

GROWTH AND MINERAL NUTRIENT STATUS OF OIL PALM
(*Elaeis guineensis* L. Jacq.) AS INFLUENCED BY
FERTIGATION AND INTERCROPS

BHOJARAJA R.

DEPARTMENT OF CROP PHYSIOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE

1996

ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ
ವಿಶ್ವವಿದ್ಯಾನಿಲಯ ಗ್ರಂಥಾಲಯ
ಗಾ.ಕೃ.ಪಿ.ಐ., ಬೆಂಗಳೂರು-65

- 7 MAY 1996

Tk. 4080

ಅನುಸ್ಥಾನ ಸಂ.....

ಪು. ಸಂ.....

GROWTH AND MINERAL NUTRIENT STATUS OF OIL PALM
(*Elaeis guineensis* L. Jacq.) AS INFLUENCED BY
FERTIGATION AND INTERCROPS

BHOJARAJA R

Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
for the award of the Degree of

Master of Science (AGRICULTURE)

in
CROP PHYSIOLOGY

BANGALORE

MARCH 1996

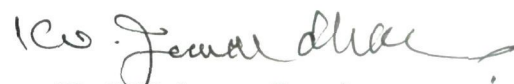
Affectionately Dedicated to
My Beloved Parents
& Late. Raghurama Reddy

**DEPARTMENT OF CROP PHYSIOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE**

CERTIFICATE

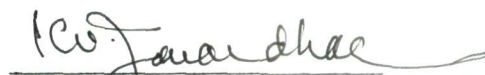
This is to certify that the thesis entitled "GROWTH AND MINERAL NUTRIENT STATUS OF OIL PALM (Elaeis guineensis L. Jacq.) AS INFLUENCED BY FERTIGATION AND INTERCROPS" submitted by BHOJA RAJA R. in partial fulfillment of the requirements for the degree of "MASTER OF SCIENCE (AGRICULTURE) in CROP PHYSIOLOGY" to the University of Agricultural Sciences, Bangalore is a record of research work carried out by him during the period of his under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or other similar titles.

BANGALORE
March, 1996


(Dr. K.V. Janardhan)
Major Advisor, Professor
Dept. of Farm Forestry

Approved by :

Chairman:

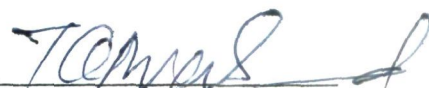

(Dr. K.V. Janardhan)

Co - Chairman:

(Dr. A.S. Kumaraswamy)

Members:

1. 
(Dr. M. Udayakumar)

2. 
(Dr. T.G. Prasad)

3. 
(Mr. G.N. Gajanana)

ACKNOWLEDGEMENT

I have immense pleasure in expressing my deep sense of indebtedness and gratitude to Dr.K.V.Janardhan, Professor, Department of Farm Forestry . I remain highly obliged to him for his invaluable and excellent guidance, manifold assistance, critical processing of the thesis manuscript, constant encouragement and magnanimous and untiring help throughout the course of this study, but for which the completion of the present work would have been far from reality.

I am equally grateful to Dr. M. Udayakumar, Professor and Head, Dept. of Crop Physiology and member of my Advisory Committee, for his valuable guidance, immense care and interest, critical suggestions and for his inspiring words.

I wish to express my whole hearted and sincere thanks to the members of my advisory committee, Dr.T.G.Prasad, Professor, Dept. of Crop Physiology, Dr. A.S.Kumara Swamy, ADR, Bramhavar and Gajanan, Associate Professor, Dept. of Soil Science and Agricultural Chemistry, Bangalore, for their technical guidance, encouragement and suggestions for improvement.

I avail this opportunity to express my gratitude to all teachers and staff of the Dept. of Crop Physiology for their help, co-operation and for making the working environment a memorable one.

My heartfelt thanks to Nataraj and Gurumurthy and Chandrashekara for their help during my Research work at Shimoga.

My special thanks to Dr. Shesha, Dr. Patil, Dr. Nanjareddy for their constant encouragement and cooperation.

I wish to thank Gani, KP, Ramu, Nattu, Purshi, for their support during my study.

A special word of thanks to Dhanu, Vincy, Gangadhar, Muni, Savitha, Keshava and Padma for their help during my research and thesis typing.

A special mention of my gratitudes to all my classmates Kulku, Giri, Bindu, Ashwini, Gopi, Mukund, Mukesh, Nagu, Ashok, Nagaraj, Tara, Sadanand.

