49.34
S_1	19.46	83.51	77.03	60.00
S_2	10.00	75.00	90.00	58.33
Mean	13.47	75.13	79.07	55.89

CV % 23.3
CD for levels of M 13.000
CD for combination 22.517

Table 13.

Mean height of palms in meters

	M_0	M_1	M_2	Mean
S_0	1.090	6.232	6.363	4.562
S_1	1.676	5.963	5.920	4.520
S_2	2.090	5.442	5.527	4.353
Mean	1.619	5.879	5.937	4.478

CV % 13.2
CD for levels of M 0.5895
CD for combination 1.0211

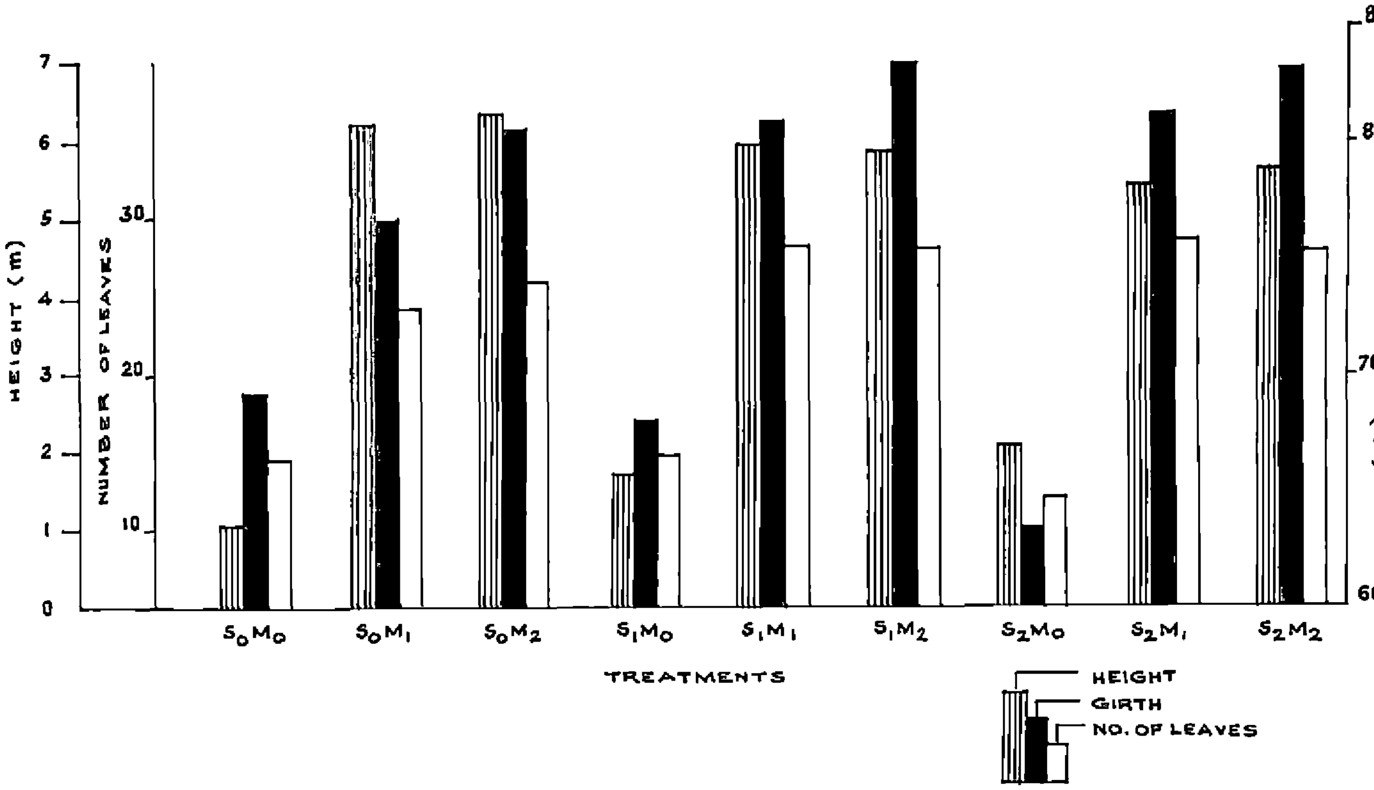

FIG. 7. EFFECT OF PALM DENSITY AND LEVELS OF NPK FERTILIZERS ON GROWTH CHARACTERS.

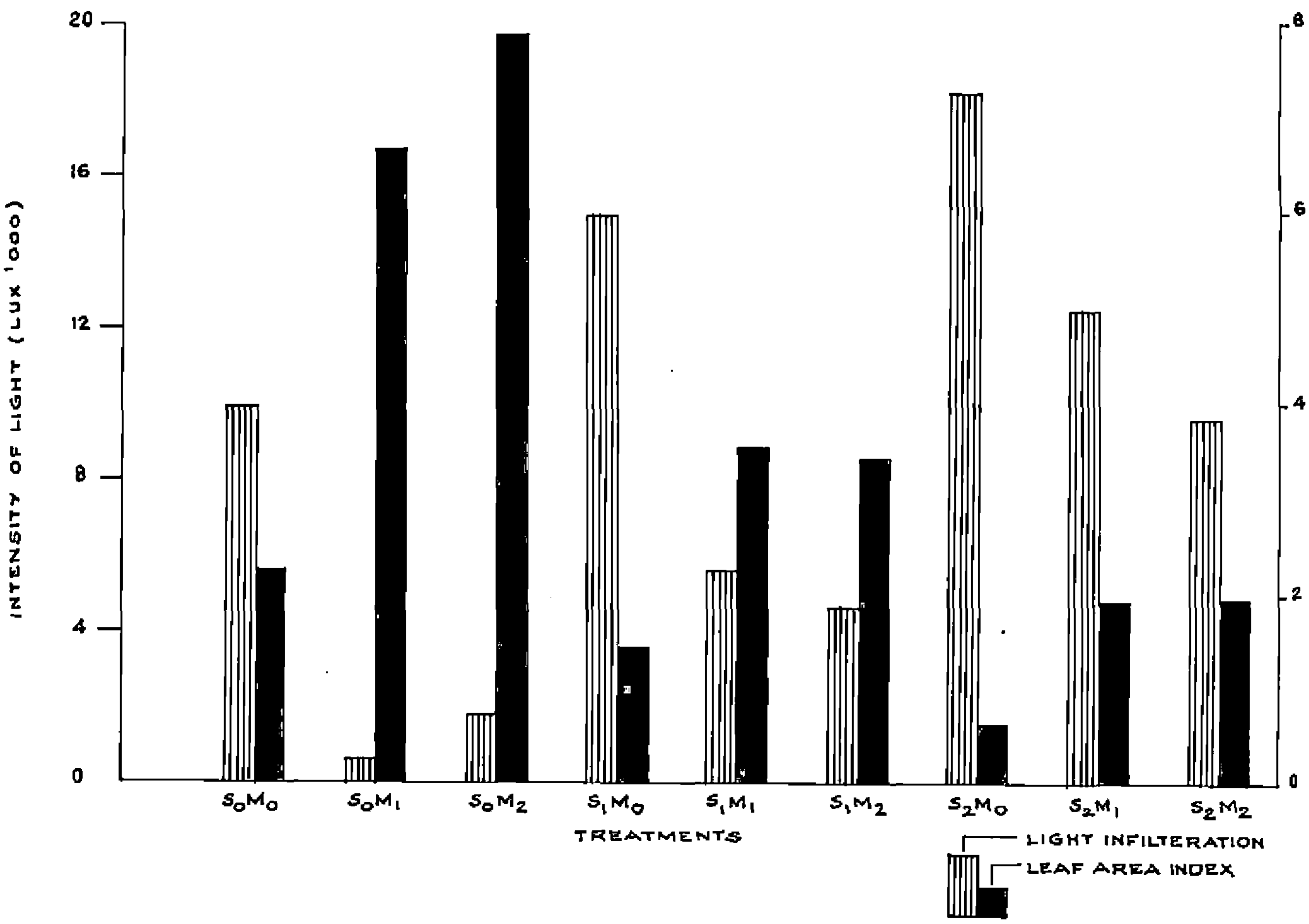

FIG. 8. EFFECT OF PALM DENSITY AND LEVELS OF NPK FERTILIZERS ON LEAF AREA INDEX AND LIGHT INFILTERATION.

unmanured plots (M_0). However manuring at the M_2 level was not more beneficial than manuring at the M_1 level. The differences in height among palms planted at different spacings were not statistically significant.

There was significant positive correlation between height of palms and yield ($r = 0.671$).

2.2(b) Girth.

The effects of spacing (S) or manuring (M) were not significant during the years 1972 and 1974. The effect of manuring was significant during 1973, 1975 and 1976 as well as in the combined analysis (Table 14, Fig.7 and Appendix XV). Palms receiving fertilizers were having more girth than palms receiving no fertilizers even though the reverse trend was seen in one year viz. 1973.

Significant correlation between girth and yield of palms was obtained; r being 0.849.

2.3 Leaves.

2.3(a) Total number of leaves produced.

The data on total number of leaves produced since planting for individual years 1972 to 1976 and the mean for five years are presented in Table 15 and their statistical analysis in Appendix XVI.

Table 14.

Mean girth of trunk below the crown (cm) for the individual years 1972 to 1976 and the mean for five years.

Treatments	1972	1973	1974	1975	1976	Mean
S_0 M_0	78.7	87.3	72.3	79.2	69.5	77.4
S_0 M_1	79.4	79.4	78.2	79.8	76.7	78.7
S_0 M_2	89.0	75.3	72.6	83.1	80.5	80.1
S_1 M_0	91.5	83.1	74.4	74.4	67.9	78.2
S_1 M_1	93.3	81.1	75.8	86.0	81.2	83.5
S_1 M_2	84.3	80.5	79.7	86.3	82.9	87.2
S_2 M_0	77.5	82.0	70.4	71.9	63.4	73.0
S_2 M_1	87.5	80.3	79.0	84.9	81.2	82.6
S_2 M_2	86.5	79.9	77.0	69.9	83.0	79.3
S_0	82.4	80.7	74.4	80.7	75.6	78.7
S_1	89.7	81.6	76.6	82.2	77.3	81.5
S_2	83.8	80.7	75.5	75.6	75.9	78.3
M_0	82.6	84.1	72.4	75.2	66.9	76.2
M_1	86.7	80.3	77.7	83.6	79.7	81.6
M_2	86.6	78.6	76.4	79.8	82.1	80.7
General mean	85.3	81.0	75.5	79.5	76.3	79.5
CV %	8.5	5.0	7.0	8.3	3.2	6.8
CD for levels of M	-	4.05	-	6.55	2.41	3.62
CD for Combination	-	7.01	-	11.35	4.17	6.27

Table 15.

Total number of leaves produced per palm since planting for the years 1972 to 1976 and the mean for five years

Treatments	1972	1973	1974	1975	1976	Mean
$S_0 N_0$	51.67	57.50	63.50	70.27	83.50	65.29
$S_0 N_1$	77.17	88.50	99.10	110.23	121.23	99.25
$S_0 N_2$	78.30	89.87	100.50	111.97	122.17	100.56
$S_1 N_0$	60.50	69.90	77.80	87.13	95.17	78.10
$S_1 N_1$	82.30	96.00	107.67	120.50	133.13	107.92
$S_1 N_2$	86.00	99.40	112.03	124.70	138.43	112.11
$S_2 N_0$	60.30	68.87	77.87	87.23	97.40	78.33
$S_2 N_1$	86.50	100.77	113.77	126.43	141.77	113.85
$S_2 N_2$	85.20	99.53	111.67	125.93	140.23	112.51
S_0	69.04	78.62	87.70	97.49	108.97	88.36
S_1	76.27	88.43	99.17	110.78	122.24	99.38
S_2	77.33	89.72	101.10	113.20	126.47	101.56
N_0	57.49	65.42	73.06	81.54	92.02	73.91
N_1	81.99	95.08	106.84	119.06	132.04	107.00
N_2	83.17	96.27	108.07	120.87	133.61	108.40
General mean	74.21	85.59	95.99	107.16	119.23	96.44
CV %	6.0	6.3	6.7	6.6	6.8	6.7
CD for levels of S or N	4.454	5.409	6.401	7.073	8.159	2.699
CD for combination	7.714	9.368	11.088	12.251	14.133	4.674

Spacing as well as manuring had highly significant effect on leaf production in all the years. The combined analysis also revealed the same result. Wider the spacing, greater was the production of leaves and 10 m x 10 m (S_2) and 7.5 m x 7.5 m (S_1) spacings were significantly superior to 5 m x 5 m (S_0) spacing. Also fertilizer application significantly increased the production of leaves. However the differences between M_1 and M_2 levels were not significant.

2.3(b) Number of functioning leaves.

The beneficial effects of wider spacing as well as fertilization were evident (Table 16, Fig. 7 and Appendix XVII) on the number of functioning leaves. Palms receiving fertilisers had a greater number of fuctioning leaves than those receiving no fertilisers. Palms in wider spacing (S_1 and S_2) had more number of leaves than in closer spacing (S_0).

Number of leaves and palm yields were found to be positively and significantly correlated (r = 0.810).

2.3 (c) Rate of production of leaves.

The data are presented in Table 17 and Appendix XVIII.

The rate of leaf production had stabilised by 1972 and there were no wide variations in succeeding years. As already seen under total number of leaves produced since planting,

Table 16.

Number of leaves per palm for individual years 1972 to 1976 and the mean for five years.

