NUTRITIONAL STATUS OF SOILS IN RELATION TO FOLIAR NUTRIENT LEVELS IN OIL PALM

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Nutritional status of soils in relation to foliar nutrient levels in oil palm" is a bonafide record of research work done by me during the course of research and that the thesis has not been previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellayani,
10 June, 1988.

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CERTIFICATE

Certified that this thesis entitled "Nutritional status of soils in relation to foliar nutrient levels in oil palm" is a record of research work done independently by Sri.Solomon Chacko 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

Vegetable oils, both edible and non-edible play a vital role in the Indian economy. Apart from their use as a cooking medium, vegetable oils are extensively used in the manufacture of vanaspati, margarine, soaps, cosmetics, lubricants, glycerine etc. In India vegetable oils are extracted from oil seeds like groundnut, cottonseed, mustard, sunflower, soyabean and castor, out of which the greatest contribution in oil production comes from groundnut (52%) followed by cotton-seed (19%) and mustard (15%). The remaining part of the annual vegetable oil production significantly comes from other crops like coconut and oil palm.

In India the annual demand for vegetable oil far exceeds its production. The annual deficit between the demand and production of vegetable oil in India is placed around 1.8 million/tonnes. This deficit is expected to increase even upto 7 million tonnes by 2000 A.D. This deficit cannot be made good from the various oil seed crops currently grown.

In Kerala coconut is the major oil producing crop. Unfortunately due to the root (wilt) and other diseases the nut production has come down considerably. All attempts to check the diseases have not borne fruit so far. Eventhough the State of Tamil Nadu, Karnataka and Andhra Pradesh have taken up coconut cultivation, overall picture of oil production in India is not bright.

To compensate the shortfall, restricted quantities of palm oil and coconut oil are being imported into India, every year. Even with these imports the demand of vegetable oil is so high that the prices have gone up considerably. Coconut oil is imported mainly from Sri Lanka and palm oil from Malaysia.

Of the known oil yielders, oil palm (Elaeis guineesis) tops the list with a production potential of six to eight tonnes of oil per hectare per year and hence it is a potential alternative to other oil seed crops. Under Indian conditions also, the oil palm ranks first in oil production (3000-5000 kg of oil per hectare per year) followed by coconut (1100 to 1600 kg), ground nut (600-1000 kg) and soyabean (400-600 kg). Therefore, oil palm is considered to be capable of reducing the deficit in edible oil in the country. The imported palm oil was well accepted by the consumers and this has prompted the Government to try large scale cultivation of oil palm.

In the Quilon district of Kerala, oil palm is grown in about 4000 hectares, in the plantations of Oil Palm India Limited, located at Yeroor, Chithara and Kulathupuzha. The Forest Development Corporation has brought 1300 hectares under oil palm in Andaman and Nicobar islands. Twenty five hectares each have been planted with oil palm, at the CPCRI Research Centre at Palode and the farm of the State Agricultural Department at Thodupuzha. The performance of the oil palm in all these areas has proved promising. Some oil palm plantations at Yeroor are 15 years old and are producing about 3000 to 5000 kg of oil per hectare per year. With the recent introduction of a pollinating agent Elaeidobius kamerunicus, the yield is fast increasing and is expected to go even upto 5 to 6 tonnes or above of oil per hectare per year. A good management of the plantations will also add much towards increased production.

At present only very little information is available on the nutritional status of the oil palm growing soils and also the nutrient content of the palm leaf tissue.

The present investigation was taken up in the oil palm plantation of oil palm India LTD at Yeroor, Quilon district and also in plantations of the CPCRI Research Station at Palode, Trivandrum district with a view to studying the various aspects of oil palm nutrition and oil palm growing soils. The present investigation was aimed at establishing correlation between:-

1. Age of palms and nutrient concentration in leaves.
2. Age of fronds and nutrient concentration in leaves.
3. Nutrient content of soil and leaf concentration.
4. Soil nutrient content and nutrient concentration in different fronds.
5. Yield and leaf nutrient concentration.

Review of Literature

REVIEW OF LITERATURE

Like any other crop, oil palm requires rational manuring for obtaining higher and stabilised yield. For a proper appraisal of plant nutrition in oil palm, leaf analysis has been accepted as a valuable guide. Several workers have carried out research in oil palm nutrition and its fertilizer requirements in relation to soil and climatic conditions obtaining in the major oil palm growing countries. (May, 1956; Broeshart, 1957; Rosenquist, 1962; Hew and Ng, 1968; Ollagnier et al. 1970; Hew et al., 1973; Tan, 1973; Warrier and Piggot, 1973; Turner and Gillbanks, 1974; Foster and Chang, 1976 and Hartley, 1977).

Investigations have revealed that leaf nutrient levels are influenced by many factors, such as soils (Coulter, 1958; Hartley, 1977, Ng, 1972), fertiliser application (Warrier and Piggot, 1973), age of palms (Ochs and Olivèn, 1976; Forster and Chang, 1977a), vegetative growth (Lo, Chan, Goh and Garden, 1973) and climatic factors, including rainfall (Smilde and Chapas, 1963; Smilde and Leyritz, 1965; Ng and Thamboo, 1966; Martineau, Knecht and Ramachandran, 1969; Hartley, 1977; Ochs and Olivin, 1976; Forster and Chang, 1977a, 1977b).

2.1 Nutrient removal by oil palm

Several researchers like Ferweda (1955), Tinker and Smilde (1963), Ng Siew Kee (1968) and Ollagnier et al. (1970) have estimated the nutrient requirement of oil palm.

The nutrient removal, according to Tinker and Smilde (1963) was 0.63, 0.10, 0.38 and 0.28 kg of N, P, K and Mg per palm respectively whereas in Malaysia the nutrient removal was found to be 0.53, 0.07, 0.69 and 0.19 kg of N, P, K and Mg per palm from a hectare per year respectively Ng (1970). The nutrient removal of oil palm has been assessed and found to be 30.0, 7.0, 18.0, 13.0 and 10.0 kg of N, P, K, Ca and Mg respectively (Ollagnier et al., 1970).

Tinker and Smilde (1963) have worked out the N, P, K and Mg requirements of oil palm plantations in Nigeria yielding 9.6 tonnes of fresh fruit bunches/ha/year. They found the same to be 0.20, 0.04, 0.23 and 0.03 kg/palm/year respectively. Under Malaysian conditions the same was found to be 0.49, 0.08, 0.63 and 0.14 kg/palm/year (Ng and Thamboo, 1966) for a plantation yielding 24 t/ha.

2.2 Effect of age of palms on concentration of nutrients in leaf

For diagnostic purposes, leaf analysis can be successfully applied in perennial crops where response to fertilizers will be slower (Hartley, 1977). Leaf analysis in oil palm has been accepted as a reliable guide for maintainance of adequate plant nutrition. The available literature on the effect of age of palms on nutrient concentration of leaf has been reviewed.

2.2.1 Nitrogen

Nitrogen plays no small role in controlling the growth and fruiting of oil palm. Nitrogen is commonly required for rapid growth of oil palm (Hartley, 1977).

Rosenquist (1962) reported a higher rate of leaf production and an increase in the number of leaves per palm as a result of increased nitrogen application. Several authors like Sly (1963), Vander Vossen (1970), Green (1972) and Tan (1976) have also got positive responses to nitrogen application in the yield of oil palm.

Prevot and Ollagnier (1959) have found an increase in leaf nitrogen content by nitrogen fertilization. Ollagnier et al., 1970 have reported that leaf nitrogen increases from 2.30 to 2.70 per cent by nitrogen application. Warrier and Piggot (1973) claim to have found a high concentration of tissue nitrogen in fertilized plots. According to Hartley (1977) nitrogen application increases leaf nitrogen.

Prevot and Ollagnier (1959) have found that when leaf level of nitrogen has been raised to 2.70 per cent there exists a positive correlation between potassium levels and yield. Bull (1964) observed an increase in yield when the leaf nitrogen content was raised to 2.7 per cent. Forde et al. (1965) obtained responses to yield at a leaf nitrogen level of 2.4 per cent. Ollagnier et al. (1970) have found an yield increase of over 50 per cent when the leaf nitrogen concentration was raised from 2.3 to 2.7 per cent. Responses to nitrogen were also obtained in palms where the leaf nitrogen contents were about 2.6 per cent (Umar Akbar et al., 1976).

In West Africa Bachy (1964) has found a fall in leaf nitrogen content with the age of palms. Bachy (1965) also observed that leaf nitrogen diminished in a linear way decreasing by about 0.021 per cent for every unit increase in the age of palms.

Ng Siew Kee (1968) has come to the conclusion that leaf nitrogen generally diminishes with advancing age. According to Tan (1973) leaf nitrogen level tends to decline with increasing age of the palm. A decline in the leaf nitrogen level with advance in age was observed also by Foster and Chang (1976).

Knecht et al. (1977) have observed that leaf nitrogen decreases in a linear way with advance in age of palms. Leaf nitrogen goes down by about 0.015 per cent for every unit increase in the age of the palms.

2.2.2 Phosphorus

Comhaire (1968) regards phosphorus manuring as the pivot of oil palm cultivation. According to Ollagnier et al. (1970) phosphorus is essential for full expression of qualitative characters in oil palm.

Forde et al. (1965) have found that phosphorus application helps to increase phosphorus content of tissues. Warrier and Piggot (1973) have observed low tissue phosphorus content when phosphorus fertilizers were not applied.

Bull (1964) has observed an increase in yield when there was higher content of leaf phosphorus in the range of 0.16 to 0.17 per cent. Forde et al. (1965) have found yield increase due to leaf phosphorus around a concentration of 0.147 per cent. Ollagnier et al. (1970) have seen response to phosphorus only when tissue phosphorus concentration is raised to a level higher than 0.15 per cent. Reports of yield increase of about 32 per cent by an increase in leaf phosphorus is reported by Green (1972). Foster and

Chang (1976) in Malaysia, have claimed yield increase of one tonne/ha by an increase in phosphorus level by 0.003 to 0.005 per cent. As against these findings Bachy (1969) could not get any increase in yield with an increase in the phosphorus content of leaves.

Bachy (1965) has found that the leaf phosphorus content decreases with an increase in the age of the palms at certain places whereas the opposite trend was noticed at some other places. At Cameroon, leaf phosphorus increased by about 0.001 per cent for every unit increase in the age of palms, while at Pobe, phosphorus content decreased with age of palms.

A decrease in leaf phosphorus content with increase in age of palms has been observed by Ng Siew Kee (1968). A similar tendency has been noticed by Ng and Chaah (1969), also. Tan (1973) is of the view that no consistent pattern is evident between leaf phosphorus content and age of palms.

In twenty trials conducted by Foster and Chang (1976), a decline of leaf phosphorus with age has been found on the coastal soils of West Malaysia. According to Knecht and Ramachandran (1977) leaf phosphorus is low and erratic in young palms of 3 to 4 years. In Estate I, there was a tendency for leaf P to decrease with age of palms upto about 16 years and then to increase. However, in Estates II and III, no consistent pattern has emerged between leaf phosphorus status and age of palms.

2.2.3 Potassium

Ollagnier et al. (1970) are of opinion that potassium is the critical element in the manuring of oil palms and have ascertained its requirement and its sensitivity under varying situations. Hartley (1977) considers potassium as the most commonly required element in oil palm.

Warrier and Piggot (1973) have found very low levels of leaf potassium in the absence of potassium fertilizers. He has noted an increase in tissue concentration of potassium only when KCl was applied.

Prevot and Ollagnier (1959) are of the opinion that when leaf potassium level is more than 1 per cent, there is significant and positive correlation between nitrogen and yield. Ochs (1965) has found that yield increases by 4 to 12 per cent for every gain of 0.1 per cent of potassium level in the leaf. He has shown that yield decreases linearly as the leaf level of potassium goes below its optimum concentration. Forde et al. (1965) have reported yield improvement of individual palms with a leaf potassium content by 1.20 per cent.

Bachy (1969) and Warrier and Piggot (1973) have also obtained increased yield, when leaf potassium was increased.

Ollagnier et al. (1970) have shown that the response of potassium is very closely linked with potassium concentration in the leaf, particularly when this level is below critical level. Foster and Chang (1976) in Malaysia have got an yield increase of one tonne Fresh Fruit Bunch/ha by an increase in tissue level of potassium by 0.05 to 0.08 per cent.

In West Africa, Bachy (1964) has found a decline in potassium content with age in all three localities he has investigated. Another study made by Bachy (1965) revealed that leaf potassium decreased in a linear way with increase in age of palm. Leaf potassium decreased at the rate of 0.02 per cent per unit increase in the age of palm.