Treatments	1972	1973	1974	1975	1976	Mean
$S_0 M_0$	8.67	8.97	12.43	9.03	10.47	9.91
$S_0 M_1$	22.23	23.33	22.27	21.23	24.50	22.71
$S_0 M_2$	23.43	23.47	21.13	21.77	26.20	23.20
$S_1 M_0$	12.23	11.97	14.37	12.90	15.00	13.29
$S_1 M_1$	24.50	24.80	22.77	21.97	28.53	24.51
$S_1 M_2$	25.40	25.33	23.73	24.50	28.50	25.49
$S_2 M_0$	10.00	10.73	10.00	11.17	11.67	10.71
$S_2 M_1$	24.77	23.77	24.77	23.33	28.87	24.97
$S_2 M_2$	23.97	26.17	22.87	23.37	28.30	24.93
S_0	18.11	18.59	18.61	17.34	20.39	18.61
S_1	20.71	20.70	20.29	1979	24.01	21.10
S_2	19.56	20.22	19.21	19.29	22.94	20.20
M_0	10.30	10.56	12.27	11.03	12.39	11.31
M_1	23.83	23.97	23.27	22.18	27.30	24.06
M_2	24.23	24.99	22.58	23.21	27.67	24.54
General mean	19.47	19.84	19.37	18.81	22.45	19.97
CV %	7.9	7.5	8.6	8.4	7.1	7.0
CD for levels of S or M	1.529	1.496	1.669	1.586	1.586	0.896
CD for combination	2.648	2.591	2.891	2.749	2.749	1.552

Table 17.

Rate of production of leaves per palm for the years 1972 to 1976 and the mean for five years

	1972	1973	1974	1975	1976	Mean
$S_0 M_0$	6.3	6.2	6.0	5.8	6.9	6.3
$S_0 M_1$	11.8	11.2	10.4	11.2	10.5	11.0
$S_0 M_2$	11.9	11.7	10.6	11.5	10.6	11.3
$S_1 M_0$	8.5	8.6	8.4	9.5	10.0	9.0
$S_1 M_1$	12.5	13.7	11.7	12.3	12.3	12.5
$S_1 M_2$	14.0	13.7	12.9	13.4	13.3	13.5
$S_2 M_0$	8.6	8.6	9.0	9.3	10.2	9.1
$S_2 M_1$	14.1	14.3	13.0	13.5	13.8	13.7
$S_2 M_2$	14.1	14.3	13.3	13.0	14.4	13.8
S_0	10.0	9.7	9.0	9.5	9.3	9.5
S_1	11.7	12.0	11.0	11.7	11.9	11.6
S_2	12.3	12.4	11.8	12.0	12.8	12.2
M_0	7.7	7.8	7.8	8.2	9.0	8.1
M_1	12.8	13.1	11.7	12.3	12.2	12.4
M_2	13.3	13.2	12.3	12.6	12.8	12.8
General mean	11.3	11.4	10.6	11.1	11.3	11.1
CV%	8.9	7.5	9.7	7.2	5.2	
CD for levels of S or M	1.04	0.86	1.03	0.79	0.59	0.37
CD for combination	1.74	1.49	1.78	1.37	1.02	0.63

spacing as well as manuring had significant effect on rate of production of leaves also.

2.3(d) Total length of leaves.

The data for five consecutive years from 1972 to 1976 and the mean for five years are presented in Table 18 and their analysis of variance in Appendix XIX.

The effect of manuring was highly significant in all the years as well as in the pooled analysis. Manuring either at M_1 or M_2 level increased the leaf length significantly over M_0 level though there was no significant difference between M_1 and M_2 level. The leaf length was also affected by spacing (1973 and 1975). With increased spacing, the leaf length increased in 1973, but the reverse was the case with S_2 in 1975. However no significant differences were noticed in the combined analysis.

2.3(e) Length of petiole.

This was recorded only once. The data are presented in Table 19 and ANOVA in Appendix XX. The main effects of both spacing and manuring and their interaction were found to be highly significant. At all levels of spacing, fertilization had increased the length of petioles as compared to unfertilised plots. In plots with no manuring, longer petioles

Table 18.

Mean length of leaves in cm for the years 1972 to 1976 and the mean for five years

	1972	1973	1974	1975	1976	Mean
S_0M_0	371.7	361.4	405.2	371.0	463.7	394.6
$S_0\ M_1$	534.7	528.6	579.9	567.1	635.3	569.1
$S_0\ M_2$	577.2	523.6	552.7	568.7	659.3	576.3
$S_1\ M_0$	414.3	436.0	443.8	413.1	461.4	433.7
$S_1\ M_1$	520.6	530.3	569.0	557.7	601.1	555.7
$S_1\ M_2$	538.2	511.3	545.8	571.4	611.7	555.8
$S_2\ M_0$	389.4	418.3	426.3	325.8	462.5	404.5
$S_2\ M_1$	534.2	546.3	540.4	551.3	579.4	550.3
$S_2\ M_2$	538.2	679.2	521.7	544.2	591.3	574.9
S_0	494.6	471.2	512.6	502.3	586.1	513.3
S_1	491.2	492.5	519.5	514.1	558.1	515.1
S_2	487.3	547.9	496.1	473.8	544.4	509.9
M_0	391.8	405.2	425.1	370.0	462.5	410.9
M_1	529.8	535.1	563.1	558.7	605.3	558.4
M_2	551.4	571.4	540.1	561.4	620.8	569.0
General mean	491.0	503.9	509.4	496.7	562.9	512.8
CV %	7.3	9.5	7.2	5.3	6.2	6.9
CD for levels of S or M	34.88	47.86	36.50	26.50	34.88	23.15
CD for combination	60.42	82.89	63.21	45.90	60.42	41.13

Table 19.

Mean length of petiole (cm)

	M_o	M_1	M_2	Mean
S_o	120.7	161.3	163.7	148.6
S_1	122.7	144.7	150.0	139.1
S_2	134.3	148.0	150.0	144.1
Mean	125.9	151.3	154.6	143.9

CV % 3.7

CD for levels of S or M 5.31

CD for combination 9.19

Table 20.

Mean length of leaf blade (leaflet bearing portion) (cm)

	M_o	M_1	M_2	Mean
S_o	343.0	413.7	495.3	417.3
S_1	338.7	456.3	462.0	419.0
S_2	332.7	432.0	441.3	402.0
Mean	338.1	434.0	466.2	412.8

CV % 9.3

CD for levels of M 38.52

CD for combination 67.71

were produced at the widest spacing (S_2) where as the reverse trend was observed in M_1 and M_2 plots.

2.3(f) Length of leaf blade.

Manuring (M_1 and M_2) had significant effect in the production of longer blade portion than unmanured plots (Table 20 and Appendix XXI).

2.3(g) Breadth of leaves.

The results (Table 21 and Appendix XXII) indicated that the breadth of leaves was increased by manuring. The breadth of leaves was only 165 cm in palms receiving no fertilizers as compared to 214 cm in manured palms. There were no differences between palms in M_1 and M_2 plots.

2.3(h) Number of leaflets.

The data on number of leaflets on one side of a leaf for five consecutive years from 1972 to 1976 and the mean for five years were studied. (Table 22 and Appendix XXIII).

The effect of manuring alone was highly significant in all the years as well as in combined analysis. Manuring at the highest (M_2) and medium (M_1) levels had resulted in an increased number of leaflets, but the differences between M_2 and M_1 were not significant.

Table 21.

Mean breadth of leaves in cm.

	M_o	M_1	M_2	Mean
S_o	159.6	225.3	227.6	204.2
S_1	168.5	215.6	201.8	195.3
S_2	166.8	200.5	210.9	192.7
Mean	165.0	213.8	213.4	197.4

CV%	6.0
CD for levels of M	11.78
CD for combination	20.39

Table 22

Mean number of leaflets (on one side of a leaf) for the years 1972 to 1976 and the mean for five years.

	1972	1973	1974	1975	1976	Mean
$S_0 M_0$	83.5	86.8	98.0	86.8	101.2	91.3
$S_0 M_1$	117.9	108.8	108.8	115.6	118.7	114.0
$S_0 M_2$	119.9	114.0	110.2	116.3	123.1	116.7
$S_1 M_0$	95.7	89.1	99.9	96.9	108.5	98.0
$S_1 M_1$	125.2	106.3	108.4	115.5	121.9	115.5
$S_1 M_2$	118.2	114.0	110.6	119.0	123.4	117.0
$S_2 M_0$	93.2	90.4	94.0	89.8	103.4	94.2
$S_2 M_1$	117.8	109.7	107.1	109.1	122.2	113.2
$S_2 M_2$	120.8	119.4	106.3	111.4	123.9	116.4
S_0	107.1	103.2	105.7	106.2	114.3	107.3
S_1	113.0	103.1	106.3	110.5	117.9	110.2
S_2	110.6	106.5	102.5	103.5	116.5	107.9
M_0	90.8	88.8	97.3	91.2	104.4	94.5
M_1	120.3	108.3	108.1	113.4	120.9	114.2
M_2	119.6	115.8	109.0	115.6	123.5	116.7
General mean	110.2	104.3	104.8	106.7	116.3	108.5
CV%	13.3	3.5	7.5	5.8	3.2	7.6
CD for levels of M.	14.67	4.05	7.82	6.23	3.77	3.47
CD for combinations	25.41	6.34	13.53	10.80	6.52	6.02

2.3(i) Length of leaflets.

The data recorded during 1976 and the analysis of variances are presented in Table 23 and Appendix XXIV respectively.

The length of the longest leaflets was significantly higher in palms receiving fertilizers (126.2 cm at M_1 and 130.2 cm at M_2 as compared to 95.4 cm at M_0 level).

2.3(j) Breadth of leaflets.

Similar to the length of leaflets, the breadth was increased by fertilization. Palm density was also found to have influence of on breadth. Palms at lesser densities (S_1 and S_2) had produced broader leaflets as compared to highest density (S_0). (Table 24 and Appendix XXV).

2.4 <u>Leaf area and light infilteration.</u>

2.4(a) Leaf area index.

The mean data are presented in Table 25, Fig. 8, and the analysis of variance in Table in Appendix XXVI.

The effect of both spacing and manuring as well as their interaction were highly significant. At all levels of spacing manuring had increased the Leafl Area Index. S_0 ..
also, at all levels of manuring, LAI was found to increase

Table 23

Mean length of longest leaf lot (cm)

	M_0	M_1	M_2	Mean
S_0	95.6	132.6	134.0	120.7
S_1	97.5	124.9	131.1	117.8
S_2	93.1	121.2	125.5	113.3
Mean	95.4	126.2	130.2	117.3

CV%	10.3
CD for levels of M	12.12
CD for combination:	20.99

Table 24

Mean breadth (maximum) of longest leaf lot (cm)

	M_0	M_1	M_2	Mean
S_0	4.77	6.28	6.40	5.82
S_1	5.33	7.47	6.70	6.50
S_2	5.20	6.83	6.73	6.26
Mean	5.10	6.86	6.61	6.19

CV%	5.4
CD for levels of S or M	0.33
CD for combinations	0.57

Table 25

Leaf Area Index

	M_0	M_1	M_2	Mean
S_0	2.32	6.74	7.96	5.68
S_1	1.50	3.60	3.50	2.86
S_2	0.65	1.92	1.95	1.51
Mean	1.49	4.09	4.47	3.35

CV % 9.60
CD for levels of S or M 0.316
CD for combinations 0.547

Table 26

Mean light intensity (lux) per day falling on the ground under the canopy of different treatments

	M_0	M_1	M_2	Mean
S_0	10041	593	1939	4191
S_1	14981	5767	4816	8521
S_2	18072	12511	9680	13421
Mean	14364	6290	5478	8711

with increases in palm density. Thus the leaf area was found to be affected by spacing as well as manuring.

The correlation between LAI and yield was not significant ($r = 0.013$). But when LAI and yield under the same spacing were taken individually, it was found that they were highly correlated viz. for S_0, $r = 0.889$, for S_1, $r = 0.882$ and for S_2 $r = 0.826$.

2.4(b) Light infilteration.

The mean data (ie. mean of different days as well as of different times of the day) of light intensity in lux falling on the ground are presented in Table 26 and Fig. 8.

The intensity was maximum in wider spacings ie $S_2 > S_1 > S_0$. In the case of effect of manuring, the intensity was maximum in plots without fertilization (M_0) than in plots receiving fertilizers (M_1 and M_2).

The correlation studies revealed that there was significant but negative correlation between infilteration and LAI, r being $- 0.901$. The correlations with number of functioning leaves ($r = -0.591$) and yield ($r = -0.297$) were found to be non-significant.

3. Leaf Nutrient Status

The data on per cent content of N, P, K, Ca, Mg, Na, Cl and S in leaf are presented in Table 27 and the analysis of variance table in Appendix XXVII.

3.1 Nitrogen.

The N level was significantly higher in plots receiving fertilizers than unfertilised plots. However there was no significant difference between palms receiving M_1 and those receiving M_2 level of fertilizers. Plant density had no significant effect on the leaf N status.

There was a significant positive correlation between foliar nitrogen level and yield of nuts (r = 0.8329)(Table 28 and Fig. 9).

3.2 Phosphorus.

As in the case of N, the leaf P level was significantly higher in fertilised plots. When palms were spaced wider, the P level of leaves was also found to be significantly high. Phosphorus content was also found to be positively correlated (r = 0.6719) with yield. (Table 28 and Fig. 9).

The intercorrelation between leaf N and leaf P levels were also found to be significant, r being 0.6694 (Table 29).

Table 27

Mean percent of nutrients in leaf on oven dry basis

	N	P	K	Ca	Mg	Na	Cl	S
S_0 M_0	0.98	0.10	0.33	0.39	0.67	0.39	0.58	0.15
S_0 M_1	1.43	0.12	1.41	0.54	0.45	0.15	0.87	0.18
S_0 M_2	1.46	0.13	1.63	0.43	0.40	0.15	0.69	0.17
S_1 M_0	1.10	0.13	0.27	0.43	0.78	0.35	0.53	0.15
S_1 M_1	1.37	0.14	0.78	0.46	0.61	0.23	0.54	0.16
S_1 M_2	1.58	0.15	0.99	0.38	0.51	0.21	0.84	0.18
S_2 M_0	1.08	0.14	0.32	0.38	0.64	0.45	0.69	0.18
S_2 M_1	1.52	0.16	0.80	0.50	0.55	0.31	0.67	0.18
S_2 M_2	1.57	0.15	0.87	0.39	0.55	0.27	0.79	0.17
S_0	1.29	0.12	1.12	0.46	0.53	0.23	0.71	0.17
S_1	1.35	0.14	0.68	0.42	0.63	0.26	0.64	0.17
S_2	1.39	0.15	0.66	0.42	0.58	0.34	0.72	0.18
M_0	1.06	0.13	0.31	0.40	0.70	0.40	0.60	0.16
M_1	1.44	0.14	1.00	0.50	0.53	0.23	0.69	0.18
M_2	1.54	0.14	1.17	0.40	0.51	0.21	0.77	0.17
General Mean	1.34	0.14	0.82	0.43	0.58	0.28	0.69	0.17
CV%	16.0	7.1	23.5	25.5	13.8	12.9	32.7	17.1
CD for levels of S or M	0.215	0.010	0.192	-	0.080	0.074	-	-
CD for combination	0.372	0.054	0.333	-	0.138	0.128	-	-

Table 28

Correlation between yield of nuts and foliar nutrient levels.

	Nutrients	r		Nutrients	r
1.	Nitrogen	0.8329*	5.	Magnesium	-0.4605
2.	Phosphorus	0.6719*	6.	Sodium	-0.4340
3.	Potassium	0.3438	7.	Chlorine	0.4272
4.	Calcium	-0.1342	8.	Sulphur	0.3261

* Significant at 0.05 level.

Table 29

Inter correlation between foliar nutrient levels.

	N	P	K	Ca	Mg
N	-	0.6694*	0.7247*	0.3724	-0.7769*
P	-	-	-0.1023	0.0040	-0.0700
K	-	-	-	0.4416	-0.8961*
Ca	-	-	-	-	-0.3690
Mg	-	-	-	-	-

* Significant at 0.05 level.

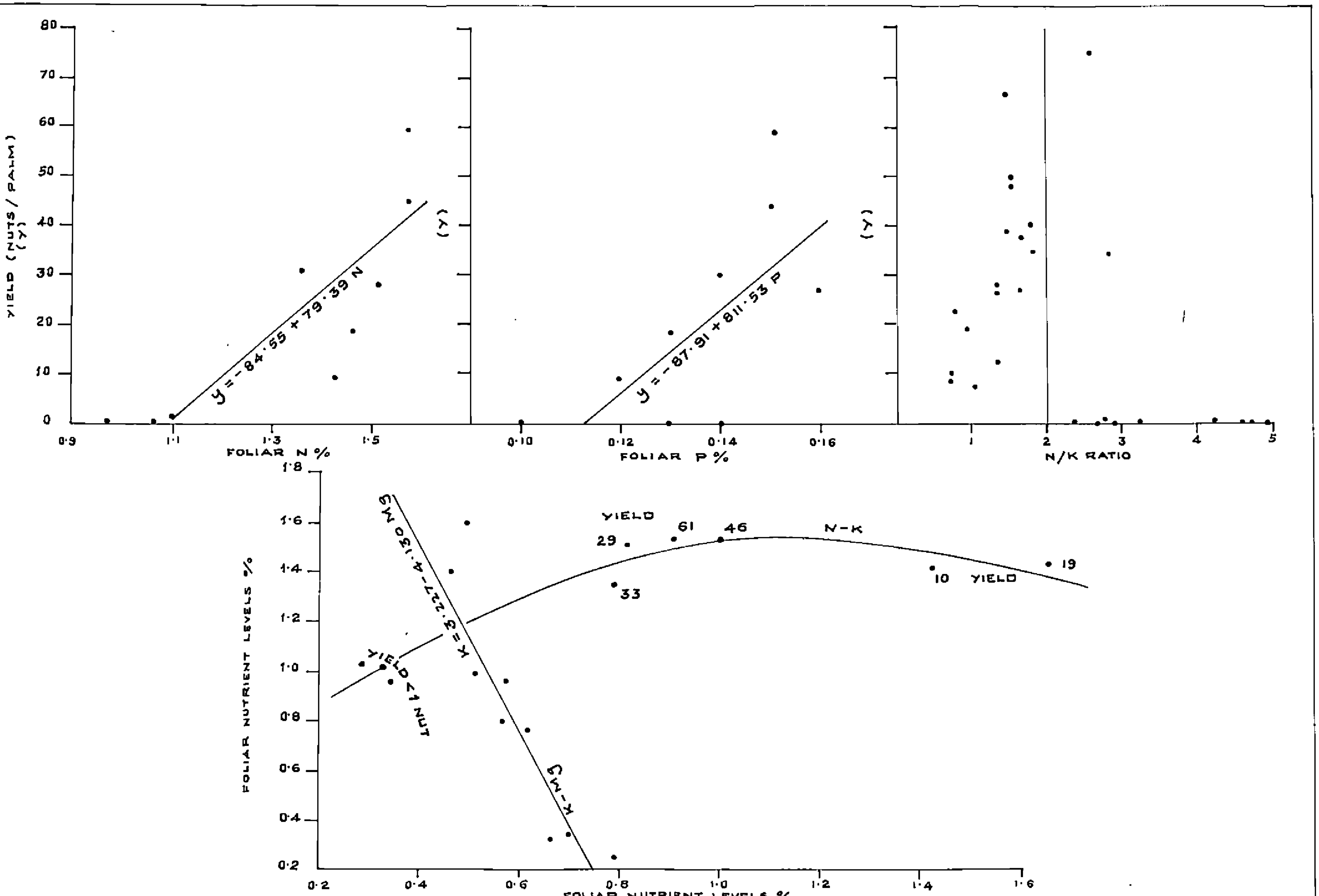

FIG. 9. RELATIONSHIP BETWEEN YIELD AND FOLIAR NUTRIENT LEVELS AND BETWEEN FOLIAR NUTRIENT LEVELS.

3.3 Potassium.

At all levels of spacing the K content of leaves was significantly lower in unfertilized plots. In M_2 plots the K levels were significantly higher than in M_1 plots with higher palm densities (S_0 and S_1) though there was no significant difference between M_1 and M_2 in S_2 plots. In M_1 and M_2 levels of fertilization, the plots with highest density (S_0) registered significantly higher K level.

The relation between yield and foliar K level, though positive was found to be non-significant (Table 28). But N/K ratio and yield, and foliar N level and K level were correlated r being -0.4371 and 0.7247 respectively (Table 29 and Fig. 9). The correlation between percent oil and foliar K was not significant (r = 0.212).

3.4 Calcium.

Ca levels in leaves were not influenced by any of the treatments. The mean Ca content recorded ranged between 0.38% and 0.54%. There was neither significant correlation with yield (r = -0.1342) nor with other foliar nutrient levels (Table 29). The K/Ca ratio was increased by manuring (Table 30).

Table 30

Ratio of foliar nutrient levels

	N/K ratio				K/Ca ratio			
	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean
S_0	2.97	1.01	0.90	1.63	0.85	2.61	3.70	2.39
S_1	4.07	1.76	1.60	2.48	0.63	1.70	2.61	1.65
S_2	3.38	1.90	1.80	2.36	0.84	1.60	2.23	1.56
Mean	3.47	1.56	1.43		0.78	1.97	2.85	

Table 31

Soil pH at different depths of sampling.

	Depths			
	0 - 25 cm	25 - 50 cm	50 - 75 cm	75 - 100 cm
S_0	4.4 - 5.7	4.2 - 5.6	3.8 - 5.4	4.0 - 5.3
S_1	4.6 - 5.6	4.1 - 5.6	3.8 - 5.4	3.8 - 5.4
S_2	4.5 - 5.6	4.0 - 5.4	4.0 - 5.2	3.9 - 5.1
M_0	5.2 - 5.7	5.2 - 5.6	5.0 - 5.4	5.0 - 5.4
M_1	4.5 - 4.7	4.1 - 4.7	4.1 - 4.9	4.0 - 4.8
M_2	4.4 - 4.6	4.0 - 4.4	3.8 - 4.1	3.8 - 4.2

3.5 Magnesium.

The Mg content of leaves decreased with fertilizer applications from 0.70% in unfertilized plots to 0.53% in M_1 and 0.51% in M_2 plots. Spacing had no effect on the magnesium content of leaves.

There was no significant correlation between Mg levels and yield (Table 28). But the intercorrelations between N and Mg levels, and K and Mg levels were negative and significant (Table 29 and Fig.9). The sum of K, Ca and Mg was found to be 1.41%, 2.03% and 2.08% in M_0, M_1 and M_2 plots respectively.

3.6 Sodium.

The Na content of leaves was lower in palms receiving fertilizers than in unfertilized palms. The content was higher in palms in S_2 plots than in S_1 and S_0 plots. The correlation coefficient on yield was non-significant ($r = -0.4340$).

3.7 & 3.8 Chlorine and Sulphur.

Neither manuring nor spacing affected the Cl and S content of leaves. The Cl values ranged between 0.53% to 0.87%. Sulphur content ranged between 0.15% to 0.18%.

No significant correlations were obtained for these nutrients with yield (Table 28).

4. Soil Nutrient Status.

4.1 Soil Reaction.

The data on ranges of pH for the four depths viz. 0 - 25 cm, 25 - 50 cm, 50 - 75 cm and 75 - 100 cm are presented in Table 31. The pH of the soil decreased with increasing levels of fertilization. Generally the pH decreased with depth especially in plots receiving the highest dose of fertilizers. There was no effect of spacing on pH.

4.2 Organic carbon.

Generally there was no significant difference in organic carbon content (%) of the soil due to treatment effect (Table 32 and Appendix XXVIII). However, the data for the four depths showed that the organic carbon content gradually decreased with depth and it was only 0.247% (General mean) at the lowest depth of 75 - 100 cm as against 0.657% in the top layer of 0 - 25 cm.

4.3 Nitrogen.

In general the total N content of soil at the time of sampling did not reflect any variation due to fertilizer

Table 32

Mean content of organic carbon (%) in soil at different depths of sampling.

	Depth			
	0 - 25 cm	25 - 50 cm	50 - 75 cm	75 - 100 cm
S_0 M_0	0.547	0.455	0.331	0.197
S_0 M_1	0.595	0.511	0.354	0.292
S_0 M_2	0.752	0.443	0.359	0.251
S_1 M_0	0.741	0.488	0.3[illegible]5	0.239
S_1 M_1	0.634	0.505	0.331	0.241
S_1 M_2	0.662	0.466	0.320	0.180
S_2 M_0	0.623	0.438	0.297	0.275
S_2 M_1	0.764	0.489	0.219	0.309
S_2 M_2	0.595	0.404	0.219	0.241
S_0	0.631	0.470	0.348	0.247
S_1	0.679	0.486	0.339	0.220
S_2	0.661	0.443	0.245	0.275
M_0	0.637	0.460	0.331	0.237
M_1	0.664	0.501	0.301	0.281
M_2	0.670	0.438	0.299	0.224
General Mean	0.657	0.466	0.311	0.247
CV %	25.0	12.7	13.6	36.7
CD for levels of S	-	-	0.0424	-
CD for combination.	-	-	0.0734	-

application (Table 33 and Appendix XXIX). However the main effects of S and M were significant for second zone of sampling (25 - 50 cm) only; the N content reduced as the spacing increased and the N content increased with increasing levels of fertilization. In general there was slight decrease in the nutrient levels with increasing depths.

4.4 Phosphorus.

The effect of manuring on the available P status of soils was highly significant in the top 0 - 25 cm layer. (Table 34 and Appendix XXX). The P content of the top 0 - 25 cm of the soil in unfertilized plots was less than 4 ppm. This was comparable with the available P status of the lower layers (25 - 100 cm) of fertilized as well as unfertilized plots. In the 0 - 25 cm layer of fertilized plots heavy build up of P was evident (158 ppm in M_2 plots and 55 ppm in M_1 plots as compared to 4 ppm in M_0 plots).

4.5 Potassium.

The mean data and the abstract of ANOVA tables for all the four depths are presented in Table 35 and Appendix XXXI, respectively.

Manuring alone had significant effect on available K status of soils at all the four depths. The K status of

Table 33

Mean content of nitrogen (%) in soil at different depths of sampling.

	Depth			
	0 - 25 cm	25 - 50 cm	50 - 75 cm	75 - 100 cm
S_0 M_0	0.041	0.036	0.030	0.032
S_0 M_1	0.047	0.041	0.033	0.029
S_0 M_2	0.049	0.049	0.033	0.033
S_1 M_0	0.040	0.032	0.030	0.033
S_1 M_1	0.045	0.036	0.035	0.035
S_1 M_2	0.039	0.042	0.031	0.036
S_2 M_0	0.043	0.033	0.030	0.031
S_2 M_1	0.046	0.036	0.031	0.033
S_2 M_2	0.048	0.035	0.031	0.035
S_0	0.046	0.042	0.032	0.031
S_1	0.041	0.037	0.032	0.035
S_2	0.046	0.035	0.031	0.033
M_0	0.041	0.034	0.030	0.032
M_1	0.046	0.038	0.033	0.032
M_2	0.045	0.042	0.032	0.035
General mean	0.044	0.038	0.032	0.033
CV %	12.7	13.4	15.6	16.6
CD for levels of S or M.	-	0.0047	-	-
CD for combinations.	-	0.0087	-	-

Table 34

Mean content of phosphorus (ppm) in soil at different depths of sampling.