Ng Siew Kee (1968) observed that leaf potassium concentration generally declined with advancing age. Tan (1973) also has observed a decrease in tissue potassium concentration with increase in age. In twenty trials undertaken by Foster and Chang (1976) there was no decline in potassium levels with increasing age. Knecht and Ramachandran (1977) have found that leaf potassium decreases in a linear way with increase in age of palms. Leaf potassium is generally high in young palms of 3 to 4 years. Leaf potassium is lower for palms above 30 years. According to them leaf potassium decreases at the rate of 0.019 per cent for every unit increase in the age of palms.

2.2.4 Calcium

Literature available on calcium nutrition of oil palm is very few. However, one recent experiment conducted at the United Plantations in Malaysia shows that there is an increase in yield to the extent of 10 per cent as a result of application of calcium (Hartley, 1977). But calcium fertilization has not shown any effect on nitrogen, phosphorus and magnesium concentration in the leaf. However, a decrease in leaf potassium and an increase in leaf calcium has been noticed.

Bachy (1965) has reported that leaf calcium decreases in a linear manner with the increase in age of palm. Leaf calcium shows a decrease of 0.005 per cent for every unit increase in age of palms. Ng Siew Kee (1968) has observed a general decline in calcium concentration of tissues with increasing age. In twenty trials conducted by Foster and Chang (1976) a decline in leaf calcium with age have been observed on the coastal soils in West Malaysia.

On the contrary, Knecht and Ramachandran (1977) have found that unlike leaf nitrogen and potassium, leaf calcium increases in a linear way with the age of palms. The leaf calcium showed an increase of about 0.010 to 0.012 per cent for every unit increase in the age of palms.

2.2.5 Magnesium

Magnesium as a constituent of chlorophyll has a very important and significant role to play in the physiology and yield of oil palm.

Breure and Rosenquist (1976) have reported that frond production in oil palm has increased by Magnesium chloride application. Tan (1976) has observed a greater number of aborted bunches at high levels of magnesium.

Yield improvement resulting from application of magnesium to deficient palms has been observed by Ferwerda (1955) in Ivory Coast. Gunn (1962) has found responses for 3.41 kg Mg SO_4 per palm. Experiments on young palms in Peru have revealed that magnesium chloride application increases the yield significantly Daniel and Ochs (1975).

Chan and Rajaratanam (1976) have reported that Mg tends to increase leaf N. Similarly, application of Mg gives only minimal decrease in leaf K. There is no increase in the Fresh Fruit Bunch per palm when there is an increase in the leaf Mg content. They have further noted that there is no response to magnesium if the leaf levels are in excess of 0.20 to 0.22 per cent.

In West Africa, Bachy (1964) has found a decline in magnesium content of palm with advance in age. According to Bachy (1965) leaf magnesium decreases in a linear way with increase in the age of palms. The leaf Mg shows a decrease of about 0.014 per cent for every unit increase of the age of palms. Ng Siew Kee (1968) has also observed a general decline in leaf magnesium concentration with increase in the age of palms. Tan (1973) also observed a similar tendency.

In twenty trials carried out by Foster and Cheng (1976) a decline with age has been noticed for leaf magnesium on the coastal soils of West Malaysia. Knecht and Ramachandran (1977) have reported that leaf magnesium decreases in a linear way upto 16 years of age.

2.3 Effect of frond age on tissue concentration

The variations in the nutrient content of the frond, according to its rank are reviewed here.

Investigations by Scheidecker and Prevot (1954) on the variations in nitrogen, phosphorus, potassium, calcium and magnesium contents with the aging of the leaf have revealed that ageing of the leaf results in the impoverishment in N, P and K and an enrichment in calcium. WAIFOR fourth annual report (1956) gives the results of a study conducted on nutrient variation in leaf numbers 1, 9, 17, 25 and 33. The report reveals that the leaf N, P, K and Mg decreases with frond age while Ca increases.

Broeshart (1955) has reported a decrease in K content in leaves with the increase in the age of the leaf. In respect of leaf magnesium, the result is rather inconsistent. The result obtained by him shows that the ratio between K and Mg narrows with the increase in the age of the leaf. Prevot and Monbreton (1958) observe that mineral element levels vary with the rank of the leaf; the N content increases from 1st to 9th leaf and thereafter diminishes, and that of P and K levels decrease whilst the Ca and Mg contents increase. On the other hand sulphur and chlorine are practically independent of the rank of the leaf.

Coutler (1958) observed a decrease in K content with the increase in age of the leaf. He also observed that ratio between K and Mg decreased with the increase in the age of the leaf. But in respect of leaf Mg the results are less consistent. Experiment conducted by Prevot and Bachy (1962) on coconut about the nutrient variation in leaf numbers 1, 6, 11, 16, 21 and 26 of palms of same age indicates that leaf No.6 invariably contains the highest N content. P and K decrease from leaf No.1 to 26, whereas Ca and Mg increase.

A study of the leaf mineral composition by Smilde and Chapas (1963) on leaf numbers 1, 17 and 25 reveals that the N, P, K, Ca and Mg contents are significantly influenced by age.

Bachy (1964) has observed a general decline in K content and increase in Ca content with the increase in the age of the leaf in Columbia and Ivory Coast. Studies conducted by Ng et al. (1969) on the content of B, Mn, Cu, Zn and Fe in leaflets of mature Dura oil palms in Malaya show that concentration gradients for Cu and Zn decline with frond age, whereas there is an increase in Mn and Fe content.

Rajaratnam (1973) has observed that leaf Mg content declines with the age of the leaf. An investigation during the period 1959/60 by Bull (1960) shows a general decline of P, K and Mg concentration with the ageing of the leaf.

Studies conducted by Ng and Tan (1974) on the variation in nutrient concentration of leaf numbers 1, 9, 17, 25 showed a general decline in N, P, K, Mg, Cu and Zn content and an increase in calcium concentration with increase in frond age.

2.4 Soil nutrient analysis and palm nutrition

Indications of the tremendous variation in the availability of soil nutrients are evident from the different responses reported on the application of major nutrient fertilizers. Since significant responses to fertilizer addition have been recorded so frequently, it may be expected that strong correlations exist between soil nutrient content and the contents of these elements in the palm and its yield.

Fremond and Orgias (1952) have observed that a response to potassium fertilizer can be expected when soil available potassium level is below 0.1 me. Prevot and Ollier (1958) and Tinker and Ziboh (1959) have noticed a relationship between Magnesium deficiency symptoms and the water soluble soil content of this element in Africa. Tinker and Ziboh (1959) have found a significant relationship between potassium mole fraction (Exch.K) and yield.

In Dahomey, Ochs (1965) also has found a similar relationship between exchangeable potassium in the top 20 cm of soil and leaf potassium. When potassium in leaf number 17 was 0.9 per cent, soil potassium level was about 0.2 me. Whereas the leaf potassium was as low as 0.3 to 0.5 per cent when the soil potassium was around 0.1 me.

Ochs (1965) and Forde et al. (1965) have reported that yield is more closely related to soil potassium levels than those within the foliage when other nutrients are in good supply. Some correlation has been found by Mollegaard (1971) between soil phosphorus content and both yield and levels of this element in leaf tissues. The position of potassium is less clear because of the contradictory results obtained, whilst in Malaysia significant correlation is found between soil potassium and its levels in leaves but not with yield. Walker and Melsted (1971) have observed correlation between available soil phosphorus and the quantity applied through fertilizers.

Nair, A.M. (1981) has observed that leaf N is correlated with soil nitrogen, soil phosphorus and soil potassium contents. He has also observed that the soil nitrogen, phosphorus and potassium contents are positively correlated with leaf phosphorus content. Next to soil phosphorus content, the leaf potassium content is more correlated with other factors such as soil nitrogen, phosphorus and potassium. Calcium content of the leaf is seen correlated only with soil contents of nitrogen and potassium whereas Ca content of soil does not show any relationship with leaf calcium.

Therefore, in general, it would appear that soil analysis is a less suitable method for the detection of nutrient deficiencies than the technique of leaf analysis Ruer,(1966). However, with improved techniques and greater understanding of the interrelationship between soil nutrient status (especially of virgin soils) and that of the palm, it might well prove possible in future to use a combination of soil and leaf analysis in formulating fertiliser programmes according to Ng and Thamboo (1966).

2.5 Optimum nutrient levels

Because of interaction between one nutrient and another and that between nutrients and the environment, the precise determination of the optimal level for each nutrient element under a wide range of conditions is rendered a very formidible task. Some of the suggested critical levels for mature palms, expressed as percentage on dry matter basis in frond 17 are as follows.

1. Nitrogen -	Africa -	2.50	(Prevot and Ollagnier, 1956 Ollagnier et al. (1970)
	- Malaysia -	2.80	Jacob and Uex Kull (1963)
2. Phosphorus -	Africa -	0.15	Prevot and Ollagnier (1956) Ollagnier (1959)
	Malaysia -	0.15	Jacob and Uex Kull (1963)
3. Potassium -	Africa -	1.0	Forde et al. (1965) Ollagnier et al. (1970)
	- Malaysia -	1.0	Jacob and Uex Kull (1963)
4. Magnesium -	Africa -	0.24	Ollagnier et al. (1970)
	- Malaysia -	0.24	Jacob and Uex Kull (1963)
5. Calcium -	Africa -	0.60	Prevot and Ollagnier (1956) Ollagnier et al. (1970)
	- Malaysia -	0.70	Jacob and Uex Kull (1963)

Optima for micronutrient elements are very imperfectly known. The following published figures would appear to be those most commonly found in frond 17 in ppm but they do not necessarily indicate either optimal levels or the figures indicating deficiency.

1. Zinc - 15 ppm Jacob and Uex Kull (1963)
   15 - 20 ppm Rosinquist (1966)
2. Copper - 5 ppm Jacob and Uex Kull (1963)
   15 - 20 ppm Rosinquist (1966).

Critical levels for nitrogen, potassium and calcium corresponding to different ages have been suggested by Knecht and Ramachandran (1977).

Age in year	5	10	15	20	25	30
% N	2.78	2.68	2.59	2.49	2.40	2.30
% K	1.32	1.22	1.13	1.03	0.94	0.84
% Ca	0.52	0.57	0.63	0.68	0.74	0.79

Materials and Methods

MATERIALS AND METHODS

3.1 Location

The oil palm plantations of the Oil Palm India LTD, a joint venture of the Government of India and Government of Kerala were utilised for the investigations. The oil palm plantation at Bharatipuram, Anchal in Quilon district and the plantation at CPCRI Research Station at Palode in Trivendrum district were chosen. The estate lies at 9° North latitude and 76° East longitude. The areas receive an annual rainfall of 1570 to 3300 mm. The rainfall is fairly distributed throughout a period stretching from mid April to November. The temperature normally varies from 19°C to 38°C.

3.2 Cropping history

The area was under reserve forest prior to conversion into oil palm plantation. The area was planted during the years 1971, 1973, 1975, 1977, 1979 and 1983 as a phased programme and therefore trees of various age groups were available for investigations. The palms are planted along the contour at a distance of 9 m with a stand of 130 to 135 palms per hectare. When the investigations were started in 1986 the oldest plantation was 15 years.

3.3 Topography and soil

Most of the area is of undulating nature comprising slightly to moderately sloping terrain with somewhat level valleys in between. The palm growth is very healthy and luxurient in the valleys. The surface of the soil is gravelly with rock outcrops scattered profusely. The colour of the surface soil is very dark.

3.4.1 The oil palm

The oil palm (Elaeis guineensis Jacq.) commercially grown in Africa, Equatorial America, and South East Asia belongs to the sub family Cocoideae (Corley, 1976). The oil palm is unbranched and monoecious, grows to a height of 20 to 30 metres and lives upto 200 years. The root system consists of primaries and secondaries. The majority of roots is found in the top 15 cm of the soil with the main concentration near the trunk and the secondary concentration 1.5 to 2.0 metres from the base. Leaves are produced in spiral succession from the meristem. Crown consists of 40 to 45 open leaves at a time. Fifteen to twenty five leaves are produced annually. The leaves unfurl at the rate of about two per month and the life of a mature leaf after unfurling is about 2 years. Inflorescence reaches the central spear stage in two years and a further 9 to 10

months are required for flowering and anthesis. Each flower primordium is a potential producer of male and female organs, but one remains rudimentary and the other develops into a male or female inflorescence. The number of bunches per palm is dependent upon the number of leaves and also on the number of inflorescence reaching maturity without abortion. The period from sex differentiation to anthesis is about two years. The sex ratio is partly determined by genetic factors and partly by climatic and other environmental conditions at the time of sex differentiation. The oil palm is cross-pollinated. Male flowers begin to open from the base of the spikelet and all the flowers in an inflorescence usually open within two days. Flowering begins at the base of the female inflorescence and all the flowers open within 24 hours. The time taken from flowering to harvesting is 5 to 6 months. Bunch failure is usually higher when there is a high sex ratio and when a large number of inflorescence has set fruits.

3.4.2 Variety

There are two varieties of oil palm5viz. Dura and Pisifera. A hybrid named Tenera is cultivated in the estate and the studies were made on this hybrid crop.