	Depth			
	0 - 25 cm	25 - 50 cm	50 - 75 cm	75 - 100 cm
$S_0 M_0$	3.667	2.567	0.470	0.800
$S_0 M_1$	75.033	3.700	0.301	0.433
$S_0 M_2$	128.633	9.233	0.670	1.000
$S_1 M_0$	5.967	1.800	0.331	0.433
$S_1 M_1$	53.000	10.067	0.770	0.433
$S_1 M_2$	211.367	15.067	0.570	0.633
$S_2 M_0$	2.300	1.333	0.472	0.667
$S_2 M_1$	36.767	2.900	0.570	0.833
$S_2 M_2$	132.667	2.433	0.969	0.733
S_0	69.111	5.167	0.480	0.744
S_1	90.111	8.378	0.561	0.501
S_2	57.244	2.222	0.669	0.743
M_0	3.978	1.900	0.421	0.633
M_1	54.933	5.556	0.539	0.567
M_2	157.556	8.911	0.730	0.789
General mean	72.156	5.456	0.567	0.663
CV %	80.1	106.9	57.7	45.2
CD for levels of M.	57.7837	-	-	-
CD for combinations.	100.0843	-	-	-

Table 35

Mean content of potassium (ppm) in soil at different depths of sampling.

	Depth			
	0 - 25 cm	25 - 50 cm	50 - 75 cm	75 - 100 cm
$S_0 M_0$	21.00	23.00	20.00	18.00
$S_0 M_1$	105.00	108.67	192.33	123.00
$S_0 M_2$	84.33	121.67	123.00	101.70
$S_1 M_0$	22.00	23.00	18.00	16.00
$S_1 M_1$	59.67	40.00	53.00	151.33
$S_1 M_2$	88.67	61.33	96.00	173.33
$S_2 M_0$	29.00	20.00	20.00	20.00
$S_2 M_1$	78.00	55.67	97.00	89.33
$S_2 M_2$	83.67	47.00	104.00	130.67
S_0	70.11	84.45	111.78	80.89
S_1	56.78	41.44	55.67	113.56
S_2	63.55	40.89	73.67	80.00
M_0	24.00	22.00	19.33	18.00
M_1	80.89	68.11	114.11	121.22
M_2	85.56	76.67	107.67	135.22
General mean	63.48	55.59	80.37	91.5
CV %	63.7	82.8	68.6	68.8
CD for levels of S or M.	40.391	46.005	55.094	53.729
CD for combinations.	69.960	79.683	95.425	93.061

soil was significantly higher in fertilized plots than in unfertilized plots. This was manifest at all depths. There was gradual increase in the K content from top layer to the lowest 75 - 100 cm layer.

4.6 Calcium.

In the top layer the CaO content was higher in plots receiving M_2 level of fertilization than in M_1 and M_0 plots where as in the lower depths (25 - 100 cm) reverse was the case with the CaO content of fertilized plots being lower than that of unfertilized plots. (Table 36 and Appendix XXXII).

4.7 Magnesium.

The Mg content of soils was lower in fertilized plots at all depths upto 100 cm than in unfertilized plots.(Table 37 and Appendix XXXIII).

Table 36

Mean content of calcium (m.e./100 g soil) at different depths of sampling.

	Depth			
	0 - 25 cm	25 - 50 cm	50 - 75 cm	75 - 100 cm
S_0 M_0	2.51	3.05	2.36	2.33
S_0 M_1	1.95	1.42	2.39	2.22
S_0 M_2	4.04	1.68	1.46	1.31
S_1 M_0	1.93	2.38	2.58	2.47
S_1 M_1	1.91	1.35	1.18	1.66
S_1 M_2	3.76	0.89	0.61	0.83
S_2 M_0	1.93	2.29	2.45	2.15
S_2 M_1	2.00	1.94	2.97	2.76
S_2 M_2	3.51	1.11	1.30	0.96
S_0	2.83	2.05	2.07	1.95
S_1	2.53	1.54	1.46	1.65
S_2	2.48	1.78	2.24	1.96
M_0	2.12	2.57	2.46	2.32
M_1	1.95	1.57	2.18	2.21
M_2	3.77	1.22	1.12	1.03
General mean	2.61	1.79	1.92	1.85
CV %	29.6	16.1	36.3	22.3
CD for levels of S or M.	0.770	0.288	0.697	0.412
CD for combinations:	1.334	0.499	1.208	0.714

Table 37

Mean content of magnesium (me/100 g soil) at different depths of sampling

	Depth			
	0 - 25 cm	25 - 50 cm	50 - 75 cm	75 - 100 cm
$S_0 M_0$	2.71	3.18	3.39	3.26
$S_0 M_1$	0.81	0.62	0.73	1.21
$S_0 M_2$	0.72	0.46	0.46	0.45
$S_1 M_0$	2.39	2.55	3.21	3.65
$S_1 M_1$	0.70	0.52	0.68	0.78
$S_1 M_2$	1.30	0.36	0.19	0.29
$S_2 M_0$	2.69	3.40	3.69	3.15
$S_2 M_1$	0.82	0.46	0.75	1.33
$S_2 M_2$	0.54	0.25	0.21	0.25
S_0	1.41	1.42	1.53	1.64
S_1	1.46	1.15	1.36	1.58
S_2	1.35	1.37	1.55	1.58
M_0	2.60	3.04	3.43	3.35
M_1	0.78	0.53	0.72	1.11
M_2	0.85	0.36	0.28	0.33
General mean	1.41	1.31	1.48	1.60
CV %	53.7	16.5	40.9	31.2
CD for levels of S or M.	0.757	0.217	0.605	0.499
CD for combination	1.311	0.375	1.047	0.864

D I S C U S S I O N

DISCUSSION

1. Yield and Yield Components

1.1 Yield of nuts.

When the palms were not fertilized, the yield did not vary due to spacing and yield was practically zero. When fertilizers were applied at the rate of 340 g N, 225 g P_2O_5 and 450 g K_2O per palm, the per palm yields at a spacing of 7.5 m x 7.5 m and 10.0m x 10.0m were higher than at a spacing of 5.0m x 5.0m. However when the fertilizer dose was doubled, a spacing of 10.0m x 10.0m was more beneficial than 7.5 m x 7.5 m increasing the yield of individual palms from 46 to 61 nuts per year (1976 yield). The yield per palm was consistently maximum in the plots with lesser density of planting (S_2) followed by medium density (S_1) and highest density (S_0). Similar results have been reported by Muhammad et al (1974) from Veppankulam, Tamil Nadu from a spacing cum manuring experiment laid out in 1961 where an yield increase from 10 nuts per palm at 6.1 m x 6.1 m spacing to 17 nuts per palm at 9.1 m x 9.1 m spacing was recorded in 1969. Shetty (1978) reported an yield increase of 607.1% in plots receiving fertilisers at the rate of 0.68 kg N, 0.46 kg P_2O_5 and 0.90 kg

K_2O over no manuring plots. Nelliat et al (1978) have also reported similar results from an experiment conducted at Kasaragod. While the cumulative yield for six years was only 13 nuts per palm at M_0 level, at M_1 level (500N: 500P: 1000Kg) the yield was 95 nuts and at M_2 (1000 : 1000 : 2000) the yield was 165 nuts. Whitehead and Smith (1968) have also reported similar results from the spacing trial on Jamaican Tall variety, where a spacing of 35' x 35' was found to result in higher yields (95.1 nuts per palm) than a spacing of 22' x 22' (53.5 nuts per palm). In another experiment in Jamaica, maximum yield was obtained with a spacing of 40' x 40' followed by 20' x 20', 30' x 30' and 25' x 25' (Smith, 1972). The author however did not attribute any specific reasons for the inconsistencies in response to spacing.

Though the average yield per palm at a palm density 100 per hectare with M_2 level of fertilisation compares well with figures given by many workers in India and abroad, 64 nuts (Menon and Pandalai, 1958) and 75.2 nuts (Markose and Nelliat, 1971) for India and 68.1 nut (Smith, 1968) for Philippines, it should be noted that the yields reported from unfertilised plots in the present study is practically none (a mean yield of a nut per palm in the 12th year). The poor yield was probably due to the poor fertility status and the deficiency of essential elements in the soil. Since the crop was entirely rainfed, moisture stress during summer months also might have contributed to the poor yields. The poor yields in closely spaced plots (5 m x 5 m) can be attributed to the higher competition for light and soil moisture.

Thus a higher dose of fertilisers can be recommended in plots where palm densities are lower. It also implies that in a fertile soil a higher density can be maintained. But a common argument against this is that in fertile soils palms tend to grow larger and require more air space. However this reasoning cannot be very valid since leaf spread may not increase beyond a maximum, determined primarily by the genetical set up. However it would be interesting to quote the consensus of opinion among experienced planters in Sri Lanka as reported by Child (1974) "plant density should not exceed 160 to a hectare on the worst land and 140 on the best".

In interpreting the results it should be noted that the choice of the optimum combination of spacing and manuring should depend on the maximum return per unit land area. Though per palm yields were higher at S_2 spacing than at S_1 in M_2 plots, per hectare yields were always highest in S_1 plots (7.5 m x 7.5 m) because it accommodates 78% more palms than S_2 per unit area whereas the increase in yield per palm from S_1 to S_2 was only 33% (46.4 nuts in S_1 M_2 against 60.8 in S_2 M_2). But contrary results have been reported from

Jamaica (Whitehead and Smith, 1968). They got maximum yield of 4815 nut per acre at the closest spacing (22'). This spacing was very near to the optimum that has been arrived at in that study (25'), and that might be the reason for this observation. The spacing of 7.5 m x 7.5 m on the square was in agreement with the views of several workers (Patel, 1938; Menon and Pandalai, 1958 and Smith, 1972). However, Muhammad et al (1974) were of the view that 9.1 m x 9.1 m would be optimum for maximum yield, but it appears that yield per unit area was not taken into account.

It is also important to consider economics of fertilization. At M_1 level the cost of fertilizers would work out to less than Rs.3/- and at M_2 level to less than Rs.6/- per palm/year. At the S_1 spacing the increase in yield during 1976 between M_0 and M_1 plots was 32 nuts which at current prices would cost Rs.32/-. The difference in yield between M_1 and M_2 plots at S_1 spacing was less than 14 over an additional investment of Rs.3/-. Similarly at S_2 spacing, the increase in yield between M_0 and M_1 plots was 29 nuts. Between M_1 and M_2, it was 32 nuts.

On the basis of per hectare yields at S_1 spacing, the increase in yield due to M_1 level of manuring over M_0 level was 5711 nuts costing about Rs.5711/- for a manure input costing Rs.534/-. The increase on account of M_2 level of fertilization over M_1 level was 2404 nuts costing Rs.2404/- over an additional investment of Rs.534/-.

1. 2 Copra per nut.

This is also important as copra is the product which generally goes to the market. Highest palm density of 400 palms per ha at 5.0m x 5.0m had produced lesser out-turn of copra per nut than other two spacings (7.5 m x 7.5 m and 10.0 m x 10.0 m). There were no significant differences between S_1 and S_2 spacings. Thus maximum copra yields were obtained in the same spacing where yields of nuts also was higher. Also no significant difference had been noted between M_1 and M_2 levels of fertilization in S_1 and S_2 plots even though there was an increase of 9% in copra out turn due to M_2 level over M_1 level at S_0 spacing. The effect of manuring was only to the extent of 3.2 g. The effect would have been more clear had M_0 level also was available for comparison, since the mean value of four M_0 plots was 128 g/nut. The effect of manuring in increasing yield of copra has been attributed to KCl application by many workers. N is reported to have negative effect on yield of copra. (Muliyar and Nelliat, 1971; Magat et al, 1975 and Prudente et al, 1976).

The correlation between yield of nuts and copra per nut was non significant. However, significant correlation has been reported by Anon (1977).

1.3 Percent oil in copra.

Oil percentage was negatively correlated with per palm yields. The maximum oil percentage (70%) was recorded in $S_2 M_1$ plots and the least (65%) in $S_2 M_2$ plots. This may be due to the fact that yields/palm were also higher in $S_2 M_2$ plots and the dilution effect has been manifest. . Smith (1968) held the view that oil percentage tends to be lower in sites where higher yield of nuts are obtained. However the general observations were that oil percentage was not affected by manuring (Muliyar and Nelliat, 1971 and Ramney, 1972b). similar trends have been reported in oil palm also (Corley et al, 1973).

1.4 Weight and volume of nuts.

1.4(a) Weight of whole nuts.

At higher palm densities (S_0) the weight of nuts was lower though per palm yields were also less. Fertilization at the M_1 level resulted in the heaviest nuts (1292 g) and M_2 level produced nuts of lower weight (1211 g), where as M_0 plots produced the lowest weight (1166 g). Muliyar and Nelliat (1971) have reported that nitrogen adversely affected the weight of nuts. So, the lower weight at M_2 level may be attributed to the adverse effect of N.

1.4(b) Volume of whole nuts.

The volume of whole nuts was positively correlated with weight of whole nuts ($r = 0.7511$) and the treatment effects, as in the case of weight, were significant. Whitehead and Smith (1968) reported that nut size decreased with increased plant density. Von Uexkull (1971) was of the view that size decreased rapidly in the absence of K where as Smith (1969) stated that neither N nor K influenced nut size, though P did influence.

1.4(c) Weight and volume of husked nuts.