The seed material was imported from Malaysia. The Tenera has a mesocarp content of 65 to 95 per cent of fibre and is dark in colour. It has higher sex ratio and produces larger bunches than Dura.

3.5 Age groups of palms investigated

The studies were made in the plantation at Bharatipuram on the oil palms planted during the following years.

1. Group I - 1971 planting
2. Group II - 1973 planting
3. Group III - 1975 planting
4. Group IV - 1977 planting
5. Group V - 1979 planting
6. Group VI - 1985 planting

The samples from the bearing palms and non-bearing palms were collected during 1986.

3.6 Collection of leaf samples

For collection of leaf samples the standard leaf sampling procedure as described by Chapman and Gray (1949) was followed. The leaf samples from the 17th frond were collected to assess the nutrient variation with respect to different age groups. Leaf samples from the 1st, 9th, 17th, 25th and 33rd were also collected from Seven year old plantations from the same location to assess the variation in nutrient status with respect to maturity of leaves in different rank of fronds.

3.6.1 Identification of fronds

Fronds in the oil palm grow in a spiral formation. They are arranged either in a 'left handed spiral' or in a 'right handed spiral'. In the case of a 'left handed spiral' the course of spiral will run from high left to low right and in a 'right handed spiral' the spiral will trace a course from high right to low left. The first frond will be at the apex of one of the steep spiral paths and is classified as frond 1. It may be noted that as one approaches the centre of the crown, the path of the spiral becomes difficult to follow. Having identified frond 1, in the case of a 'left handed palm' the sampler should look back down the frond 1 spiral and slightly to the right, in order to identify frond 9, further down the spiral and again slightly to the right will be frond 17, and still further down the spiral and also slightly to the right are the fronds 25 and 33. In the case of a 'right handed palm' the sampler should repeat the same procedure except moving slightly to the left. As a further cross check, sampler should note that frond 17 will be positioned in a region half way between the apex of the crown and the ripe bunbhes. Fronds 9, 17, 26 and 33 can be identified easily in relation to frond 1 due to the fact that in any given steep spiral, these fronds appear after an interval of 8 fronds in terms of chronological growth. In essence, a whorl is comprised of 8 fronds.

3.6.2 Leaf sampling procedure

Twelve palms from each age group viz. 15, 13, 11, 9, 7 and 3 were selected and specific frond from each palm was cut down. The samples were collected between 7 a.m. and 11 a.m.

Six leaflets from each side of the middle portion of the rachis were taken with the help of a clean knife and the leaflets were thoroughly cleaned with damp cotton wool. The midribs and marginal 2 mm area of the laminae were removed. Middle portion of the laminae consisting of 20 - 30 cm was taken and within 48 hours of collection the laminae were cut into small pieces and dried to a constant weight at 70°C in an air oven. After being dried they were ground in a "Retsch Ultra Centrifugal Mill" with the use of a 0.5 mm mesh. The powdered leaf samples were kept in air tight polythene jars for further analysis.

3.6.3 Collection of soil samples

Soil samples from Bhavathipuram estate were collected to correlate leaf nutrient status with soil nutrients. Sampling was limited to one metre radius from the bole, at a depth of 50 cm (Ruer, 1967). Augering was done at 8 to 10 places within this radius around the bole and composite samples were drawn. The samples were air dried, passed through a 2 mm sieve and kept in polythene bags for further analysis.

3.6.4 Correlation between leaf nutrient status and yield

The oil palm plantation at Palode was selected for this study. The fresh fruit bunch yield of 24 oil palms of 10 years age for the year 1985 was collected from the records available at the station. Leaf samples were also taken from the 17th frond from each of the above palms as described earlier.

3.7 Methods for plant analysis

3.7.1 Nitrogen

Total nitrogen in the plant samples was determined by microkjeldahl method using Parnas and Wagner apparatus, as described by Jackson, 1973.

Preparation of plant extract

Five hundred mg of the powdered leaf sample was digested with 10 ml of analar concentrated sulphuric acid until the contents turned clear. The digest was made upto 100 ml with distilled water, filtered and used for the determination of P, K, Ca, Mg, Zn and Cu.

3.7.2 Phosphorus

From an aliquot of the single acid extract of the plant sample, phosphorus was determined by Vanadomolybdo phosphoric yellow colour method (Jackson, 1973).

3.7.3 Potassium

The single acid extract was diluted and the potassium in the diluted extract was estimated in a EEL Flame photometer.

3.7.4 Calcium, Magnesium, Zinc and Copper

Ca, Mg, Zn and Cu in the plant extract were determined in a Perkin Elmer model PE 3030 Atomic Absorption Spectrophotometer, after diluting the extract.

3.8 Soil analysis

3.8.1 Available nitrogen

Available nitrogen was determined by alkaline - permanganate method (Jackson, 1973) by distilling 20 g of soil with 0.32 per cent potassium permanganate and 2.5 per cent sodium hydroxide for 30 minutes. The ammonia released was absorbed in standard acid and the excess acid was titrated with standard alakali. From the volume of acid consumed by ammonia the nitrogen content was calculated.

3.8.2 Available phosphorus

The available phosphorus content of the soil was determined by the chlorostannous reduced phosphomolybdic blue colour method in hydrochloric acid system, after extracting the soil with Bary No.1 reagent (Brey and Kurtz, 1945). The colour intensity was read in a Klett Summerson photoelectric colorimeter.

3.8.3 Exchangeable potassium

Exchangeable potassium was determined in the neutral normal ammonium acetate extract of the soil after destroying the organic matter by treatment with aquaregia, using an EEL Flame photometer (Jackson, 1973).

3.8.4 Exchangeable, calcium and magnesium

From an aliquot of the aqua regia treated ammonium acetate extract, calcium and magnesium were determined in a Perkin Elmer - PE 3030 Atomic Absorption Spectrophotometer.

3.8.5 Available zinc and copper

Available zinc and copper in the soil samples were determined in the DTPA extract using Atomic Absorption Spectrophotometer mentioned above.

3.9 Statistical analysis

The statistical procedures given by Snedecor and Cohren, 1967 were followed.

Results

RESULTS

The plant samples and the respective soil samples were analysed and the results were statistically analysed. The mean values of N, P, K, Ca, Mg, Zn and Cu in plant with respect to different age groups are presented in Table 1. Analysis of variance was done for each parameter under study and the results are presented in Appendix I. Table 2 represents linear regression equation of leaf nutrient concentration with respect to age of palms. Fig.1 illustrates the relationship between leaf nutrients and age of the palms.

4.1 Effect of age of palms on concentration of nutrients in leaf

4.1.1 Nitrogen

Significant difference in the amount of nitrogen was observed with respect to age of the palms. Maximum nitrogen content of 2.82 per cent was noticed in three year old palms and it was seen progressively decreasing to the extent of 2.32 per cent in fifteen year old palms. Nitrogen was not significantly different among the palms of nine, eleven and thirteen years, but it was comparatively low in fifteen and seven year old palms.

Table 1. Effect of age of palm on concentration of nutrients in fronds (mean values)

Age group (years)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)
3	2.82	0.12	1.38	0.39	0.49	25.20	6.33
7	2.31	0.13	1.29	0.41	0.46	23.06	5.24
9	2.43	0.14	1.24	0.43	0.42	21.60	5.51
11	2.38	0.14	1.20	0.47	0.39	20.26	5.01
13	2.35	0.14	1.15	0.50	0.37	15.76	4.35
15	2.32	0.15	1.13	0.58	0.35	9.23	4.10

The correlation between nitrogen and age of the palms (r = -0.6378) was also found to be significant and negative. The simple linear regression of nitrogen and age of the palms was also significant. Forty one per cent of the variation in leaf nitrogen is attributed to age of palms as evidenced from the regression equation.

Fig.1.1 gives a graphic relationship between nitrogen and age of the palms. Leaf nitrogen decreases by about 0.03 per cent for every unit increase in the age of the palms.

4.1.2 Phosphorus

There was significant effect of age of palms on the phosphorus content of leaves. Fifteen year old palms registered the maximum phosphorus content of 0.15 per cent which was significantly higher than that of all other younger age groups. The content of phosphorus did not show much variation between age groups thirteen and eleven. However there was significant decrease in the concentration of phosphorus in palms of age group from nine years and below.

The correlation between phosphorus and age of palms (r = 0.8295) was positive and significant. The simple linear regression of phosphorus and age of palms were found to be statistically significant. Sixty eight per cent of the

Table 2. Regression of leaf nutrients on age of palms

Sl. No.	Equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
1	N = 2.7679 - 0.0346 x	48.0136	41	-0.6378**
2	P = 0.1111 + 0.0027 x	154.4798	68	0.8295**
3	K = 1.4394 - 0.0215 x	22.3604	24	-0.4919**
4	Ca = 0.3195 + 0.0150 x	30.6009	30	0.5531**
5	Mg = 0.5321 - 0.0122 x	36.3508	34	-0.5846**
6	Zn = 31.1087 - 1.2331 x	37.4392	34	-0.5902**
7	Cu = 6.8332 - 0.1798 x	11.9609	14	-0.3819**

x. Age of palms

** Significant at 1 per cent level

variation in phosphorus is attributed to age of palms as explained by the regression equation.

Fig.1.2 gives a picture of the relationship between phosphorus and age of the palms. It is seen that the phosphorus content in leaves increases by about 0.002 per cent for every unit increase in the age of the palms.

4.1.3 Potassium

It was noticed from the data that age of palms had a significant effect on the content of potassium in plant leaves. Maximum potassium content of 1.38 per cent was noticed in the younger palms of three years standing and it decreased with advancing age to a minimum of 1.13 per cent at the fifteenth year. The potassium content in three year old palms was statistically on par with that of seven years and was significantly higher compared to older palms. Seven year old palms were statistically on par with nine and eleven year old palms. Seven year old palms were however superior in potassium content to palms of thirteen and fifteen years. It was observed that from the ninth year onwards potassium content did not very significantly with the age of the palms.

The correlation between potassium and age of palms was computed to be 0.4919. The value is significant and negative. The simple linear regression of potassium and age of palms was substantial. Twenty per cent of the variation in the potassium content of leaf is explained by the regression equation.

Fig.1.3 illustrates the relationship between potassium and age of the palm. Leaf potassium diminishes by about 0.021 per cent for every unit increase in the age of the palms.

4.1.4 Calcium

Significant difference in the amount of calcium was noticed with respect to the age of palms. Fifteen year old palms contained maximum calcium (0.58 per cent) which was considerably higher when compared to the younger palms. Palms of age thirteen, eleven and nine years were on par while thirteen year old palm had a higher concentration of calcium over seven and three year old palms. Younger palms of age three, seven and nine years also did not show much variation in calcium content.

The correlation coefficient between leaf calcium and age of palms was 0.5531 which was significant and positive. The simple linear regression equation of leaf Ca and age of palms was found to be significant. Thirty per cent of the variation in the content of leaf calcium is associated with the age of palms as seen from the regression equation.

Fig.1.4 shows the relationship between leaf calcium and age of the palms. Calcium increases by about 0.016 per cent for every unit increase in the age of the palms.

4.1.5 Magnesium

Data reveals significant difference in the content of magnesium with respect to the age of the palms. Table 1 shows that maximum magnesium content of 0.49 per cent was in three year old palms. The palms showed a noticeable decrease in the content of this nutrient content with advancement in age. Three year palms recorded maximum magnesium content which was on par with that of seven year old palms. There was no substantial difference between palms of seven and nine years age and also among palms of nine, eleven and thirteen years.

The correlation coefficient between leaf magnesium and age of palms was 0.5846 which was significant and negative. Simple linear regression equation of magnesium and age of palms was quite significant. Thirty four per cent of the variation in the leaf magnisium is explained by the regression equation.

Fig.1.5 illustrates the relationship between leaf magnesium and age of palms. Magnesium decreases by about 0.012 per cent for every unit increase in the age of palms.

4.1.6 Zinc

The concentration of zinc in the leaf showed a significant variation with respect to the age of palms. The concentration of zinc decreased from 25.20 ppm in three year old palms to 9.23 ppm in fifteen year old palms. However, there was no significant variation in the concentration of zinc among seven, nine and eleven year old palms. But three year old palms were significantly superior in zinc content compared to 13 and 15 year old palms. Fifteen year old palms showed significantly lower amount of leaf zinc when compared to younger palms.

4.1.7 Copper

There was no significant difference in the amount of leaf copper with respect to the age of the palms. But the correlation between copper content and age of palms (-0.3819) was significant at one per cent level. The simple linear regression of leaf copper and age of palms was also significant. Fourteen per cent of the variation in leaf copper is explained by the fitted regression equation.