Wider spacing resulted in larger sized nuts though the weights were not significant. Same trend was seen in the case of volume of whole nuts. Effect of manuring was not significant in the present study, but adverse effect of N and beneficial effect of K have been reported by Muliyar and Nelliat (1971). The volume of husked nuts was found to be positively correlated with weight ($r = 0.8299$).

1.4(d) Ratio of weight of husked nuts and whole nuts.

The ratio was higher at closer spacing (S_0) than at S_1 and S_2. It may be seen than yields were lower at S_0 than at S_1 and S_2. However, the ratio was higher at M_2 level where yields were also higher.

1.4(e) Ratio of weight of copra and husked nuts.

The treatments were not found to have affected the ratio indicating that the two are more or less in a constant proportion.

1.5 Female flowers.

1.5(a) Production of female flowers.

The maximum number of female flowers were produced in $S_2 M_2$ combination followed by $S_2 M_1$ or $S_1 M_2$ over the years. Irrespective of spacing M_2 level of manuring had increased the production by 46% (1976 data) over M_1 level. In the combined analysis, the corresponding figure was 31.8%. The production for M_0 plot was around two flowers per palm indicating that the palms were under severe deficiency. Similar results have been reported by Nelliat et al (1978). Production of female flowers as well as yield was the highest where plant density was the lowest. There was a positive correlation between yield of palms and female flower production. Anon (1970) also reported similar relationship in Jamaica. The reason for the low production in S_0 plots may also be due to insufficient utilisation of sun light and other environments.

Among the factors influencing productivity, number of female flowers per inflorescence is often the most important.

This is explained by the significant correlation obtained between yield of nuts and female flower production. There are several reports in support of this. According to Child (1974), the increased production is mainly due to the beneficial effects of fertilizers applied. Markoso and Nolliet (1975) have also held this view. According to Salgado (1947) and Anon (1970), nitrogen in particular as well as N P interaction are responsible for this increased production. Beneficial effects of N was seen in increased production of female flowers by 20 - 40% (Anon, 1967). Uexkull (1971) has stated that potash application had improved the crown habit and ultimately female flower production in Philippines.

1.5(b) Percent set.

Spacing (plant density) in general had no effect on setting percentage which was significantly higher in fertilised plots than in unfertilised plots.

Thus the poor yields of unfertilised plots was due to lesser number of female flower production as well as a lower setting percentage. Also the volume and weight of nuts as well as copra out turn were lower in unfertilised plot.

The increase in setting percentage by manuring has been attributed mainly as effect of potash. Salgado (1947) observed that setting percentage increased by 35% on account of K_2O application. Smith (1969) also reported the beneficial effects of K in flower setting and in the ability of the palms to carry fruit. But Nelliat (1978) did not find significant effect of fertilizer levels on setting percentage.

2. Vegetative Growth Characters

2.1 Number of bearing palms.

The effect of manuring was highly significant. Plots receiving fertilizers had significantly more number of bearing palms at the 12th year of planting than unfertilised plots.

This reveals the beneficial effect of fertilizers in the production of inflorescences and the ability of the palm to complete the reproductive cycle. The palms in the unfertilised plots suffered severely due to the deficiency of the nutrients. It was seen that the flower set was also significantly less in M_0 plots. Several workers have supported this view, especially the effect of KCl fertilization in the reproductive growth of palms (Salgado, 1947; Smith, 1969 and Mendoza and Prudente, 1972).

2.2 Height and girth of palms.

2.2(a) Height.

The height of palms was significantly affected by manuring, but not spacing. The height of palms under fertilization, was 3.7 times more than palms under no fertilisation. The rate of growth in any crop could be the combined influence of climate, soil and the nutrition. The increased height could be attributed to the combined effect of all the major elements viz. N, P and K. This could be further explained by the significant correlation obtained between yield and height. Anon (1970) also reported similar relationship.

The complete effects of nitrogen in plant metabolism could be achieved only if phosphoric acid and potash are also added (Menon and Pandalai, 1958). Patel (1938) had stated that cultivation and manuring and better soil conditions favour the production of taller stems. Reports from Jamaica indicate that nitrogen increased trunk height (Anon, 1970). Muhammed et al (1974) also got similar results in Veppankulam.

As discussed else where, lower trunk height in N_0 plots indicates the poor inherent fertility of soil.

It is popularly believed that when planting density increases, the palms tend to grow lanky (Patel, 1938; Menon and Pandalai, 1958). But spacing did not have significant effect on trunk height in this study. However the trend was in favour of the opinion of Patel (1938) and others. The mean height at wider spacing S_2 was 4.353 m followed by S_1

(4.520 m) and S_0 (4.560 m). Similar results were obtained by Whitehead and Smith (1968) and Muhammad et al (1974). This tendency though not serious can be attributed to mutual shading and resulting competition for light.

2.2(b) Girth.

Palms receiving fertilizers had large trunks than those receiving no fertilizers. The girth size like height is indicative of vigour and growth and was influenced among other factors by soil and fertility. Patel (1938) and Menon and Pandalai (1958) hold similar views. Like height, girth was also significantly correlated with yield. The girth increase in this case was the effect of fertilization. The low content of K in soil (Table 35) in M_0 plots might have played a significant role in the low girth of palms in those plots. Fremond and Ouvrier (1971) have recorded that absence of K application in the initial seven years (in an Ivory coast experiment) had produced smaller trees with less girth.

2.3 Leaves.

2.3(a) Total number of leaves.

Manuring at M_1 and M_2 levels had increased the total number of leaves produced since planting as compared to unfertilized plots. Nelliat et al (1978) obtained similar results. Among other factors like seasonal influence, nutrition is of great importance. As the greater number of production of leaves is an index of vigour, the beneficial effect of nutrition was manifest. Fremond and Cuvrier (1971) have found that absence of K application in particular resulted in reducing the total number of leaves produced in W. African tall coconuts grown in quarternary marine sands of IRHO. But reports from Jamaica (Anon, 1970) show that increasing rates of N application resulted in corresponding increases in the frond production right upto the highest level tried viz. 3.63 Kg of ammonium sulphate per palm per year.

Spacing also had significant effect on the production of total number of leaves since planting. Wider the spacing, greater was the production. This shows that palms at lower densities utilise the sun light and other environmental factors more efficiently to produce more vegetative dry matter. However in a spacing cum manuring experiment at Veppankulam, Muhammad <u>et al</u> (1974) did not find any effect of spacing on any of the vegetative characters.

2.3(b) Number of functioning leaves.

The same results as in the total number of leaves produced were obtained in the case of functioning leaves.

Nelliat et al (1978) reported similar results from an experiment at Kasaragod. There was significant correlation between yield of nuts and number of leaves. Menon and Pandalai (1958) also obtained similar results. The mean number of leaves in the crown in fertilized plots in 1976 (27.5) was in agreement with the figures (22 to 35) quoted by Patel (1938). But according to Child (1974), there may be 30 leaves in a healthy tall palm.

2.3(c) Rate of production of leaves.

Results similar to those seen under total number of leaves produced and number of functioning leaves above were obtained. Both these characters are dependent on the rate of production of leaves. It can be seen that yields were also higher in palms with greater rate of production of leaves. According to Patel (1938), trees having greater rate of production of leaves in general give better yield than others. S_0 plots had the lowest rate of production of 9.5 leaves as compared to S_1 (11.6 leaves) and S_2 (12.2 leaves). However Muhammad et al (1974) did not obtain any effect on rate of production of leaves by manuring from forth year onwards till 9th year (for which period data were available) though they found significant difference in the initial two years. The above authors also did not observe any effect of spacing from the spacing cum manurial experiment conducted at Veppankulam.

The rate of leaf production had stabilised by 8th year in the experimental palms as there were no wide variations from then.

2.3(d) Total length.

The length of leaves was influenced mainly by manuring. Palms receiving fertilizers had longer leaves in the decreasing order, $M_2 > M_1 > M_0$. Patel (1938) had recorded that manuring resulted in the production of larger leaves. Nelliat et al (1978) also obtained similar results. Absence of K application is reported to reduce the length of fronds (Fremond and Ouvrier, 1971). Even though effect of spacing was significant in two years, there was no difference in the combined analysis. The average length of a leaf in fertilized plots (1976) was found to be 6.1 m which is in conformity with findings of Davis (1954) and Child (1974).

2.3(e) Length of petiole.

At all levels of spacing fertilized palms had longer petiole than in unfertilized palms. But Nelliat et al (1978) did not find differences in this character due to manuring.

Manuring coupled with higher palm density resulted in longer petioles. At higher densities competition for light might have induced the plants to produce longer petioles.

The finding of Davis (1954), that a little less than a quarter of the total length of a leaf represents the petiole, is in confirmity with the present findings. However, according to Menon and Pandalai (1958), a short leaf stalk is preferred since it indicates a short stalk for the bunch also and the support for the bunches will be more efficient.

2.3(f) Length of leaf blade.

Manuring had increased the length of leaf blade significantly over no manuring. Since spacing did not show any significance, it has to be inferred from the discussion above (2.3(d) and 2.3(e)) that the effect of higher densities in producing longer leaves was more due to elongation of petiole than the blade portion.

2.3(g) Breadth of leaves.

The effect of nutrition was evident in increasing the breadth of leaves. As in the case of length of leaf blade, the beneficial effects of manuring had been manifest. Ultimately the leaf area is increased.

2.3(h,i & j) Number, length and breadth of leaflets.

The effect of treatments on number of leaflets, its length and breadth are discussed below.

Manuring had significantly increased the number of leaflets per leaf as well as length of leaflets, but spacing did not effect these characters. Increase in number of leaflets is a desirable character (Menon and Pandalai, 1958). Uexkull (1971) has reported that potash application increases leaf area. Fremond and Cuvrier (1971) have also reported that absence of K reduces the weight of leaflets. As nitrogen is an important nutrient in increasing growth habits, its effect also might have contributed to the increased number and length. Nelliat et al (1978) did not find significant effect of fertilization on length and number of leaf lets.The number of leaflets per leaf in manured plots tallies with the average number of 200 - 250 cited by Davis (1954); but according to Child (1974), the average was about 200 only.

The mean length of 128 cm (1976) in manured plots was 28% more than what was quoted by Menon and Pandalai (1958); but was in conformity with the range of 90-135 cm given by Child (1974).

Palms in fertilised plots had produced leaflets with significantly more width than unmanured plots. Nelliat et al (1978) have reported similar results. When the number of leaflets on a leaf was less, their width was also less. Menon and Pandalai (1958) have made similar observations.

The effect of wider spacing in producing leaflets of more width might be due to better utilisation of sun light in effective growth and vegetative dry matter production.

2.4 Leaf area and light infilteration.

2.4(a) Leaf Area Index:

At all levels of manuring, LAI was found to increase with increase in density. The increases were in geometric proportion. The effect of plant density in affecting the LAI could be anticipated since LAI is dependent on area occupied by palms. At wider spacing area per palm was more and hence a lower LAI.

The leaf area was affected by manuring as well. Fertilisation at M_1 and M_2 level significantly increased the leaf area at all plant densities as compared to unfertilized plots, but there were no significant differences between M_1 and M_2 plots. LAI could be compared with crop growth. If height, girth, and number of leaves of palms are taken as an index of crop growth, exactly similar trends were seen in the case of these characters under the same spacing. So it could be inferred that under same densities, crop growth rate increases with LAI. Corley (1973) had obtained similar results in oil palm. It is interesting to note that the proportion of LAI among the three spacings (S_0, S_1, S_2) at M_2 level of fertilization is the same as the proportion of planting density ie. 4.0 : 1.8 : 1.0. At M_1 level of fertilization the ratio was 3.5 : 1.9 : 1.0 and at M_0 level 3.6 : 2.3 : 1.0 indicating that the increase in leaf area/palm due to fertilisation was influenced by spacing. At M_0 level, as the plant density increased from 178 to 400 (125%), LAI increased by 57% where as in M_1 plots the increase was 84% and in M_2 plots 128% (the same as the increase in plant density).

The correlation between yield and LAI was not significant. But when LAI and yield under the same spacing were studied, it was found to be correlated for all the spacings individually. So it has to be inferred that if spacing is not varying, the yield of palms and LAI are correlated. This can be explained by the fact that palms with more LAI are able to utilise sun light and other environments in a better efficient way.

2.4(b) Light infilteration.

The intensity of light falling on the ground through the canopy of the coconut palms was maximum in wider spacings. This is because of less interception by the leaves. The infilteration was also maximum in unfertilised plots. This was because the general growth of palms in M_0 plots was very poor; so also the length of leaves. The number of leaves did not appear to have effected variation in infilteration in this study since the correlation was not significant. However the correlation coefficient was negative ($r = -0.297$). This is further supported by the highly significant negative correlation between infilteration and LAI ($r = -0.901$).

The findings suggest immense possibilities for intercropping or under planting in plots where palm densities are less. Nair and Balakrishnan (1976) have found that 56% of the sunlight on a bright day is infiltered through a stand of 178 palms per hectare.

3. Leaf Nutrient Status

3.1 Nitrogen.

The application of fertilisers had significantly increased the leaf level of N from 1.06% in unfertilised palms to 1.44% in M_1 plots and 1.54% in M_2 plots, though the difference between leaf levels of fertilized plots M_1 and M_2 was not statistically significant. There was a positive correlation (r = 0.8329) between yield of nuts and leaf N level indicating that N fertilisation is important in the soils. Anon (1970) and Magat (1978) have reported similar results. The response here is more evident when N levels are above 1.3% (Fig. 9). However even with an application of 680 g N/tree, the leaf N level (1.54%) was less than the critical level of 1.8% to 2.0% suggested by IRHO (Fremond et al, 1966) and 1.98% suggested from Sri Lanka.(Anon, 1969), though the yields were above 60 nuts/tree in S_2 M_2 plots. At Kasaragod (Anon, 1972), the leaf nutrient level was increased from 1.60% (500 g N per tree) to 1.80% (1000 g N per tree). Kamaladevi et al (1976) have suggested that a lower critical limit may be applicable to West Coast Tall palms on the West Coast. The results of many workers (Pillai and Davis, 1963; Ramanandan and Pillai, 1974) on the West Coast also support this view Thomas (1973) from Tanzania also reported similar findings.