EFFECT OF AGE OF PALMS ON LEAF NUTRIENT CONCENTRATION

Fig. 1.1

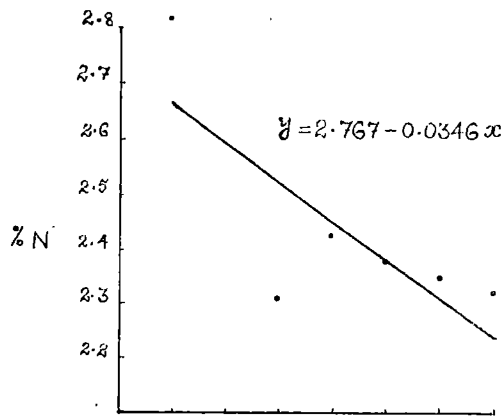


Fig. 1.2

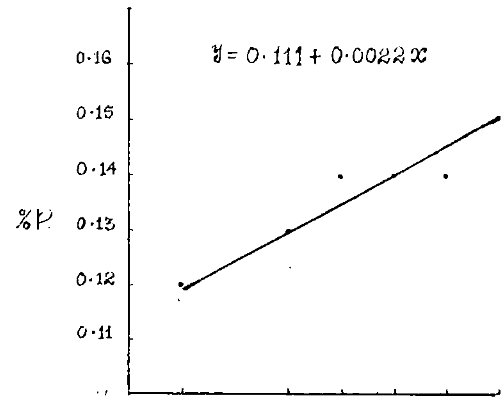


Fig. 1.3

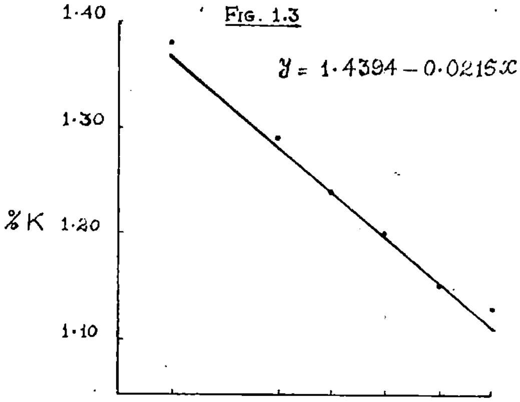


Fig. 1.4

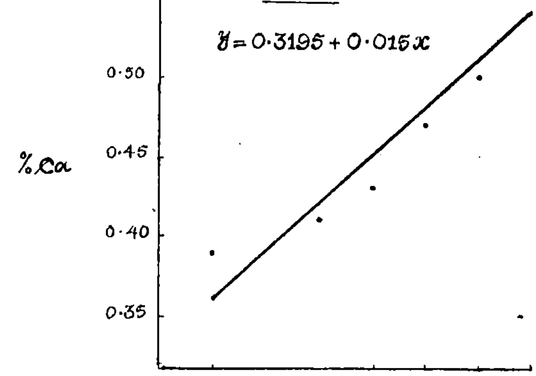


Fig. 1.5

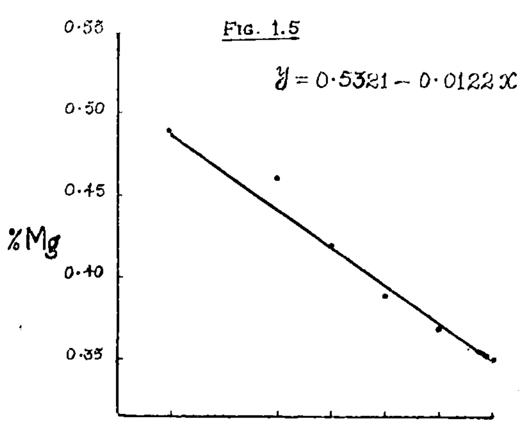


Fig. 1.6

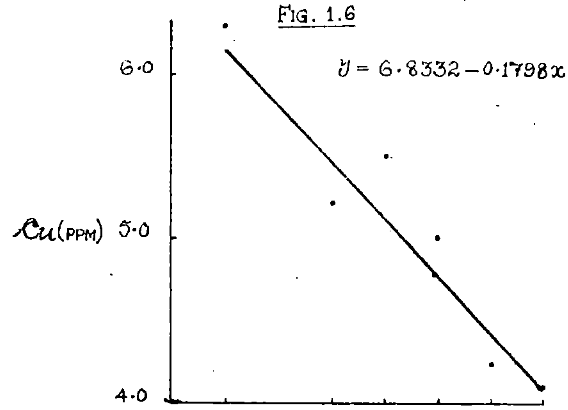


Fig. 1.7

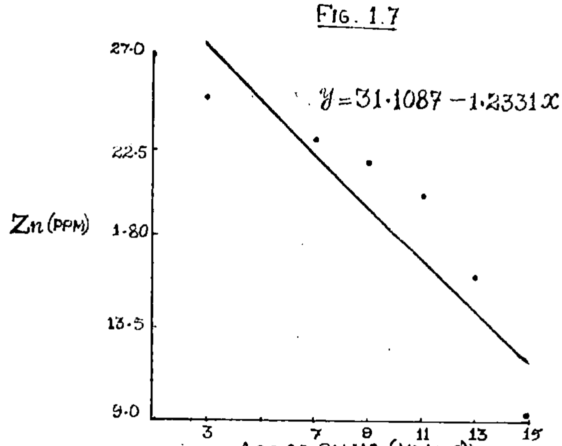


Fig.1.7 presents the relationship between copper and age of palms. Copper decreases by about 0.17 ppm for every unit increase in the age of the palms.

4.2 Leaf maturity and nutrient concentration

The results of the investigations conducted to study the effect of age of fronds on nutrient concentration are presented in Table 3. The average contents of N, P, K, Ca, Mg, Zn and Cu in the 1st, 9th, 17th, 25th and 33rd fronds are given in Table 3 and the analysis of variance in Appendix II. Fig.2 explains the nutrient variation with respect to different frond positions.

4.2.1 Nitrogen

It was observed from the data that there was significant difference in the amount of nitrogen with respect to the rank of the frond. Maximum nitrogen content of 2.41 per cent was seen in the first leaf and minimum nitrogen content in 33rd leaf (1.86 per cent). Nitrogen content in the 1st, 9th and 17th frond were found to be on par and considerably superior to that of 25th and 33rd frond which were on par. Fig.2.1 illustrates the trend of leaf nitrogen with reference to the rank of the frond.

Table 3. Effect of age of fronds on leaf nutrient concentration (mean values)

Frond position (from top)	N(%)	P(%)	K(%)	Ca(%)	Mg(%)	Zn(ppm)	Cu(ppm)
1	2.41	0.19	2.13	0.37	0.53	95.61	11.66
9	2.37	0.16	1.40	0.39	0.50	63.46	6.25
17	2.30	0.13	1.28	0.41	0.45	23.06	5.23
25	1.95	0.12	1.09	0.44	0.43	19.55	3.78
33	1.86	0.11	0.82	0.51	0.38	15.95	3.18

4.2.2 Phosphorus

Analytical data reveals significant difference in the amount of leaf phosphorus with the rank of the frond. Maximum leaf phosphorus content of 0.19 per cent was noted in the first frond and it diminished to a minimum of 0.11 per cent in the 33rd frond. The leaf phosphorus content decreased remarkably from the first to 17th frond. The 17th and 25th fronds were on par, but the 17th frond was found to be superior to the oldest one viz. 33rd frond which was on par with 25th. Fig.2.2 explains the gradient of leaf phosphorus with respect to the age of frond.

4.2.3 Potassium

The analytical data revealed marked variation in the amount of leaf potassium with reference to the rank of palm fronds. First frond registered maximum content of leaf potassium (2.13%) while the 33rd registered minimum (0.82%). The leaf potassium varied appreciably with respect to different frond position except that of 9th and 17th fronds which however, were on par. Fig.2.3 gives a graphical representation of the deminishing trend of potassium with reference to the rank of the frond.

4.2.4 Calcium

The data on calcium content in the leaf revealed that there was significant influence of frond position on the concentration of this nutrient. With advancing age of the fronds the calcium content increases from 0.37 per cent in the first frond to 0.51 per cent in the 33rd frond. Eventhough the calcium content in the leaf increased with the age of the frond the increase was not statistically appreciable among 1st, 9th, 17th and 25th fronds. Fig.2.4 shows the level of leaf calcium with reference to the rank of the frond.

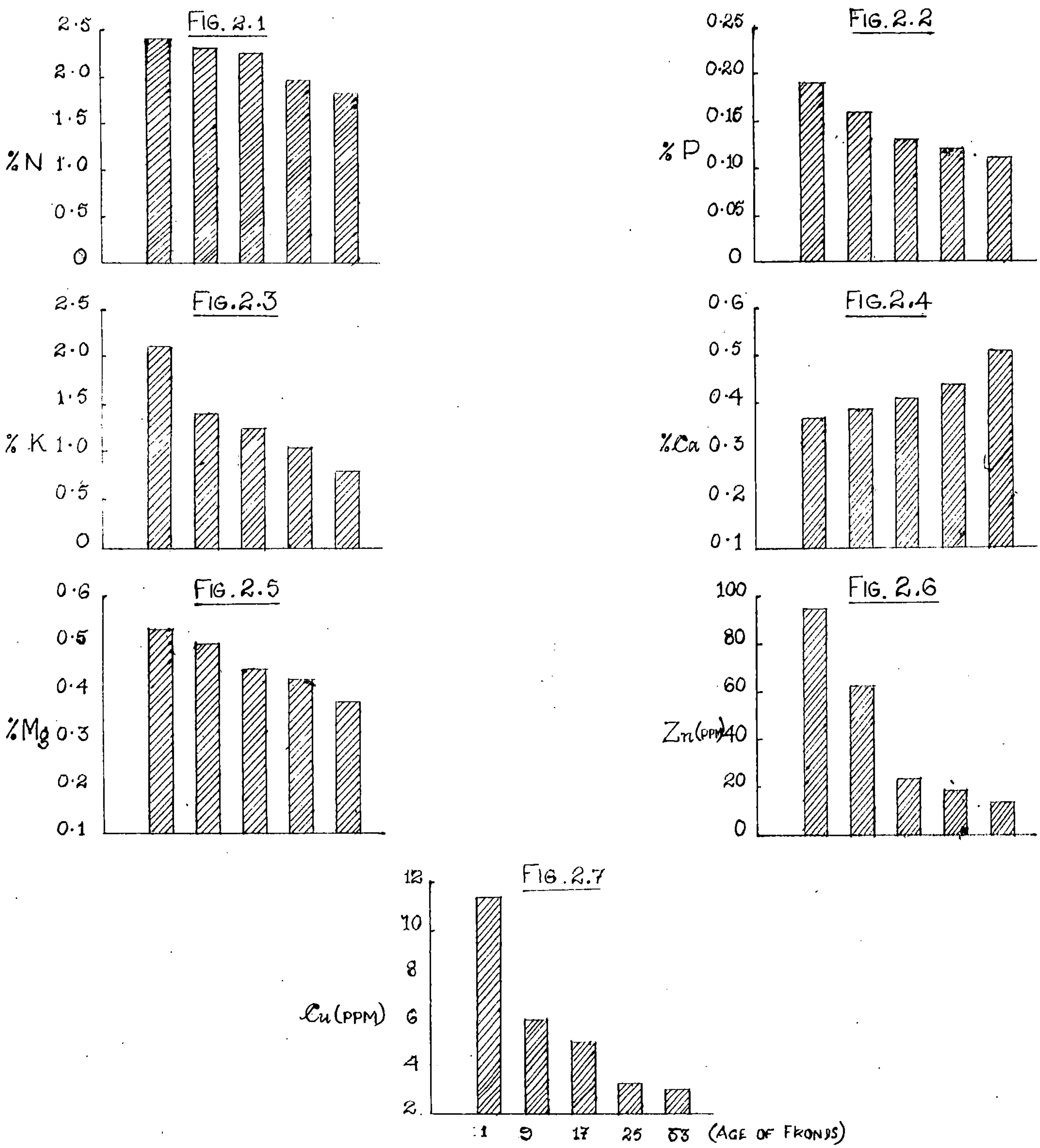
4.2.5 Magnesium

Unlike the variation in leaf calcium content the variation in the leaf magnesium significantly decreased with the rank of the frond. The 1st, 9th and 17th leaves were on par and statistically superior to 25th and 33rd fronds. The 9th, 17th and 25th fronds were on par whereas the 17th, 25th and 33rd fronds also were on par and showed no significant variation in magnesium content. Fig.2.5 illustrates the variation in leaf magnesium with reference to the rank of the fronds.

4.2.6 Zinc

It is evident from Table 3 that there is marked difference in the amount of leaf zinc with the rank of the

EFFECT OF AGE OF FRONDS ON LEAF NUTRIENT CONCENTRATION



frond. The first frond showed 95.61 ppm of leaf zinc which drastically dropped to 15.95 ppm in the 33rd frond. The first frond showed significant superiority to the older leaves. The 9th frond ranked second in zinc content. However from the 17th frond to 33rd frond the leaf concentration of zinc was statistically on par. Fig.2.6 illustrates the level of leaf zinc with reference to the different ranks of the oil palm fronds.

4.2.7 Copper

As in the case of zinc, the copper content of leaf varied considerably from 11.66 ppm in the 1st frond to 3.18 ppm in the 33rd frond. The 1st frond was on par with the 9th frond and superior to the older ones. Similarly, in leaf copper content, the 9th frond was on par with the 17th one and was superior to older ones. The 17th, 25th and 33rd fronds did not vary significantly with respect to leaf copper content. Fig.2.7 represents the gradient of leaf copper with the rank of the oil palm fronds.

4.3 Correlation between leaf nutrient and soil nutrient content in palms of different age groups

Simple correlation and linear regression were worked out to assess the relationship between soil and leaf nutrient contents for different age groups viz., 15, 13, 11, 9, 7 and 3 years and for different nutrients viz., N, P, K, Ca, Mg, Zn and Cu.

4.3.1 Nitrogen

It may be observed from Table 4.1 that significant positive correlation exists between leaf nitrogen and soil nitrogen in all the age groups under investigation. The highest correlation (91%) was noted in 11 year old palms and lowest (68%) in palms of age nine years. The correlation coefficient was significant at 1 per cent level in 15, 11, 7 and 3 year old palms whereas the same was significant only at 5 per cent level in 13 and 9 year old palms.

The simple linear regression of soil nitrogen and leaf nitrogen was found to be significant and positive in all the age groups. In the 11 year old palms 82 per cent of the variation in leaf N is explained by the regression equation but it was only 45 per cent in nine year old palms.

4.3.2 Phosphorus

In the case of phosphorus its content in the soil was found not to influence the leaf phosphorus content considerably in 3, 11 and 15 year old palms. But soil phosphorus and leaf phosphorus were found to be highly correlated in 9, 7, 9 and 13 year old palms. The highest correlation of 68 per cent was observed in seven year old palms.

The simple linear regression of soil phosphorus and leaf phosphorus was found to be significant and positive in 7, 9 and 13 year old palms. Forty seven per cent of the variation in leaf phosphorus is explained by the regression equation.

4.3.3 Potassium

The correlation values (Table 4.3) reveals the significant influence of soil phosphorus on the concentration of the element on the leaves on all the age groups except the youngest group investigated (3 year old). Thirteen year old palms registered highest correlation of 88 per cent but in three year old palms it was only 44 per cent.

The simple linear regression of leaf potassium and soil potassium was found to be positive and significant in all age groups except the 3 year old. In 13 year old palms 78 per cent of the variation in leaf potassium was found to be on account of soil potassium as explained by the regression equation.

4.3.4 Calcium

The calcium content of leaf was seen significantly correlated with soil calcium content in 7, 9, 13 and 15 year old palms. But no such relationship existed in 3 and 11 year old palms. The highest correlation (92%) was observed in 9 year old palms and lowest (51%) in 3 year old palms.

The simple linear regression of leaf Ca and soil Ca was found to be positive and significant in palms of age 7, 9, 13 and 15 years. In 9 year old palms 85 per cent of the variation in leaf calcium was found to be on account of soil calcium as explained by the regression equation.

4.3.5 Magnesium

Table 4.5 showed significant positive correlation between leaf magnesium and soil magnesium in 7 and 13 year old palms only, whereas the same was not significant in 3, 9, 11 and 15 year old palms. The highest correlation (81%) was observed in 13 year old palms.

The simple linear regression of leaf magnesium and soil magnesium was found to be positive and significant in 7 and 13 year old palms. Sixty five per cent of variation in leaf magnesium on account of soil Mg is explained by the regression equation in 13 year old palms.

4.3.6 Zinc

Among the micronutrients, the content of zinc in the soil exerted a significant influence on the leaf zinc content, only in palms of age groups 3 and 11 years. The 3 year old palms registered highest correlation of 74 per cent.

The simple linear regression of soil Zn and leaf Zn was found to be significant and positive in 3 and 11 year old palms. In 3 year old palms 56 per cent of the variation in leaf Zn was on account of soil Zn as explained by the regression equation.

4.3.7 Copper

In the case of copper a significant correlation (85%) exists only in 11 year old palms. Moreover, correlation between soil and leaf copper content was found negative but insignificant in 15 year old palms.

The simple linear regression of soil and leaf copper was found to be positive and significant in 11 year old palms where 73 per cent of the variation in leaf Cu is explained by the regression equation.

Table 4.1 Regression of leaf nitrogen on soil nitrogen in different age groups

Age of palms	Equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
15	$y = 1.8907 + 0.0023\ x$	18.6789	65	0.8070**
13	$y = 1.0245 + 0.0082\ x$	8.9172	47	0.6866*
11	$y = 1.0245 + 0.0082\ x$	46.1974	82	0.9067**
9	$y = 1.8451 + 0.0040\ x$	8.4132	45	0.6760*
7	$y = 1.9091 + 0.0030\ x$	21.2776	68	0.8248**
3	$y = 1.5626 + 0.0083\ x$	15.4796	60	0.7794**

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4.2 Regression of leaf phosphorus on soil phosphorus in different age of palms

Age of palms	Equation	Test of significance	Coefficient determination (r^2%)	Correlation coefficient (r)
15	y = 0.1460 + 0.0001 x	0.6564	6	0.2482
13	y = 0.1394 + 0.0001 x	7.9656	44	0.6659*
11	y = 0.1329 + 0.0003 x	0.8158	7	0.2746
9	y = 0.1187 + 0.0007 x	6.0229	37	0.6131*
7	y = 0.0896 + 0.0015 x	9.9019	47	0.6863*
3	y = 0.1073 + 0.0005 x	3.3397	25	0.5004

* Significant at 5 per cent level

Table 4.3 Regression of leaf potassium on soil potassium in different age of palms

No.of palms	Regression equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
15	y = 0.9452 + 0.0021 x	11.6774	53	0.7340**
13	y = 0.7287 + 0.0029 x	35.8241	78	0.8842**
11	y = 0.7599 + 0.0051 x	27.2570	73	0.8552**
9	y = 1.0569 + 0.0032 x	11.9774	54	0.7382**
7	y = 1.0366 + 0.0035 x	17.3695	63	0.7966**
3	y = 1.0575 + 0.0027 x	2.4111	19	0.4408

** Significant at 1 per cent level

Table 4.4 Regression of leaf calcium on soil calcium in different age groups

Age of palms	Regression equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
15	y = 0.3555 + 0.0006 x	15.7252	61	0.7818**
13	y = 0.2488 + 0.0022 x	14.6599	59	0.7710**
11	y = 0.3679 + 0.0002 x	4.5804	31	0.5605
9	y = -0.0383 + 0.0055 x	57.7295	85	0.9232**
7	y = 0.3007 + 0.0004 x	9.6819	49	0.7014*
3	y = 0.3028 + 0.0003 x	3.5518	26	0.5119

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4.5 Regression of leaf magnesium on soil magnesium in different age groups

Age of palms	Regression equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
15	$y = 0.3094 + 0.0004\ x$	2.6730	21	0.4593
13	$y = 0.2837 + 0.0008\ x$	18.9676	65	0.8087**
11	$y = 0.0549 + 0.0003\ x$	1.2426	11	0.3325
9	$y = 0.3323 + 0.0043\ x$	4.5099	31	0.5575
7	$y = 0.2162 + 0.0022\ x$	12.8912	56	0.7504**
3	$y = 0.3457 + 0.0007\ x$	4.3473	30	0.5505

** Significant at 1 per cent level

Table 4.6 Regression of leaf zinc on soil zinc in different age groups

Age of palms	Regression equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
15	y = 6.2984 + 6.3595 x	3.3222	24	0.4994
13	y = 13.1441 + 2.5194 x	2.5758	20	0.4526
11	y = 7.6578 + 33.2541 x	9.2815	48	0.6938*
9	y = 19.4604 + 2.4085 x	1.0175	9	0.3039
7	y = 20.6125 + 3.1463 x	0.9233	8	0.2907
3	y = 9.3120 + 23.3546 x	12.7345	56	0.7484**

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4.7 Regression of leaf copper on soil copper in different age groups

Age of palms	Regression equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
15	y = 4.0184 - 0.0146 x	0.0001	0.001	-0.0034
13	y = 3.8529 + 0.5998 x	0.3029	2	0.1715
11	y = -0.3195 +17.0759 x	27.4484	73	0.8561**
9	y = 3.8963 + 3.3801 x	3.4598	25	0.5070
7	y = 4.7417 + 1.9162 x	0.4839	4	0.2148
3	y = 4.1139 + 4.5730 x	2.0387	16	0.4115

** Significant at 1 per cent level

4.4 Correlation between leaf nutrients in different frond position and the soil nutrient content

In order to assess the suitability of sampling the 17th frond as an index of the nutrient status of the plant, correlation studies were carried out between the content of different nutrients in the soil and in the leaves with reference to different frond positions. The correlation coefficients for different nutrient elements and different frond positions are presented in Table 5.

In the case of nitrogen, among the correlation coefficients obtained for five leaf positions a positive and significant relationship (r = 0.8283) could be established only in the 17th frond. With regard to phosphorus, even though there was positive correlation between soil and leaf concentration in the 9th, 17th, 25th, and 33rd fronds, none of them was found statistically significant. The correlation coefficient for potassium was found to be significant at 1 per cent level (0.7152) in the 17th frond.

The relationship of the soil and leaf calcium content was significant in the 1st, 9th, and 17th leaf positions. In the case of Mg the correlation coefficient was maximum (0.7503) and significant in the 17th frond closely followed by the 33rd frond (0.7306). In the case of the

Table 5.1 Regression of soil nitrogen on leaf nitrogen in different fronds of the oil palm

No. of the leaf	Regression equation	Test of significance	Coefficient of determinations (r^2%)	Correlation coefficient (r)
1	y = 1.9227 + 0.0037 x	2.1112	17	0.4175
9	y = 2.1881 + 0.0014 x	0.4557	4	0.2088
17	y = 1.9073 + 0.0030 x	21.8479	68	0.8283**
25	y = 2.6022 - 0.0048 x	1.0730	9	-0.3113
33	y = 2.3089 - 0.0034 x	1.3539	11	-0.3453

** Significant at 1 per cent level

Table 5.2 Regression of soil phosphorus on leaf phosphorus in different fronds of the oil palm

No. of the leaf	Regression equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
1	$y = 0.3148 - 0.0043\ x$	5.0795	33	0.5803
9	$y = 0.1206 + 0.0015\ x$	2.9338	22	0.4762
17	$y = 0.0896 + 0.0015\ x$	8.9019	47	0.6862
25	$y = 0.1022 + 0.0009\ x$	3.4766	25	0.5078
33	$y = 0.1097 + 0.0002\ x$	0.2681	2	0.1615

Table 5.3 Regression of soil potassium on leaf potassium in different fronds of the soil palm

No.of the leaf	Regression equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
1	$y = 2.0735 + 0.0008x$	0.1556	1	0.1236
9	$y = 0.7308 + 0.0094x$	8.9479	47	0.6871*
17	$y = 1.0366 + 0.0035x$	17.3695	63	0.7966**
25	$y = 0.9106 + 0.0025x$	0.9894	9	0.3000
33	$y = 0.8711 - 0.0007x$	0.0744	0.7	0.0854

* Significant at 5 per cent level
** Significant at 1 per cent level

Table 5.4 Regression of soil calcium on leaf calcium in different fronds of the soil palm

No.of the leaf	Regression equation	Total of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
1	y = 0.2502 + 0.0004 x	11.6168	53	0.7330**
9	y = 0.2890 + 0.0004 x	7.7856	43	0.6615*
17	y = 0.3007 + 0.0004 x	9.6819	49	0.7013*
25	y = 0.3535 + 0.0003 x	2.4241	19	0.4417
33	y = 0.4002 + 0.0004 x	3.3014	24	0.4980

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 5.5 Regression of soil magnesium on leaf magnesium in different fronds of the oil palm

No. of the leaf	Regression equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
1	$y = 0.6803 - 0.0013\ x$	2.0656	17	0.4136
9	$y = 0.4704 + 0.0003\ x$	0.2503	2	0.1562
17	$y = 0.2162 + 0.0022\ x$	12.8912	56	0.7503**
25	$y = 0.2892 + 0.0013\ x$	1.6711	14	0.3782
33	$y = 0.1700 + 0.0019\ x$	11.4541	53	0.7306**

** Significant at 1 per cent level

Table 5.6 Regression of soil zinc on leaf zinc in different fronds of the oil palm

Leaf No.	Regression equation	Test of significance	Coefficient of determination (r^2%)	Correlation coefficient (r)
1	$y = 105.8236 - 13.0857\ x$	0.2731	2	0.1627
9	$y = 75.1930 - 15.0339\ x$	2.7212	21	0.4624
17	$y = 20.6125 + 3.1463\ x$	0.9233	8	0.2906
25	$y = 21.7965 - 2.8802\ x$	3.4286	25	0.5052
33	$y = 13.9318 + 2.5873\ x$	2.2313	18	0.4270

Table 5.7 Regression of soil copper on leaf copper in different fronds of the oil palm

No. of the leaf	Regression equation	Test of significance	Coefficient of determination ($r^2\%$)	Correlation coefficient (r)
1	y = 9.6921 + 7.5315 x	0.6274	5	0.2428
9	y = 6.3532 - 0.3938 x	0.0060	0.06	0.0244
17	y = 4.7281 + 1.9271 x	0.4994	4	0.2179
25	y = 3.8031 - 0.0757 x	0.0007	0.007	0.0264
33	y = 3.9237 - 2.8244 x	0.6627	6	0.1624

micro nutrients (Zn and Cu) positive correlation could be obtained in the 17th frond, but the values were not significant.