3.2 Phosphorus.

Manuring as well as spacing influenced the P level in leaves. Palms in fertilized plots registered a higher level of leaf P (0.14%) than unfertilised palms (0.13%). These figures are above the critical level proposed by IRHO (0.12%) indicating that the palms in this experiment do not suffer from a deficiency of the nutrient. As in the case of nitrogen, a significant positive correlation was found between P level and yield of nuts (r = 0.6719) as well as with N level (r = 0.6694). However, in view of the appreciably high level of P, it appears that application of P at M_1 level (225 g/palm/year) would suffice. But Kamaladevi et al (1973) and Prudente et al (1976) did not obtain significantly higher values of leaf P level due to fertilisation. The findings in the present study also indicate the importance of P in the nutrition of coconut. Ganapathy (1971) could not establish any relationship between yield and leaf nutrient status.

3.3 Potassium.

At all levels of spacing K level was influenced by manuring. In M_0 plots the K level (0.31%) was much lower than the critical levels of IRHO (0.8 to 1.0%). With fertilisation it increased from 0.33% in M_0 plots to 1.41% in M_1 plots and 1.63% in M_2 plots at a planting density of 400 per hectare (S_0). At lower plant densities (S_1 and S_2) the rate of leaf K level increase was less (Table 27) where yields per palm were higher than in S_0 plots. This is probably due to dilution effect as the growth rate and yields were higher in S_1 and S_2 plots than in S_0. It also indicates that the K dosage of 900 g/tree at the M_2 level was not sufficient when the plants had more vigorous growth and gave higher yields. This shows the high requirement of potash by coconut palms. Thomas (1973) had recorded that the leaf K levels were lower in high yielding palms. Magat *et al* (1975) have observed similar situation in Philippines also. Only at M_1 and M_2 levels of fertilisation, spacing had effect, the palms in the highest densities (S_0) had very high leaf K level (1.5%) as compared to fertilised plots in S_1 and S_2 which had 0.9% and 0.84% respectively. No significant correlation was obtained between yield and leaf K level.

The correlation between N and K levels was positive and significant. But the correlation between N/K ratio and yield was negative (r = -0.4371). However the maximum N/K ratio obtained in fertilised plots was only 1.90 (Table 30); the optimum quoted by earlier researches is 2.25 where N level was less than 1.8% (Smith, 1969). Figure 9 indicates the same result ie. when N/K ratio is more than two, the yields are practically none. Higher yields are obtained when N/K ratios are around 1.7. The very high N/K ratio in unfertilised plots (upto 4.07) may be due to the comparitively low K content in palms in these plots. Hence it appears that the optimum may not be applicable to palms under severe deficiency of nutrients. The percent oil and foliar K were not significantly correlated. But Smith (1968) obtained significant correlation between oil percent in copra and leaf K level in Malayan Dwarf Palms.

3.4 Calcium.

Though the Ca levels were not found to be influenced by fertilization and spacing, the mean value (0.5%) in palms receiving M_1 levels of fertilisation was comprable to the critical levels of IRHO (0.5%). The K manuring had increased the K/Ca ratio (Table 30). Child (1974) had suggested such a condition.

3.5 Magnesium.

The Mg content of leaves decreased from 0.70% in unfertilised plots to 0.53% and 0.51% in M_1 and M_2 plots. These levels are higher than the critical level suggested by IRHO (0.30%). Thomas (1973) had recorded similar results from a trial in Tanzania.

The K levels were found less in unfertilised plots and there was significant negative correlation between Mg and K contents (r = -0.8961). Hence the K - Mg antagonism is expected to be the cause, the greater the absorption of K, smaller becomes the Mg content of leaves. Several workers have reported such a situation (Coomans and Ochs, 1976; Kulliyar and Nelliat, 1971). The sum of K, Ca and Mg was 1.4% in M_0 plots, 2.03% in M_1 plots and 2.08% in M_2 plots. Out of the total, K was 56.3% in M_2 plots where as it was 49.3% in M_1 plots and 21.9% in unfertilised plots (M_0).

Eventhough these values are not equal to what Bachy (1963) suggested (ie. K + Ca + Mg should be 2.7% and of this K should be 67 to 70%), they are indicative of the high requirement of K. Further studies may be required whether these values are applicable under our conditions.

3.6 Sodium.

The Na content of leaves decreased from 0.40% in M_0 plots to 0.23% in M_1 plots and 0.21% in M_2 plots. As spacing increased, there was also an incrase in Na content from 0.23% in S_0 plots to 0.26% and 0.34% in S_1 and S_2 plots respectively. The levels in fertilised plots were less than the critical level of 0.40% (IRHO). Coconut palms have high tolerance to Na upto 0.60% (Sankaranarayanan et al, 1958). According to Corley (1976), sodium has not been shown to be essential for most plant species.

3.7 & 3.8 Chlorine and Sulphur.

Neither manuring nor spacing affected the chlorine and sulphur content of leaves. The Cl content was found to be 0.77% at M_2 level of manuring against the critical level of 0.50% to 0.60% suggested by Ollagnier and Ochs (1971). The satisfactory level of Cl in unfertilized plots might have been obtained by absorption of Cl added to the soil through rain water. Magat (1978) suggested such a condition. The atmosphere in the region might contain relatively more Cl due to nearness to sea. Johnson et al (1957) suggested that plants take up enough Cl from atmosphere. Sulphur levels, 0.18% in fertilised plots was lower than critical levels of 0.20% suggested by Southern (1969). However, the anionic nutrition of these elements require further studies before the importance of these elements in coconut fertilization on West Coast can be accessed. This is particularly important in view of the fact that anionic nutrition has given encouraging results abroad (Ollagnier and Ochs, 1972, Magat, 1978).

4. Soil Nutrient Status

4.1 Soil reaction.

The pH of the soil decreased considerably from the range of 5.2 - 5.7 in unfertilised plots to 4.4 - 4.7 in fertilised plots in the top 0 to 25 cm layer. The same trend was noticed in lower three layers also. Similar results have been reported by Kamaladevi et al (1975), Pushpadas et al (1973) and Nelliat, (1973). This decrease was common when ammonium sulphate was applied to laterite soils and it also suggests that Ca application may be necessary to maintain the pH. The pH of the soil before planting of the experiment in 1964 was

5.3 which is very comparable to the pH range of 5.2 - 5.7 in unfertilised plots.

4.2 Organic carbon.

There was no significant difference in the organic matter content of soil due to fertilisation. Nelliat (1973) also reported similar results. There was considerable decrease in the organic carbon content from 0.657% in top layer to 0.247% in lowest 75 - 100 cm layer. This may be due to the reason that if at all any organic refuse was left in the plots, it was in the top layer only.

4.3 Nitrogen.

There was no difference in N content of the soil inspite of application of 680 g of N in the form of ammonium sulphate. Nethsinghe (1962) reported similar results. This may be due to the time lag between fertilizer application (September) and sampling (February) indicating that the nutrients were partly absorbed by plants and partly lost in leaching. This also suggests that the palms are under a N stress for quite a long period of the year and application in two or even three split doses will prove beneficial. Promising results on splitting of N have been reported by Markose and Nelliat (1975).

4.4 Phosphorus.

The effect of manuring on P status of soil was highly significant in the top 0 - 25 cm layer. The heavy build up to 158 ppm in M_2 level of fertilisers and 55 ppm in M_1 level as compared to 4 ppm in M_0 level was due to the application of superphosphate. This is in agreement with the view of Fotyma (1978). The very low level in the lower depths was on account of the immobility of P and suggests that placement of the nutrient is important. Skipping of P application or reducing the dosage after building up a reserve can also be thought of as a general recommendation. Finding of Wahid et al (1975) corraborates this view. It may also be noted that the leaf P level was also high in fertilised plots.

4.5 Potassium.

The available K status of unfertilised plots remained significantly lower in all the four depths. The level of the nutrient in fertilised plots increased progressively from 86 ppm (0 - 25 cm) to 135 ppm (75 - 100 cm). This suggests that the K fertiliser applied is leached down the profile, unlike P which is not a mobile nutrient. Holliat (1973) has reported that there was a build up to K in soil on account of continued application of fertilisers. But Nothsinghe (1962) did not find any difference in soil K content between fertilised and unfertilised plots.

4.6 Calcium.

In the top layer CaO content was higher in fertilised plots than in unfertilised plots, where as reverse trend was seen in lower depths (25 - 100 cm). Ramanandan and Pillai (1974) have found that Ca content was more in manured plots. This suggests that application of superphosphate would suffice to meet the Ca requirement of the palms.

4.7 Magnesium.

The Mg content of the soil was consistently lower in fertilised plots than unfertilised plots. Ramanandan and Pillai (1974) have reported similar results. The leaf nutrient status was also lower in fertilised plots indicating that application of Mg is necessary to improve the nutrition of the palm.

S U M M A R Y

S U M M A R Y

A spacing cum manurial experiment on the West Coast Tall coconut palms initiated in 1964 at the Coconut Research Sub Station, Balaramapuram of the Kerala Agricultural University was utilised (1) to study the effect of palm density and levels of NPK fertilizers on yield and quality of coconuts; (2) to study the soil and leaf nutrient status and vegetative characters for possible correlations, if any, with yield and the possibility of utilising the analytical data for assessing the nutrient requirement of the palms. The treatments consisted of three spacings (5.0 m x 5.0 m) 7.5 m x 7.5 m and 10.0 m x 10.0 m on square) and three levels of NPK fertilizers (control - no fertilizer, 340 g N + 225 g P_2O_5 + 450 g K_2O per palm per year and 680 g N + 450 g P_2O_5 + 900 g K_2O per palm per year). A brief summary of the results are furnished below.

When palms were not fertilized, the yields, which were practically none, did not vary due to spacings. When fertilizers were applied at the rate of 340 : 225 : 450 g NPK, the per palm yields were higher at a spacing of 7.5 m x 7.5 m and 10.0 m x 10.0 m than at a spacing of 5.0 m x 5.0 m. When fertilizer dose was doubled from 340 : 225 : 450 to 680 : 450 : 900 g, the per palm yield increased from 46 nuts (at 7.5 m x 7.5 m) to 61 nuts (at 10.0 m x 10.0 m).

The experiment showed that higher dose of fertilisers can be applied with advantage in plots with lesser densities, and also that fertile soils can maintain a larger number of palms per unit area with application of 680 : 450 : 900 g NPK per palm.

Yield of 8225 nuts per hectare was the maximum at a palm density of 178 (7.5 m x 7.5 m) as compared to 7453 at a density of 400 per hectare (5.0 m x 5.0 m spacing). At current prices, the increase in profit, by highest dose of fertilisers over medium dose with a density of 178 palms/hectare, was Rs.2,404/- for an additional manure in put of Rs.534/-.

Copra out turn per nut was maximum at densities of 178 and 100 palm/hectare where yield of nuts was also higher and hence, out turn copra per hectare would also be high at these densities.

The oil per cent in copra was negatively correlated with per palm yields. Maximum oil percentage (73%) was obtained from unfertilised plots where yields were practically none and the lowest (63%) in plots receiving the double dose of fertilisers.

The weight of nuts was lower at a density of 400 palms/ hectare than at a density of 178 or 100 per hectare, though the yields were also low at the higher density. Fertilised palms produced heavier nuts than unfertilized palms and the heaviest nuts were obtained at medium level of fertilization.

Wider spacing resulted in larger sized nuts. The volume of whole nuts was positively correlated with its weight, so also the volume of husked nuts with weight of husked nuts. The ratio of weight of husked nuts and whole nuts was highest at a palm density of 400 per hectare. It was also highest at the highest dose of fertilizers.

The production of female flowers was practically none in unfertilized plots. At the higher level of manuring (680 + 450 + 900 g), the female flower production was 46% more than at lower level of 340 + 225 + 450 g. The female flower production was positively correlated with palm yields.

Flower setting percentage was not generally influenced by palm density, but fertilization significantly increased the set over no fertilization.

Manuring was found to enhance earliness in bearing where as spacing had no significant effect.

The height of palms was increased by manuring and palms receiving fertilizers had larger trunks (girth) than those without fertilizers. The height and girth of palms were significantly correlated with yield of nuts. Though the effect of spacing was not significant on height, palms in closer spacing tended to grow taller than wider spacing.

Spacing as well as manuring had significant effect on rate of production of leaves, number of leaves and total number of leaves produced since planting. Manuring at higher levels had produced more number of leaves (27) than unmanured plots (12 leaves). Wider the spacing, greater was the leaf production (23.5 leaves in lower densities as compared to 20.4 leaves in highest density). The number of leaves and yield of palms were significantly correlated.

Fertilization produced longer leaves (longer petioles as well as blade portion) as compared to unfertilized palms (605 to 621 cm in fertilized plots and 463 cm in unfertilized plots). Manuring coupled with higher palm density resulted in longer petioles. The breadth of leaves as well as length and breadth of leaflets and number of leaflets were all increased by manuring, but spacing did not effect increase in these characters except that the breadth of leaflets was more in wider spacings. When number of leaflets was less, their width was also less.