4.5 Correlation between yield and plant nutrients

Fresh Fruit Bunch yield of 24 palms and the corresponding leaf nutrients content are presented in Table 6. Correlation coefficients were worked out between leaf nutrients status and yield and the results are presented in Table 7.

The data reveal that the correlations of yield with leaf N ($r = 0.6618$) and K ($r = 0.6533$) were highly significant and positive. P was found to be correlated with yield only at 10 per cent level of significance. Leaf Ca and Mg were found to have no correlation with yield. Leaf nutrients among themselves were found to be correlated. Nitrogen content of the leaf was positively correlated to the content of P, K and Ca. Leaf Mg was found to have a negative influence on all other nutrients (leaf N, $r = -0.4359$; leaf K, $r = -0.4158$ and leaf Ca, $r = -0.4856$) and also with yield.

4.5.1 Path coefficient analysis

Path coefficient analysis was used to partition the correlation coefficients of nutrient concentration of leaf tissue into direct and indirect effects. The residual effect in this study was computed to be 0.576. The results of the path analysis are given in Table 8. The direct and indirect effects of N, P, K, Ca and Mg on yield were estimated. The maximum direct effect was observed for leaf N (53%) followed by leaf K (52%) and leaf Mg (35%). The direct effects of P and Ca were only 2 and 5 per cent respectively. The correlation between leaf N and yield was 66 per cent of which 53 per cent was the direct effect and remaining 13 per cent was the indirect effect of leaf N via leaf P, K, Ca and Mg. The maximum indirect effect was from leaf K (25%). The indirect effects via leaf P and leaf Ca were 1 and 2 per cent respectively while there was 15 per cent reduction in the amount of correlation through the negative indirect effect of Mg. Though the correlation between leaf P and yield was observed as 40 per cent its direct effect was only 2 per cent. So this correlation is the sum total effect of the indirect effects via other nutrients especially leaf N (25%) leaf K (15%). The influence of leaf P via leaf Mg was negative accounting for about 5 per cent reduction. Of the 65 per cent correlation between leaf K and yield, 52 per cent was direct effect of leaf K and remaining 13 per cent was the indirect effect via other nutrients especially leaf N (26%). Here about 15 per cent reduction in the correlation is accounted for by the negative indirect effect via leaf Mg. The correlation between leaf Ca and yield was 24 per cent while its direct effect was only 5 per cent. This correlation is the result of positive indirect effects via N (19%), P (1%), K (15%) and negative indirect effect via Mg (17%). The correlation between leaf Mg and yield was very small and negative (12%) while its direct effect was 35 per cent. So this significant reduction in correlation is due to its negative indirect effects via leaf N, P, K and Ca especially via leaf N (23%) and leaf K (21%). The direct and indirect influences of leaf nutrients contributed to 43 per cent in the yield of the palm.

Table 6. Fresh fruit bunch yield and the corresponding leaf nutrients content

Sl.No.	Yield (kg) fresh fruit bunch	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
1	2	3	4	5	6	7
1	11.0	2.4402	0.145	0.84	0.4028	0.5198
2	26.0	2.4402	0.145	1.36	0.6524	0.3850
3	7.0	2.3226	0.125	1.12	0.2128	0.5468
4	98.0	2.5578	0.145	1.52	0.3082	0.4734
5	23.0	2.4402	0.135	0.96	0.4158	0.4318
6	16.0	2.3814	0.125	1.20	0.3626	0.3726
7	10.0	2.4402	0.135	1.24	0.4332	0.3624
8	56.0	2.4419	0.145	1.36	0.4468	0.3850
9	39.0	2.4402	0.140	1.24	0.4635	0.4276
10	42.5	2.4402	0.145	1.52	0.6524	0.3690
11	23.0	2.5578	0.145	1.28	0.5874	0.3716
12	17.5	2.4402	0.140	1.28	0.4152	0.4228

Table 6. (Contd.)

1	2	3	4	5	6	7
13	8.0	2.4402	0.140	1.00	0.4158	0.4228
14	10.0	2.4402	0.125	1.28	0.4028	0.4318
15	23.0	2.4402	0.140	1.28	0.5338	0.4734
16	23.0	2.5578	0.140	1.20	0.3626	0.3726
17	15.0	2.4402	0.145	1.16	0.4574	0.4318
18	48.5	2.5578	0.135	1.36	0.4332	0.3716
19	55.5	2.4990	0.140	1.24	0.6524	0.4228
20	27.5	2.4402	0.130	1.24	0.4332	0.4318
21	4.0	2.2638	0.135	0.96	0.4158	0.4318
22	17.0	2.4402	0.140	1.36	0.3434	0.3758
23	20.5	2.3814	0.145	1.36	0.2914	0.4734
24	2.8	2.3226	0.130	1.00	0.2128	0.4734

Table 7. Correlation between yield and different leaf nutrients

	N	P	K	Ca	Mg
Yield	0.6618**	0.3988	0.6533**	0.2887	-0.1241
N		0.4726*	0.4887*	0.3627	-0.4359*
P			0.2946	0.4561*	-0.1485
K				0.2981	-0.4158*
Ca					-0.4856*
Mg					

* Significant at 5 per cent level
** Significant at 1 per cent level

Table 8. Path analysis - Direct and indirect influence of leaf nutrients on yield

	N	P	K	Ca	Mg	Total r
N	0.5326	0.1111	0.2526	0.0186	-0.1532	0.6618**
P	0.2517	0.0235	0.1523	0.0234	-0.0522	0.3988
K	0.2603	0.0070	0.5169	0.0153	-0.0461	0.6533**
Ca	0.1932	0.0108	0.1541	0.0513	-0.1707	0.2387
Mg	-0.2322	-0.0035	-0.2149	-0.0249	0.3514	-0.1241

Residue = 0.576

Underlined figures are the direct effects.

Discussion

DISCUSSION

The present study was taken up with a view to assessing the fertility status of the oil palm growing soils of Kerala and the nutrient content in the leaf of palms of different age groups. The correlation between nutrient contents of leaf and soil and the contribution of each nutrient towards yield have also been studied. It is hoped that the results of the present investigation may be helpful in carrying out further studies to work out a better fertilizer management for oil palm in Kerala. Another aim of the study was to verify the suitability of the index leaf already established by I.R.H.O. The salient findings of the study are discussed in the light of the available literature.

5.1 Effect of age of palms on concentration of nutrients in leaf

Several investigations have been carried out to find out correlation if any between the age of palms and nutrient concentration in the 17th frond which is considered as the index leaf.

5.1.1 Nitrogen

The nitrogen content varied from 2.82 per cent in 3 year old palms to 2.32 per cent in 15 year old palms. It is seen that the decrease was progressive with advancing age. The decrease in leaf N with increasing age of palms may be attributed to the increased demand of the element for bunching, as the palm passes from the vegetative to the bunching phase (Oil palm starts bunching from 4th year onwards). Ng Siew Kee (1968) has reported that leaf nitrogen generally diminishes with advancing age. Bachy (1965) has shown that leaf N diminishes in a linear way by about 0.021 per cent for every unit increase in the age of the palms. The results obtained in the present study corroborate the above findings by showing a decrease of 0.03 per cent in leaf N content with unit increase in the age of palms.

The highest nitrogen content in the leaves of 3 year old palms as compared to the palms of the other age groups points to the need for an abundant supply of nitrogen to the palm for establishing a healthy stand and to prepare for the bunching phase which starts from the 4th year onwards. In the present study there was a sudden decline in the nitrogen content in the 7 year old palms whereas there was no significent variation in the nitrogen content beyond this period. This is a further indication of the high demand for nitrogen in the earlier growth period of the palm. Probably some portion of nitrogen in the leaves might have been mobilized for tissue building and strengthening of the whole palm to prepare itself for increased production in the coming years. The period between the 3rd and 7th year might be considered critical in the life of the palm.

Forty one per cent of the variation in leaf nitrogen is attributed to age of palms. The data on variation in levels of leaf nitrogen with advancing age was fitted in a simple linear curve and is presented in Fig.1.1

5.1.2 Phosphorus

In the case of phosphorus a reverse trend was noticed. The P content in the leaves of the index frond was found to be the highest (0.15%) in the 15 year old palms while the 3 year old palms contained only the lowest percentage (0.11%). The increase in phosphorus content in leaves with advancing age was linear, positive and significant (r = 0.830). Between the age groups of 11 and

13 years, there was no significant difference in P content. However there was a steady increase in P content from 3 to 9 years. Leaf P level was found to increase by about 0.002 per cent for every year. At Cameroon the increase was by about 0.0013 per cent as reported by Bachy (1965). However he did not get a consistent trend in the increase of the element with advancing age of palms. In the case of his investigation at Pobe the P content was found to increase with age. Ng Siew Kee (1968) and Ng and Cheah (1969) have also found similar trends in leaf P content of oil palm. However, Tan (1973) is of the view that no consistent pattern is evident between leaf phosphorus content and age of the palm. There was a decline of leaf P with advancing age of the palm in the coastal soils of West Malaysia (Foster and Cheng, 1976). The above works suggest the absence of a regular consistent pattern in the P content with reference to the age of oil palms. The varying trend may be attributed to the varying soil and agro-climatic conditions prevailing in different oil palm plantations. Comhaire (1968) opines that P is the pivot of oil palm cultivation and that it plays an important role in the growth and yield of oil palm plantations. According to him P has an important role in the plant metabolism which in turn is a function of regional differences. In the light of the above said findings, it is

evident that uniform trends can never be expected world wide, with reference to the P content in oil palm leaves.

The present investigation has established that there was significant increase in P content of oil palm leaves with increase in age. Sixty eight per cent of the variation in leaf P is attributed to the influence of age of palm. However, the supply of the element to the palm especially in the earlier life span of the palm cannot be neglected. This point is further supported by the fact that palms of age groups from 3 to 9 years had substantially less phosphorus content than older palms. Probably the younger palms might have received little phosphorus, either native or applied.

5.1.3 Potassium

The potassium content of the leaves in the index frond gave a decreasing trend with an increase inthe age of the palms. The leaves of the three year old palms, the youngest age group investigated contained the highest percentage of potassium (1.38%) and it decreased consistently with age giving a minimum of 1.13 per cent in the oldest palms (15 years). The decline was significant and the present study reveals that the potassium content in the leaf declines steadily with increasing age. The rate of decline was to the tune of 0.021 per cent per unit increase in age of palms. This agrees with the finding of Bachy (1965) who found that the rate of decrease was 0.02 per cent. Other authors (Bachy, 1964; Ng Siew Kee, 1968 and Tan, 1973) have also found a decreasing K content in leaf with advancing age. Knecht and Ramachandran (1977) also have observed that leaf K was higher in young palms of 3 to 4 years, while it was lower in palms of 30 years and above, with a decrease of 0.019 per cent per year. In all the investigations taken up by them leaf K was found to decrease significantly in a linear way, with increase in age of palms. They could find fair agreement among three estates in the case of derived relationship for palms at intervals of 5 years difference. The results obtained presently are in full agreement with the findings of the above authors. Eventhough the decrease in K content was linear and significant the age groups of 3 and 7 years as well as the age groups of 9, 11, 13 and 15 were on par. This shows that during the earlier periods there was higher content of potassium in the leaves and after the age of 9 years the potassium content declines and remains comparatively constant. By about 8 to 9 years the palms attain full bearing capacity and the demand for K also should be higher after this period. The oil palm like coconut is a potential K remover from soil, and due to the need of K for bunch formation, development and maturity, some of the potassium in the leaves will have to be mobilised. In the light of the results it may be concluded that a steady supply of potassium at a higher dose must be made available to the palms after it attains full bearing capacity. The contribution of age of palms towards the potassium content in leaves is only to the tune of 24 per cent.

5.1.4 Calcium

Unlike nitrogen and potassium the calcium content of leaves in the index frond showed an increasing trend. A maximum of 0.57 per cent Ca was obtained in the leaf from 15 year old palms whereas the minimum value of 0.38 per cent was noticed in 3 year old palms. Calcium is not a mobile element and is concentrated mainly in the middle lamellae of the cell wall. In almost all crops the calcium content increases as the crop approaches and attains maturity. As the plant grows more and more calcium is deposited in the middle lamellae so that the frame work of the cells get strengthened. This must be the reason why older plants contain more calcium. There was an increase of 0.015 per cent in the Ca content per unit increase in age as seen from the present study. This observation is supported by the findings of Knecht and Ramachandran (1977) who obtained an increase of 0.01 to 0.012 per cent in the Ca content with an increase in unit age of the palm. Results to the contrary are found by Bachy (1965), Ng Siew Keel (1968) and Foster and Chang (1976). Bachy (1965) has reported a decrease of 0.005 per cent for unit increase in age of the palms. This deviation can be attributed only to regional and agro-climatic differences. In the present study the contribution of increasing age to the Ca content in the index leaf was 30 per cent.

5.1.5 Magnesium

The Mg content of the leaves decreased with increase in age. The values varied from 0.49 per cent in the 3 year old palms to 0.35 per cent in the fifteen year old palms. In West Africa, Bachy (1964) noticed a similar trend in the Mg content in oil palm leaf. The study presently carried out gave a decrease of 0.012 per cent in Mg content for unit increase in age, whereas the value obtained by Bachy (1965) was 0.014 per cent. A general decline in leaf Mg content in oil palm leaves, with increase in age, was observed by several other workers also (Ng Siew Kee, 1968; Tan, 1973; Foster and Chang, 1976 and Knecht and Ramachandran, 1977). The contribution of age towards Mg content of leaf was found to be 34 per cent.

We have already seen that the Ca content was increasing with age of palms. Leaf Mg follows the opposite course. As is seen generally, a Ca-Mg antagonism is evident in the present study also. Since a cationic balance has to be established in any plant system, the increase in one cation may be accompanied by a decrease in another cation. This principle evidently accounts for the decrease in leaf Mg content and an increase in Ca content with advancing age of the palm.

5.1.6 Micronutrients (Zn and Cu)

The highest zinc concentration (25.2 ppm) was noticed in 3 year old palms, while the lowest content of 9.3 ppm was noticed in the leaves of the oldest group (15 years) of palms. There was a decrease in the content of this element with increasing age. The contribution of age towards the reduction in zinc content of oil palm was found to be 34 per cent.

However, the copper content showed a decreasing trend with increasing age of the palm, though the decrease was not significant. The copper content in palm leaves varied from 6.33 ppm in the three year old palms to 4.10 in the 15 year old palms. Since no literature regarding micronutrient studies conducted on oil palm could be located a comparison and discussion on the values presently obtained is not possible.

5.2 Leaf maturity and nutrient concentration

An attempt has been made to study the nutrient concentration in the leaves of oil palm with reference to the rank of the frond by analysing 1st, 9th, 17th, 25th and 33rd fronds.

The maximum leaf nitrogen content was noticed in the first frond whereas its content was least in the 33rd frond, the values being 2.4 per cent and 1.8 per cent respectively. There was no significant variation among the 1st, 9th, and 17th fronds and they were on par. The nitrogen content of these groups were far superior to the 25th and 33rd fronds.

As in the case of leaf nitrogen, P content of the 1st frond was maximum (0.1987%) while the 33rd frond had the minimum P content. The P content decreased progressively from the first to 17th fronds. There was no significant variation in P content between the 17th frond and 25th frond.

Potassium also was maximum (2.13%) in the first frond whereas it was the minimum in the 33rd frond. The 9th and 17th frond did not very significantly.

Unlike N, P and K, Ca was found to increase with increase in age of frond. The minimum value was recorded in the first frond (0.37%) while the value for the 33rd frond was the highest (0.51%). There was no significant difference in Ca content between the 1st and 25th fronds, though there was a progressive increase with advancement in age.

Eventhough the Mg content showed a decreasing trend there was no regularity in its variation with the increasing age of the fronds. The Mg content of the first frond was maximum (0.53%) while it was minimum (0.38%) in the 33rd frond. The 1st, 9th and 17th fronds were statistically superior in Mg content to the 25th and 33rd fronds.

Both the micronutrients Zn and Cu showed a decreasing trend with advancing age of fronds. The zinc content in the 1st frond was 95.62 ppm whereas its content in the 33rd frond was the lowest (15.96 ppm). The 1st and 9th fronds were superior in zinc content compared to older fronds.

The maximum copper content was noticed in the first frond (11.67 ppm) and the minimum value (3.18 ppm) was noticed in the 33rd frond. Here also, the first and 9th fronds contained a greater amount of copper while the older fronds did not vary significantly in its content.

It may be noted from the results of the present study the most of the plant nutrients decreased with increase in age of fronds. Only calcium showed the opposite trend. Generally most of the mobile elements are translocated to physiologically active and growing regions from older leaves. As new fronds are put up (2 each in every month) the additional requirement for elements are partially met from the soil reserve and partially from older leaves. Calcium being a non mobile element in view of it being a structural part of the plant cell, has naturally shown a higher content with increasing age of the frond. Studies conducted by several scientists support most of the findings of the present investigation. Scheidecker and Prevot (1954) have found that ageing of the leaf results in their impoverishment of N, P, K and enrichment of Ca. Similar trends have been reported in WAIFOR annual report (1956). Broeshart (1955) has found that there was decrease in K content as the age of the frond increases. He has also reported that the ratio between the content of K and that of Mg decreases with age. The data given in Table 3 presents a similar picture. According to Smilde and Chapas (1963) the mineral element content is dependent on the rank of the leaf. The irregular pattern of variation in Mg content due to age of fronds, observed in the present study is in consonance with the findings of Broeshart (1955). Rajaratnam (1973) has observed a decline in the Mg content with the advancing age of the palms. Prevot and Montrebreton (1958) has reported an increase in the Ca and Mg content with age and diminishing trend in the case of P and K. He has also observed an increase in the nitrogen content from the 1st to 9th leaf and a decrease thereafter. His observation except in the case of Mg holds good in respect of the study presently undertaken. A decline in K content and an increase in Ca content were reported by Bachy (1964).

A general decline in Zn and Cu with similar trends in N, P and K was reported by Ng and Tan (1974). This agrees with the result obtained during the course of the present investigations. It may be concluded that the plant nutrient content in the oil palm leaves is a function of the age of fronds.

5.3 Correlation between soil nutrient content and leaf nutrient content in palms of different age groups

Considering the abundance of literature suggesting a strong correlation between nutrient status of soil and plant (Fremond and Orgias, 1952; Prevot and Ziller, 1958; Tinker and Ziboh, 1959) an attempt was made in the present investigation to correlate the nutrient content of soil to that of the 17th frond which is internationally accepted as the index frond. The maturity status of the plant is a determining factor in reflecting the mineral composition of the soil (Ochs and Oliven, 1976; Foster and Cheng, 1977a) irrespective of the index frond. Hence it has to be established whether the 17th frond provides a suitable index of soil fertility for palms of all ages. Therefore the present study included correlation studies of the composition of different nutrients in the 17th frond of palms of different age groups with the content of those elements in the corresponding soil.

In the case of nitrogen, significant correlation was established between the content in the 17th frond and soil concentration in palms of all age groups. The linear regression equation fitted with soil and leaf analysis data attributes 45 to 82 per cent of relationship between the content of N in the 17th frond and the corresponding soil nitrogen. Nair (1981) has reported a significant correlation between leaf N and soil N.

The leaf content of phosphorus was found to be significantly correlated with that of soil in the case of 7, 9 and 13 year old palms whereas no correlation could be established in the case of 3, 11 and 15 year old palms. Some correlation has been found by Mollegaard (1971) between soil P content and levels of this element in leaf tissues.

In the case of K, its content in the leaf was correlated significantly with the available K of soils in palms of 7 years and above. Similar results were reported in Malaysia by Mollggaard (1971). Ochs (1965) and Nair (1981) also found a relationship between exchangeable K in the soil and leaf K.

While Nair (1981) could not find any relationship between calcium content of the soil and leaf, the relationship was significant in the present study for 7, 9, 13 and 15 year old palms. Soil and leaf content of Mg were correlated with each other for 7 and 13 year old palms only. Significant correlation between zinc content of the soil and leaf was obtained only for 3 and 11 year old palms. However, the soil and leaf Cu content showed a remarkable correlation in 11 year old palms only.

There may be several reasons for the failure or success in establishing a relationship between soil and plant concentration of a particular nutrient. While the nature of fertilizer applied, the soil mineralogy and microbial status may effect the amount of available nutrient as estimated by extraction methods, the same needs not be reflected in the plant because the uptake and translocation of a nutrient will be further controlled by climatic conditions, plant physiology and root absorbing capacity. The nutrient absorption character of palms can also vary according to maturity. Therefore it is not the amount of nutrient in the soil which is important for better nutrition and yield, but the tissue concentration and the translocation of nutrients. Magnitude of nutrient uptake can also vary with the nature of nutrient element. Therefore no correlation can be expected in all the soils, for palms of all ages, and for all the elements. For those nutrients which provide significant correlation between soil and leaf concentration the indexing of a particular leaf and analysing the same for detection of nutrient deficiency are recommended. The 17th frond proved to be the best index for most of the elements under investigation and for palms of most of the age groups under study. A greater understanding of the interrelationship between soil nutrient status and that of the palm can be established by a combination of soil and plant analysis of a large number of samples.

5.4 Correlation between leaf nutrient concentration in different frond positions and soil nutrients

It has been established that the concentration of different nutrients in the leaves varies in response to the soil fertility status (Coulter, 1958 and Ng, 1972) and age of the palms (Ochs and Olivin, 1976). Vegetative growth (Lo, Chan, Goh and Garden, 1973) and climatic factors (Ochs and Olivin 1976; Foster and Chang 1977a; 1977b). It is essential to establish as to which one of the different fronds will show a maximum possible reflection of soil nutrient status of different mineral elements. In the present investigation correlation studies were carried out between the elemental composition of fronds at different ranks and the corresponding soil nutrient status. It is evident from the results obtained that there is remarkable relationship between leaf composition and soil fertility.

In the case of N, out of the 5 positions considered for computation, a positive and significant relationship could be established between the 17th frond and soil nutrient status. The correlation coefficient in this case was 0.8283 which was significant at 1 per cent level.

From the coefficient of determination it can be concluded that 68 per cent of the variation in soil nitrogen is reflected in the 17th leaf. The observation by Hartley (1977) carroborates the above finding. This indicates that under South Indian conditions the 17th frond is most ideal for studies on nitrogen nutrition of oil palm.

In the case of P and K also the 17th frond proved to be representative of soil fertility. For phosphorus, 47 per cent variation could be explained by the composition of 17th leaf which gave a significant correlation ($r = 0.6862$) with soil available phosphorus. Similarly the K content of the 17th leaf was significantly correlated with soil K. In this case the correlation coefficient was 0.7966 and the coefficient of determination was 63 per cent. Hence it can be suggested that the 17th frond may be considered as a suitable index for the assessment of soil fertility in the case of major elements in oil palm. The variations in the elemental content in the palm leaves in relation to soil nutrient status were fitted into regression equations which proved to be linear. This shows that content of a particular element in the index leaf is proportional to the status of that element in the soil. Hence fertilization of the soil results in the enrichment of plant composition as reflected in the index leaf. Warrier and Piggot (1973) reported that fertilizer application was a major factor influencing the leaf nutrient composition. An assessment of the concentration of nutrients in the 17th frond should therefore provide guidance towards the amount of nutrient to be applied in the soil.

While it was the 17th frond which showed maximum correlation with the soil in the case of N, P and K the same was not true for Ca. In this case the 1st frond showed maximum correlation (r = 0.7333) followed by 17th frond, with a correlation coefficient of 0.7013. The odd behaviour of the element explains this deviation. It is an immobile element. We have already seen that the Ca content in the leaf tissue increased with increase in age of palms as well as age of frond. In the case of Mg it was again the 17th frond which could reflect the soil fertility status to an extent of 56 per cent. Here the correlation coefficient was 0.7503 which was the highest among the five ranks of fronds under investigation.

No definite conclusion could be arrived at in the case of zinc and copper with regard to index leaf. However, the maximum correlation was noted in the 25th and 1st fronds, the corresponding values were 0.5052 and 0.2428 respectively.

It has already been established that the 17th leaf provides the best index of soil fertility (Hartley, 1977). Eventhough the 17th frond can be suggested as the best possible index it need not be so for all elements and palms of all ages. Further investigations are suggested to establish suitable index leaf/leaves for the evaluation of soil fertility with respect to elements other than N, P, K and Mg for palms of different age groups growing under different agroclimatic zones.