The leaf area was affected by spacing as well as manuring. At all levels of manuring, LAI was found to increase in geometric proportion with increases in plant density (1.51 at 100, 2.86 at 178 and 5.68 at 400 density). Similarly LAI was 1.49 in unfertilized plots as compared to 4.89 in medium level and 4.47 in highest level. The proportions of LAI among the three spacings at maximum level of fertilization was the same as the proportion of density ie. 4.0 : 1.8 : 1.0. At medium level, it was 3.5 : 1.9 : 1.0 and at zero level, 3.6 : 2.3: 1.0 indicating that the increase in leaf area was influenced by spacing. Yield and LAI in the same spacings were found to be significantly correlated.

The light infilteration through the canopy of coconut palms increased when palm density decreased. The intensity was maximum in unfertilized plots and the variation between fertilized plots was not marked. Infilteration was negatively correlated with LAI.

The application of fertilizers had significantly increased the leaf level of N from 1.06% in unfertilized palms to 1.44% in palms receiving medium level of fertilization and to 1.54% in palms fertilized at double dose; though there was no significant difference between fertilized plots. There was a significant positive correlation between yield of nuts and leaf N level indicating that N fertilization is important in those soils.

Palms in fertilized plots registered a high leaf P level of 0.14% as compared to 0.13% in unfertilized plots. There was a positive correlation between yield and leaf P level. Leaf levels of N and P are also found to be positively correlated. Application of P at the rate of 225 g/palm/year was found adequate. Palms in wider spacing registered a higher leaf P level.

The foliar K level was also found to be influenced by fertilization as well as spacing. The leaf K level was very low (0.31%) in unfertilized plots. Fertilization at the double dose increased the level to 1.17%. The rate of increase in K level due to fertilization was less in plots with lesser densities where yields per palm were higher. Thus the K dosage of 900 g per tree appeared to be insufficient. The correlations between N/K ratio and yield, and foliar levels of N and K were significant. When N/K ratio was in the range of 1.6 to 1.9, yields were higher.

The Ca levels in leaf were not found to be influenced by any of the treatments. However the mean values (0.4 to 0.5%) were comparable with the critical levels suggested by IRHO. Manuring had increased the K/Ca ratio from 0.78% in unfertilized plots to 2.28 in plots receiving double dose of fertilizers.

The foliar Mg content was found to decrease with fertilization. It may be noted that K levels were higher in fertilized plots and the K - Mg antagonism is manifest. There was negative correlation between K and Mg levels. The sum of K + Ca + Mg was very low in unfertilized plots (1.41%) as compared to fertilized plots (2.03 to 2.08%).

The sodium content in leaves decreased from 0.40% in unfertilized plots to 0.22% in fertilized plots. The levels in fertilized plots were much lower than the critical levels suggested by IRHO (0.40%). Wider spacing registered a higher Na level.

The Cl and S status in leaves was not affected by the treatments. Chlorine content (0.69%) was higher and S content (0.17%) was lower than critical limits suggested by Ollagnier and Ochs (1971) and Southern (1969).

The pH of the soil sharply decreased due to application of fertilizers. This trend was seen in all the four depth upto 100 cm. So Ca application may be necessary in these soils.

There was no significant effect of treatments on organic matter content of soil which decreased gradually from 0.657% in top 0 - 25 cm layer to 0.247% in 75 - 100 cm layer.

Nitrogen content in soil was also not found influenced by fertilization. This indicates that palms are under nitrogen stress for a longer period of the year and hence split a application will prove beneficial.

A heavy build up of 158 ppm P in the top 0 - 25 cm of the soil was found at the highest level of fertilization (450 g/palm) as compared to 55 ppm in medium level and four ppm in zero level plots. The build up of P content in lower layers of soil was very low. In view of the heavy build up in soil the results suggest that P application may not be required every year after an initial build up in the soil.

The soil K status was significantly lower in 0 - 100 cm layer in unfertilized plots (18 - 24 ppm). The levels in fertilized plots were in the range of 68 to 135 ppm. There was a gradual increase of K in soil from top to bottom layer. This suggests that applied K is leached down unlike P whose concentration in lower layers (25 - 100 cm) was much lower than the top 0 - 25 cm layer where fertilizers were applied. Split application of K also may be advantageous.

CaO content in the top 0 - 25 cm of soil was higher in fertilized plots, but not at the lower depths. This situation together with the satisfactory foliar level of Ca suggest that superphosphate application would meet the Ca requirement of the palms.

Mg content of soil was lower in fertilized plots than unfertilized plots. The status in leaves was similar suggesting that application of Mg is necessary.

The very poor yield of nuts even at the 12th year of planting coupled with a very low nutrient status in leaf and soil in plots without fertilization reveal the inherent poor fertility status of the soil in the region and the need for improving the same by fertilization.

R E F E R E N C E S

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* Original not seen.

APPENDIXES

APPENDIX I

Monthly rain fall data (mm) for the years 1972, 1973, 1974, 1975 and 1976.

Months	1972	1973	1974	1975	1976
January	0.0	0.0	0.0	12.2	0.0
February	6.4	0.0	0.0	76.4	0.0
March	0.0	25.0	13.3	9.3	42.4
April	51.6	194.6	68.9	310.8	18.4
May	387.0	178.1	211.3	249.9	54.6
June	108.0	350.7	65.5	431.8	81.0
July	286.2	173.0	311.1	181.9	91.1
August	41.5	53.0	352.5	174.3	129.8
September	198.7	31.4	295.5	216.9	73.8
October	387.0	185.1	160.0	374.6	159.6
November	77.8	45.0	46.1	246.7	192.3
December	106.3	79.1	0.0	54.1	12.7
Total	1650.5	1315.0	1524.2	2339.9	855.7

Note: Data on sunshine hours were not available for the period of investigation. Maximum and minimum temperature recordings were not complete and hence the same has not been incorporated.

APPENDIX II

Abstract of analysis of variance tables for yield per palm for individual years and Anova for pooled analysis.

Source	df	M. S.				
		1972	1973	1974	1975	1976
S	2	1636.7**	2327.1**	1427.8**	2522.9**	1066.1**
M	2	2723.2**	4136.9**	2630.5**	6327.2**	3395.6**
S x M	4	459.9**	504.6*	358.5**	650.9**	384.4**
Error	16	77.1	125.4	57.2	111.1	49.7

Combined analysis

Source	SS	df	MS	F
Year	2048.4	4	512.1	6.09 **
S	17389.5	2	8694.8	103.39 **
M	38151.5	2	19075.8	226.82 **
S x M	8842.1	4	2210.5	26.28 **
T x Y	2457.4	32	76.8	<1.00
Error	6727.0	80	84.1	

* Significant at 0.05 level.
** Significant at 0.01 level.

APPENDIX III

Abstract of analysis of variance tables for yield per hectare for individual years and ANOVA for pooled analysis.

Source	df	M. S.				
		1972	1973	1974	1975	1976
S	2	9147039.4 **	10094457.2 *	8703953.8 **	186427872.1 **	6722920.2 *
M	2	66511848.5 **	110097951.3 **	68909034.5 **	180128248.8 **	115360974.8 **
S x M	4	3424721.9	3459458.4	2232035.1	4075694.9	1757342.7
Error	16	1300444.9	1864592.7	770878.8	1397123.4	1197223.3

Combined analysis

Source	SS	df	MS	F
Year	70401247.9	4	17600312.0	7.68 **
S	88769472.9	2	44384736.5	19.36 **
M	1043563962.7	2	521781981.4	227.56 **
S x M	44788663.8	4	11197166.0	4.88 **
T x Y	73373398.9	32	2292918.7	1.76 *
Error	104484210.1	80	1306052.6	

* Significant at 0.05 level.
** Significant at 0.01 level.

Note: Since F ratio for T x Y inter action is significant, the testing for other effects has been done by using MS for T x Y as the denominator.

APPENDIX IV

Analysis of variance table for mean weight of copra per nut.

Source	SS	df	MS	F	
S	1045.8	2	522.9	8.35	**
M	46.7	1	46.7	<1.00	
S x M	216.4	2	108.2	1.73	
Error	625.6	10	62.6		

** Significant at 0.01 level.

APPENDIX V

Analysis of variance table for percent oil in copra.

Source	SS	df	MS	F	
S	12.317	2	6.158	6.39	*
M	46.240	1	46.240	47.97	**
S x M	15.641	2	7.821	8.11	**
Error	9.639	10	0.964		

* Significant at 0.05 level.

** Significant at 0.01 level.

APPENDIX VI

Analysis of variance table for weight of whole nuts.

Source	SS	df	MS	F
S	73484.8	2	36742.4	4.58 *
M	29040.5	1	29040.5	3.62
S x M	6414.3	2	3207.2	<1.00
Error	80222.6	10	8022.3	

* Significant at 0.05 level.

APPENDIX VII

Analysis of variance table for volume whole nuts

Source	SS	df	MS	F
S	1000147.5	2	500073.8	10.05 **
M	151984.3	1	151984.3	3.05
S x M	66200.7	2	33100.4	<1.00
Error	497715.5	10	49771.6	

** Significant at 0.01 level.

APPENDIX VIII

Abstract of analysis of variance table for weight and volume of husked nuts.

Source	df	Weight	Volume
		MS	MS
S	2	1464.4	6750.1 *
M	1	288.0	2037.6
S x M	2	342.2	533.4
Error	10	1106.5	1592.2

* Significant at 0.05 level.

APPENDIX IX

Analysis of variance table for ratio of weight of husked nuts and whole nuts

Source	SS	df	MS	F
S	0.00436	2	0.00218	6.06 *
M	0.00763	1	0.00763	21.19 **
S x M	0.00036	2	0.00018	<1.00
Error	0.00359	10	0.00036	

* Significant at 0.05 level.

** Significant at 0.01 level.

APPENDIX X

Analysis variance table for ratio of weight of copra and husked nut.

Source	SS	df	MS	F
S	0.00175	2	0.00088	2.15
M	0.00000	1	0.00000	0.00
S x M	0.00055	2	0.00028	<1.00
Error	0.00414	10	0.00041	

APPENDIX XI

Abstract of analysis of variance tables for female flower per palm for individual years and ANOVA for pooled analysis.

Source	df	M.S. 1972	1973	1974	1975	1976
S	2	14223.8 **	19190.4 **	5087.6 **	12567.3 **	4437.4 **
M	2	27341.4**	32557.4 **	12810.7 **	39466.6 **	20930.0 **
S X M	4	3695.3 **	3999.2 *	1212.9 **	2938.9 *	1221.3 **
Error	16	395.0	985.6	220.9	656.6	183.6

Combined analysis

Source	SS	df	MS	F
Year	20227.1	4	5056.8	10.36 **
S	101367.6	2	50683.8	103.80 **
M	255552.5	2	127776.3	261.68 **
S X M	48252.0	4	12063.0	24.70 **
T X Y	24362.6	32	761.3	1.56
Error	39067.4	80	488.3	

** Significant at 0.01 level.

APPENDIX XII

Abstract of analysis of variance tables for female flower set percentage for the years 1972 to 1976 and ANOVA for pooled analysis

Source	df	M.S. 1972	1973	1974	1975	1976
S	2	22.22	14.32	180.75	566.49 **	122.44
M	2	2870.41 **	1485.13 **	4097.06 **	2437.88 **	1037.26 **
S X M	4	65.71 **	137.93	220.86 *	158.48 **	79.74
Error	16	7.79	133.22	62.71	15.20	162.27

Combined analysis

Source	SS	df	MS	F
Year	2400.40	4	600.10	4.65 **
S	1010.81	2	505.41	3.92 *
M	22210.79	2	11105.40	86.13 **
S X M	944.60	4	236.15	1.83
T X Y	4126.01	32	128.94	1.69 *
Error	6099.16	80	76.24	

* Significatn at 0.05 level
** Significant at 0.01 level

Note: Since F ratio for T X Y inter action is significant, the testing for other effects has been done by using MS for T X Y as the denominator.

APPENDIX XIII

Analysis of variance table for per cent of bearing palms at 12th year of planting

Source	SS	df	MS	F
S	591.36	2	295.68	1.75
M	24364.22	2	12182.11	71.99 **
S X M	593.45	4	148.36	<1.00
Error	2707.31	16	169.21	

** Significant at 0.01 level

APPENDIX XIV

Analysis of variance table for mean height of palms

Source	SS	df	MS	F
S	0.220	2	0.110	<1.00
M	110.388	2	55.194	158.60 **
S X M	3.313	4	0.828	2.38
Error	5.569	16	0.348	

** significant at 0.01 level.

APPENDIX XV

Abstract of analysis of variance tables for mean girth of trunk for the years 1972 to 1976 and ANOVA for pooled analysis

Source	df	M.S.				
		1972	1973	1974	1975	1976
S	2	136.7	2.1	11.6	109.3	7.7
M	2	51.2	73.3 *	69.4	159.7 *	597.7 **
S X M	4	103.7	24.0	23.6	96.5	24.4 *
Error	16	52.1	16.4	27.9	43.0	5.8

Combined analysis

Source	SS	df	MS	F
Year	1674.9	4	418.7	5.90 **
S	268.1	2	134.1	1.89
M	742.0	2	371.0	5.23 *
S X M	260.0	4	65.0	<1.00
T X Y	2272.7	32	71.0	2.45 **
Error	2322.5	80	29.0	

* Significant at 0.05 level
** Significant at 0.01 level

Note: Since F ratio for T X Y inter action is significant, the testing for other effects has been done by using MS for T X Y as denominator.