5.5 Correlation and path coefficient analysis of leaf nutrient concentration with yield of oil palm

Simple correlation coefficients were computed between leaf nutrient concentration and Fresh Fruit Bunch (F.F.B) yield of oil palm. Path coefficient analysis was used to partition the correlation coefficients of nutrient concentration of leaf tissue into direct and indirect effects using methods described by Wright (1921) and Li (1956). The residual effect in this study was computed to be 0.576. Though relationship between leaf nutrient concentration and yield in oil palm has been studied, there is little information on the influence of the components of various nutrients on the yield (FFB). Estimates of correlation coefficients among different characters do not give the exact picture of the relative importance of direct and indirect influences of these characters. This work also attempts to single out the synergestic and antagonistic relationship between leaf nutrient concentration and yield.

The correlation of yield with leaf N (0.6618) and potassium (0.6533) was found to be highly significant and positive. Leaf P was found to be correlated with yield at 10 per cent level of significance. The direct and indirect effects of N, P, K, Ca and Mg on yield were estimated. The maximum direct effect was observed for leaf N (53%) followed by K (52%) and Mg (35%). The direct effects of P and Ca were only 2 per cent and 5 per cent respectively. The correlation between leaf N and yield was 66 per cent of which 53 per cent is the direct effect and remaining 13 per cent the indirect effect of leaf N via leaf P, K, Ca and Mg. The maximum indirect effect was from leaf K (25%). Prevot and Ollagnier (1959) reported that, when the leaf N content reached 2.7 per cent, there was a positive correlation between K levels and yield. Forde, Leyritz and Sly (1965) got response to yield at a level of 2.4 per cent. Warrier and Piggot (1973), Ummer Akbar et al.,

1976) also reported similar results. The above findings are in conformity with the results presently obtained.

Though the correlation between leaf P and yield was 40 per cent its direct effect was only 2 per cent. So this correlation is the sum total of the indirect effects via other nutrients especially leaf N (25%) and leaf K (15%). In the case of leaf phosphorus some workers obtained correlation between leaf P content and yield. Forde et al. (1965) have obtained yield increase upto a leaf P content of 0.147%. Similarly Nair (1981) showed positive correlation between leaf P content and yield of oil palm. However in the present study leaf P was correlated with yield only at 10 per cent level of significance.

Of the 65 per cent correlation between leaf K and yield 52 per cent was direct effect of leaf K and remaining 13 per cent is the indirect effect via other nutrients especially leaf N (26%). In the case of leaf potassium strong correlation was reported by several workers. Prevot and Ollagnier (1959) observed that when leaf K level was more than 1 per cent there was significant positive correlation between N and yield. Forde et al. (1965) obtained yield improvement of individual palms with a leaf K content of 1.20 per cent. Bachy (1969) Warrier and Piggot

(1973) and Nair (1981) got increased yield, when the leaf K content was increased.

The review on the nutrition of oil palm in the oil palm growing countries of the world reveals that responses to N and K are universal and these nutrients exert a major role in the growth and production of the oil palm. Phosphorus is required for full expression of qualitative characters and P response depends mainly on P status of the soil. Investigations on the Ca nutrition are meagre and the influence of Ca on oil palm yield has not yet been established. It appears from the present investigation that the direct and indirect influences of leaf nutrients contributed to 43% of the yield in oil palm.

Summary

SUMMARY

The present study was undertaken to find out the nutrient content of the soils growing oil palm, the nutrient content of oil palm leaves from palms of different age groups and also fronds in different positions to correlate the different parameters and find out the role of different nutrients in bunch production. The important findings are presented here.

Age of palms and nutrient concentration

1. N, K, Mg, Zn and Cu showed a decreasing trend with increasing age of palms whereas P and Ca content in the plant tissue tended to increase.

2. Maximum amount of 2.82 per cent nitrogen was noticed in three year old palms whereas it was only 2.32 per cent in 15 year old palms. The corresponding values for potassium were 1.38 per cent and 1.13 per cent, for magnesium 0.49 per cent and 0.35 per cent, for zinc 25.20 ppm and 9.23 ppm and that of copper 6.33 ppm and 4.10 ppm.

Phosphorus concentration was maximum in the leaf tissues of 15 year old palms (0.15%) and minimum in three year old palms (0.12%). Calcium content varied from 0.58 per cent in 15 year old palm to 0.39 in three year old palms.

3. There was significant correlation between age of palms and concentration of N, P, K, Ca, Mg and Zn. There was no significant relationship between age of palms and the Cu content.

4. The contribution of age of palms towards the concentration of leaf nitrogen was 41 per cent of phosphorus it was 68 per cent, of potassium, 24 per cent, of calcium, 30 per cent, of magnesium and zinc, 34 per cent and of copper 14 per cent.

Leaf maturity and nutrient concentration

All elements estimated except calcium showed a decreasing trend with age of fronds. Maximum elemental content was noticed in the 1st frond whereas it was minimum in the 33rd frond. The variation in elemental content from 1st to 33rd fronds was from 2.4 to 1.8 per cent for N, 0.19 to 0.11 per cent for P, 2.13 to 0.82 per cent for K, 0.53 to 0.38 per cent for Mg, 95.6 to 15.9 ppm for zinc, and 11.6 to 3.1 ppm for copper. Calcium content increased from

0.37 per cent in the 1st frond to 0.51 per cent in the 33rd frond. All the variations in nutrient content due to ageing of frond were significant.

Nutrient content of soil and leaf concentration

The soil and leaf samples (from the index frond) from plantations of 15, 13, 11, 9, 7 and 3 years were analysed and simple correlation and linear regression were computed. The observations are as follows:

1. With reference to nitrogen there was significant positive correlation between leaf nitrogen and soil nitrogen in all the age groups investigated. Highest correlation of 82 per cent was obtained in 11 year old palms.

2. A definite pattern of correlation between soil phosphorus and leaf phosphorus was not observed. In 3, 11 and 15 year old palms the soil phosphorus did not influence leaf P content. In 7, 9 and 13 year old palms there was significant correlation between soil P and leaf P.

3. There was significant positive correlation between soil K and K in the leaf in all age groups except three year old palms.

4. The calcium contents of 7, 9, 13 and 15 year old palms were found to have a high correlation with soil calcium. No correlation between soil calcium and leaf calcium were noticed in 3 and 11 year old palms. Eighty five per cent of the variation is attributed to soil calcium in nine year old palms.

5. In most of the age groups investigated no significant correlation was observed between soil Mg. and leaf Mg. Highest significant correlation (81%) was observed in 13 year old palms followed by 7 year old palms.

6. For micronutrients, Zn and Cu there was no definite pattern of correlation between soil and leaf content.

Content of nutrients in different frond positions and soil nutrient content

Correlation coefficient between soil and nutrient contents of 1st, 9th, 17th, 25th and 33rd fronds were worked out. Result obtained shows that the correlation between the nutrient content of 17th frond and the soil nutrient content was found to be significant for nitrogen, potassium and magnesium. Nitrogen showed the highest correlation (0.8283) at 1 per cent level. In the case of zinc and copper eventhough there was correlation with the

17th frond, the values were not significant. With regard to phosphorus, some positive correlation, though not significant could be observed with reference to 9th, 17th, 25th and 33rd fronds. For calcium significant positive correlation in the case of 1st, 9th and 17th fronds could be obtained.

Yield and nutrient concentration

The contribution of different nutrient elements towards yield was assessed using correlation and path analysis. The correlation of yield with leaf nitrogen ($r = 0.6618$) and potassium ($r = 0.6533$) was found to be highly significant and positive. Plant phosphorus was found to be correlated with yield at 10 per cent level of significance only. Calcium and magnesium were found to have no correlation with yield. The maximum direct effect of leaf nitrogen towards yield was 53 per cent followed by K (52%) and magnesium (35%). The direct effects of P and Ca were only 2 and 5 per cent respectively. The direct and indirect influences of leaf nutrients contributed to 43 per cent towards yield.

In the light of the fact that no investigation on the fertility status of oil palm growing soils and the leaf concentration of nutrient elements has been taken up so far by anyone in Kerala, it can be said that the present investigation has yielded some valuable information. The clues obtained point to the fact that monitoring of the nutritional status of the soil coupled with leaf analysis will be of very great help in formulating a schedule for fertilizer application. Based on all the data obtained N was found to contribute much towards its content in palm and yield followed by K. Higher nutrient content in young palms points to the fact that the demand for the nutrients during the initial growth period of the palm is great and that sufficient care is to be taken in maintaining a higher nutrient status in the soil during the earlier growth period upto 7 years to prepare them for heavy bearing during the later years. The role of calcium and phosphorus in yield is found to be minimal. This does not necessarily warrant a neglect in supplying these major elements. Both calcium and phosphorus are seen in higher proportion with advancing age of the palm. This may be due to their accumulation in the tissues as a function of time. An initial heavy dose of slowly available P is worth trying. Since most of the areas and palms sampled were standing on unfertilised soils, the full capacity of the palms in the uptake and utilisation of the nutrients will not be reflected in the data obtained in the present investigation. The role of phosphorus and calcium in oil palm nutrition requires further elaborate studies.

Further, no conclusion could be drawn on the role of zinc and copper presently studied. A seperate comprehensive investigation on all essential micronutrients, with regard to their availability, uptake utilization and effect on yield has to be undertaken. Further, some trials with graded levels of major plant nutrients N, P, K, Ca and Mg at different locations for a number of years will definitely help in the formulation of better fertilizer schedule for palms of different age groups and location. This can be done as a continuous phased programme.

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* Originals not seen

Appendices

APPENDIX - I

Abstract of analysis of variance table on the effect of age of palms on concentration of nutrients in fronds

Source	df	N	P	K	Ca	Mg	Zn	Cu
Between age groups	5	0.4581**	0.0016**	0.1046**	0.0562**	0.0384**	405.52**	7.84NS
Within age groups	66	0.0151	0.0005	0.0246	0.0083	0.0048	43.92	3.16
Total	71							

** Significant at 1 per cent level

APPENDIX - II

Abstract of analysis of variance table on the effect of age of fronds on nutrient concentration

Source	df	N	P	K	Ca	Mg	Zn	Cu
Between fronds of different age	4	0.7777**	0.0138**	2.8899**	0.0333**	0.0435**	14594.82**	136.8178**
Within fronds of different age	55	0.0366	0.0001	0.0567	0.0088	0.0093	823.9628	7.6264
Total	59							

** Significant at 1 per cent level

NUTRITIONAL STATUS OF SOILS IN RELATION TO FOLIAR NUTRIENT LEVELS IN OIL PALM

By

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ABSTRACT OF THE THESIS

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ABSTRACT

An investigation was taken up in oil palm grown in the plantation of oil palm India Limited at Yeroor (Bharathipuram) of Quilon district, with a view to evaluating the nutritional status of oil palm growing soils in relation to leaf nutrient content. Different age groups and different frond positions were included in the studies. Correlation between nutrient content in soil to that of leaf content, age of fronds and nutrient content in leaves, age of palms and leaf nutrient concentration and nutrient content in the soil to that in the leaf tissue were worked out. Correlation between yield and leaf concentration was also worked out using data and samples collected from the CPCRI Research Station at Palode.

There was significant correlation between age of palms and concentration of N, P, K, Ca, Mg and Zn while no significant correlation was obtained in the case of Cu. N, K, Mg, Zn and Cu showed a decreasing trend with increasing age of palms. But P and Ca content of leaf tissue increased with increase in age of palms. Maximum amount of all the nutrients was found in 3 year old palms. All elements

except Ca decreased significantly with age of fronds. Maximum concentration of nutrient was found in the first frond while it was minimum in the 33rd frond. Calcium content showed the opposite trend.

There was significant positive correlation between leaf N and soil N in all the age groups studied. The correlation between soil P and leaf tissue P did not show a regular pattern. There was significant positive correlation between soil K and leaf K content in almost all age groups. Calcium contents of 7, 9, 13 and 15 year old palms were found to have a significant correlation to soil Ca, whereas such correlation was not found in 3 and 11 year old palms. No significant correlation was observed between soil Mg and leaf Mg in most of the age groups. Micronutrients Zn and Cu did not reveal any definite pattern of correlation between the soil and leaf contents.

Correlation between the soil N, K and Mg content was highly significant with reference to their content in the 17th frond. The correlation coefficient values with reference to P content in soils in relation to the 17th frond was not found to be statistically significant. For Ca, significant positive correlation could be obtained between the soil content and leaf tissue content in the 1st, 9th and 17th fronds. There was highly positive correlation between yield and N and K in the leaf. Maximum direct effect of N on yield was worked out to be 53 per cent and that of K 52 per cent. Calcium and magnesium content of leaf was not found to be correlated with yield. But after N and K, the direct contribution of Mg towards yield was found to be 35 per cent. Direct effect of P and Ca on yield was found to be the extent of 2 and 5 per cent only.