APPENDIX XVI

Abstract of analysis of variance tables for total number of leaves produced per palm since planting for individual years 1972-76 and ANOVA for pooled analysis

Source	df	M.S.				
		1972	1973	1974	1975	1976
S	2	183.01 **	331.69 **	472.17 **	643.95 **	750.56**
M	2	1891.48 **	2749.32 **	3553.44 **	4534.90 **	5000.80**
S X M	4	6.31	8.61	25.05	11.56	16.30
Error	16	19.86	29.29	41.03	50.09	66.66

Combined analysis

Source	SS	df	MS	F
Year	33638.01	4	8409.50	203.23 **
S	4504.73	2	2252.37	54.43 **
M	34303.19	2	17151.60	414.49 **
S X M	167.81	4	41.95	1.01
T X Y	1268.39	32	39.64	<1.00
Error	3310.76	80	41.38	

** Significant at 0.01 level

APPENDIX XVII

Abstract of analysis of variance tables for number of leaves per palm for the years 1972 to 1976 and ANOVA for pooled analysis.

Source	df	M.S.				
		1972	1973	1974	1975	1976
S	2	15.29 **	11.03 *	6.50	15.01 *	31.18 **
M	2	567.61 **	583.84 **	341.69 **	410.35 **	684.84 **
S X M	4	1.68	1.61	4.74	2.66	3.98
Error	16	2.34	2.24	2.79	2.52	2.52

Combined analysis

Source	SS	df	MS	F
Year	221.91	4	55.48	12.75 **
S	143.31	2	71.66	16.47 **
M	5072.49	2	2536.25	583.05 **
S X M	35.90	4	8.98	2.06
T X Y	139.22	32	4.35	1.75 *
Error	198.72	80	2.48	

* Significant at 0.05 level
** Significant at 0.01 level

Note: Since F ratio for T X Y interaction is significant the testing for other effects has been done by using MS for T X Y as the denominator.

APPENDIX XVIII

Abstract of analysis of variance tables for rate of production of leaves per palm for individual years 1972 to 1976 and the ANOVA for pooled analysis

Source	df	M.S.				
		1972	1973	1974	1975	1976
S	2	12.70 **	18.90 **	17.89 **	16.31 **	29.36 **
M	2	83.15 **	85.95 **	52.78 **	54.93 **	36.89 **
S X M	4	0.74	0.14	0.35	1.76	0.51
Error	16	0.04	0.74	1.06	0.63	0.35

Combined analysis

Source	SS	df	MS	F
Year	11.60	4	2.90	3.82 **
S	185.61	2	92.81	122.12 **
M	611.90	2	305.95	402.57 **
S X M	7.76	4	1.94	2.55 *
T X Y	25.56	32	0.83	1.09
Error	60.90	80	0.76	

* Significant at 0.05 level

** Significaht at 0.01 level

APPENDIX XIX

Abstract of analysis of variance tables for mean length of leaves for individual years 1972 to 1976 and the ANOVA for pooled analysis

Source	df	M.S.				
		1972	1973	1974	1975	1976
S	2	119.9	14115.2 *	1299.2	3866.2 *	4069.6
M	2	67479.7 **	68639.2 **	49129.6 **	108393.4 **	68464.7 **
S X M	4	1471.3	8498.4 *	954.2	1357.2	985.2
Error	16	1284.4	2293.3	1333.6	703.2	1218.2

Combined analysis

Source	SS	df	MS	F
Year	89931.3	4	90212.6	28.15 **
S	627.2	2	313.6	<1.00
M	702551.0	2	351275.5	109.63 **
S X M	18522.2	4	4630.6	1.45
T X Y	102533.3	32	3204.2	2.57 **
Error	99578.0	80	1244.7	

* Significant at 0.05 level
** Significant at 0.01 level.

Note: Since F ratio for T X Y interaction is significant, the testing for other effects has been done by using MS for T X Y as the denominator.

APPENDIX XX

Analysis of variance table for mean length of petiole

Source	SS	df	MS	F
S	401.9	2	200.9	7.12 **
M	4438.7	2	2219.4	78.70 **
S X M	765.3	4	191.3	6.78 **
Error	451.0	16	28.2	

** Significant at 0.01 level

APPENDIX XXI

Analysis of variance table for mean length of leaf blade

Source	SS	df	MS	F
S	1580.7	2	790.3	<1.00
M	79936.2	2	39968.1	26.91 **
S X M	5783.8	4	1446.0	<1.00
Error	23765.8	16	1485.4	

** Significant at 0.01 level.

APPENDIX XXII

Analysis of variance table for breadth of leaves

Source	SS	df	MS	F
S	648.6	2	324.3	2.34
M	14185.4	2	7092.7	51.14 **
S X M	1449.8	4	362.5	2.61
Error	2219.5	16	138.7	

** Significant at 0.01 level

APPENDIX XXIII

Abstract of analysis of variance tables for number of leaflets for individual years and ANOVA for pooled analysis

Source	df	M.S.				
		1972	1973	1974	1975	1976
S	2	80.4	33.5	38.3	112.6	30.0
M	2	2546.3 **	1750.6 **	383.9 **	1636.9 **	971.2 **
S X M	4	51.8	7.7	4.2	26.9	12.3
Error	16	215.5	13.4	61.1	38.9	14.2

Combined analysis

Source	SS	df	MS	F
Year	2638.8	4	659.7	9.62 **
S	206.4	2	103.2	1.50
M	13323.3	2	6661.7	97.11 **
S X M	182.7	4	45.7	<1.00
T X Y	1865.9	32	58.3	<1.00
Error	5489.5	80	68.6	

** Significant at 0.01 level

APPENDIX XXIV

Analysis of variance table for length of leaf let

Source	SS	df	MS	F
S	254.1	2	127.1	<1.00
M	6544.7	2	3272.3	22.26 **
S X M	75.9	4	19.0	<1.00
Error	2352.2	16	147.0	

** Significant at 0.01 level

APPENDIX XXV

Analysis of variance table for breadth of leaf let

Source	SS	df	MS	F
S	2.15	2	1.08	9.82 **
M	16.32	2	8.16	74.18 **
S X M	0.68	4	0.17	1.55
Error	1.81	16	0.11	

** Significant at 0.01 level.

APPENDIX XXVI

Analysis of variance table for leaf Area Index

Source	SS	df	MS	F
S	81.35	2	40.68	406.80 **
M	47.32	2	23.66	236.60 **
S X M	17.23	4	4.31	43.10 **
Errors	1.66	16	0.10	

** Significant at 0.01 level

APPENDIX XXVII

Abstract of analysis of variance tables for nutrients in leaf

Source	df	M.S.					
		N	P	K	Ca	Mg	Na
S	2	0.0234	0.0025 **	0.6082**	0.0033	0.0206	0.0313 *
M	2	0.5786 **	0.0009 *	1.8586**	0.0310	0.0917 **	0.0950 **
S X M	4	0.0116	0.0001	0.1391 *	0.0035	0.0086	0.0038
Error	16	0.0461	0.0001	0.0371	0.0123	0.0064	0.0055

Source	df	Cl	S
S	2	0.0185	0.0003
M	2	0.0677	0.0005
S X M	4	0.0522	0.0007
Error	16	0.0508	0.0008

* Significant at 0.05 level
** Significant at 0.01 level

APPENDIX XXVIII

Abstract of analysis of variance tables for organic carbon content in soil at different depths of sampling

Source	df	M.S.			
		Depth			
		0-25 cm	25-50 cm	50-75 cm	75-100 cm
S	2	0.0052	0.0042	0.0291 **	0.0069
M	2	0.0087	0.0094	0.0029	0.0079
S X M	4	0.0298	0.0006	0.0028	0.0030
Error	16	0.0269	0.0035	0.0018	0.0082

** Significant at 0.01 level

APPENDIX XXIX

Abstract of analysis of variance tables for nitrogen content in soils at different depths of sampling

Source	Df	M.S.			
		depth			
		0-25 cm	25-50 cm	50-75 cm	75-100 cm
S	2	0.000051	0.000131 *	0.000006	0.000027
M	2	0.000053	0.000169**	0.000021	0.000018
S X M	4	0.000021	0.000027	0.000007	0.000006
Error	16	0.000031	0.000026	0.000025	0.000030

* Significat at 0.05 level
** Significant at 0.01 level

APPENDIX XXX

Abstract of analysis of variance tables for phosphorus content in soil at different depths of sampling

Source	df	M.S. Depth 0-25 cm	25-50 cm	50-75 cm	75-100 cm
S	2	2493.121	56.391	0.081	0.180
M	2	55070.868**	110.668	0.221	0.117
S X M	4	2575.715	55.492	0.116	0.096
Error	16	3343.113	33.991	0.107	0.090

** Significatn at 0.01 level

APPENDIX XXXI

Abstract of analysis of variance tables for potassium content in soil at different depths of sampling

Source	df	M.S. Depth 0-25 cm	25-50 cm	50-75 cm	75-100 cm
S	2	400.0	5619.6	7387.4	3290.8
M	2	10570.8 **	7781.8 *	25240.7 **	36887.8 **
S X M	4	619.6	1492.8	4206.4	1755.1
Error	16	1633.5	2119.1	3039.1	2890.4

** Significant at 0.01 level

APPENDIX XXXII

Abstract of analysis of variance tables for calcium content in soil at different depths of sampling

Source	df	M.S.			
		Depth			
		0-25 cm	25-50 cm	50-75 cm	75-100cm
S	2	0.330	0.599 **	1.532	0.269
M	2	3.100 *	4.434 **	4.295 **	4.582 **
S X M	4	3.134 *	0.367	0.906	0.445
Error	16	0.594	0.083	0.487	0.170

* Significant at 0.05 level
** Significant at 0.01 level

APPENDIX XXXIII

Abstract of analysis of variance tables for magnesium content in soil at different depths of sampling

Source	df	M.S.			
		Depths			
		0-25 cm	25-50 cm	50-75 cm	75-100cm
S	2	0.030	0.189 *	0.097	0.013
M	2	9.536 **	20.342 **	26.201 **	22.203 **
S X M	4	0.279	0.219 *	0.076	0.236
Error	16	0.574	0.047	0.366	0.249

* Significant at 0.05 level
** Significant at 0.01 level

EFFECT OF PALM DENSITY AND LEVELS OF NPK FERTILIZERS ON YIELD AND QUALITY OF COCONUT

BY

K. J. ABRAHAM

ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILMENT OF
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A B S T R A C T

A spacing cum manurial experiment on West Coast Tall coconut palms initiated in 1964 at the Coconut Research Sub Station, Balaramapuram of Kerala Agricultural University was utilised in this investigation with the objective of (1) determining optimum level of NPK fertilisers and density of planting to obtain maximum yield; (2) to study the quality of nuts in terms of copra and oil out turn and (3) to study the correlations, if any, of vegetative growth characters and soil and leaf nutrient status with yield. Three levels of NPK fertilizers (Control - no fertilizer, 340 : 225 : 450 g and 680 : 450 : 900 g NPK per palm per year) and three spacings (5.0 m x 5.0 m, 7.5 m x 7.5 m and 10.0 m x 10.0 m) were included in the experiment.

When palms were not fertilized the yields, which were practically none, did not vary due to spacing. Maximum yield of 61 nuts per palm was obtained at a palm density of 100 per hectare (10 m x 10 m) with the highest dose of fertilizers. Yields per unit area was maximum (8255 per hectare) at a density of 178 and a NPK level of 680 + 450 + 900 g.

Copra per nut was maximum (168 g) at lower densities where yields were also higher. Oil percent was negatively

correlated with yield. Fertilization had a depressive effect on oil out turn.

Wider spacings coupled with fertilization at medium level produced heavier nuts. The volume and weight of whole nuts as well as that of husked nuts were positively correlated.

Higher level of manuring produced 46% more female flowers than medium level and production at zero level was practically none. Yield of nuts and female flowers were positively correlated.

Flower setting was enhanced by manuring (21% to 42%), but not due to the effect of spacing.

Fertilization reduced the pre bearing age of palms.

The height of palms, girth of trunk, number of leaves, length and breadth of leaves, number of leaflets and their length and breadth were all increased by fertilization. Effect of wider spacing was seen in enhancing number of leaves and breadth of leaflets. The height of palms, girth of trunk and number of leaves were found to be positively correlated with yield of nuts.

LAI was found to increase with increases in palm density. Similarly fertilization had also increased the LAI.

At a given palm density, yield of nuts and LAI were found to be positively correlated. Infilteration of light through the canopy was negatively correlated with LAI.

The foliar level of N, P and K increased significantly due to fertilization (1.06% N, 0.13% P and 0.31% K in unfertilized plots as compared to 1.54%, 0.14%, and 1.17% respectively in plots receiving double dose of fertilisers). Yield of nuts was positively correlated with foliar levels of N as well as P. Yield was also correlated with N/K ratio. Nutrient levels of N and K were correlated. The yield was high when N/K ratio was in the range of 1.6 to 1.9%. | Leaf Mg levels were higher in unfertilized plots where K levels were lower. There was a negative correlation between K and Mg levels. Na content in leaves was less in fertilized plots. Fertilisation increased K/Ca ratio as well as the sum of K, Ca and Mg.

The pH of the solid decreased with application of fertilizers. There was little difference in N content of soil due to fertilisation. There was a heavy build up to P in the top layer of soil (Four ppm in zero level plots and 158 ppm with an application of 450 g P_2O_5 per year). There was build up of K in 0 - 100 cm depth in fertilised plots and it was maximum at the lower depth of 75 - 100 cm, CaO content was highest

(3.77 me/100 g soil) in the top layer of plots with highest fertilizer level. The soil Mg content was lower in fertilised plots.

The study on leaf and soil nutrient status suggests the necessity for increasing N and K fertilisation from the present dose of 680 g N, and 900 g K. The satisfactory level of P in leaf and heavy build up in soil suggest that the lower dose of 225 g may suffice. Ca application may be necessary to maintain the pH. Mg application may prove beneficial. In view of the fact that anionic nutrition has given encouraging results abroad, further studies are required to assess the importance of Cl and S in the nutrition of coconut in India.