I am also thankful to my friends Ashok, Umashankar, Jayamohan, Veerender, Vinayaka, Jayaprakash, Krishna murthy, Harsha, Sreedhara, who helped a lot during my research work.

Expressing a mere word of thanks to my beloved Parents, Brothers and Sisters would only dilute all my gratitudes and commitment I have to them. I owe my success to them and I shall be ever grateful.

Finally I would like to extend my thanks to V.K. Abraham, Chintamani, Venkatesh, Mathew and all the members of Karnataka Oswal Oil Palm Ltd. at Bhadravathi and Shimoga for their help during my research work.

Bangalore,
March, 1996.


(BHOJARAJA R.)

CONTENTS

Sl. No.	TITLE	PAGE
I	INTRODUCTION	1-3
II	REVIEW OF LITERATUE	4-35
III	MATERIALS AND METHODS	36-61
IV	RESULTS	62-108
V	DISCUSSION	109-125
VI	SUMMARY	126-129
VII	REFERENCES	130-138

LIST OF TABLES

Table No.	Title	Page
1.	Amount of fertilizers and other nutrient sources applied to soil and through drip system.	39
1a.	Preparation of fertigation mixture per palm having 10:5:10 ratio of N:P:K.	40
2a.	Schedule and time of application of various nutrient sources for different treatments (g/palm/time) in soil application.	41
2b.	Schedule and time of application of various nutrient sources for different treatments (g/palm/time) in fertigation.	42 & 43.
3.	Amount of fertigation mixture used per palm and total number of palms in a treatment (ml/month).	46
4.	Progressive leaf number and RLER during different periods of observation (no./no./month $\times 10^{-2}$).	63
5.	Growth characteristics as influenced by increased levels of nutrients to soil and through drip (November 1995).	65
6.	Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Nitrogen' content (%DW) in different leaf positions of young palms.	67
7.	Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Phosphorous' content (%DW) in different leaf positions of young palms.	70
8.	Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Potassium' content (%DW) in different leaf positions of young palms.	73
9.	Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Calcium' content (%DW) in different leaf positions of young palms.	76

10.	Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Magnesium' content (%DW) in different leaf positions of young palms.	78
11.	Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Iron (ppm)' content (DW) in different leaf positions of young palms.	81
12.	Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Zinc (ppm)' content (DW) in different leaf positions of young palms.	83
13.	Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Manganese (ppm)' content (%DW) in different leaf positions of young palms.	86
14.	Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Copper (ppm)' content (DW) in different leaf positions of young palms.	88
15.	Soil nutrient status of young oil palm gardens as influenced by increased application of fertilizers to soil and through fertigation.	90
16a.	Effect of application of increased levels of nutrients to soil and through drip irrigation on soil nutrient availability (at the end of expt. period). Major and secondary nutrients.	95
16b.	Effect of application of increased levels of nutrients to soil and through drip irrigation on soil nutrient availability (at the end of expt. period). Micronutrients.	97
17.	Growth characteristics of oil palm as influenced by different intercrops during November 1995.	99

18a.	Leaf nutrient status of maturing oil palms as influenced by the intercrops (Major and secondary nutrients).	101
18b.	Leaf nutrient status of maturing oil palms as influenced by the intercrops (Micronutrient).	102
19a.	Soil nutrient status of maturing oil palm garden as influenced by intercrops (avail. N and P).	105
19b.	Soil nutrient status of maturing oil palm garden as influenced by intercrops (exch.K, and avail. Ca and Mg).	106
19c.	Soil nutrient status of maturing oil palm garden as influenced by intercrops (avail. Fe and Mn).	107
19d.	Soil nutrient status of maturing oil palm garden as influenced by intercrops (avail. Cu and Zn).	108
20.	Comparative optimum nutrient status for oil palm leaves.	114
21.	Relationship between growth parameters and leaf (9th) nutrient contents.	116
22.	Nutrient interrelations in leaf 9 of young oil palms.	118
23.	Estimates of best element ratios in oil palm.	120.

LIST OF FIGURES

Fig. No.	TITLE	BETWEEN PAGES
1a.	Nitrogen content in leaf 2.	68-69.
1b.	Nitrogen content in leaf 9.	68-69
1c.	Nitrogen content in leaf 16.	68-69
1d.	Nitrogen content in different leaves.	68-69
2a.	Phosphorous content in leaf 2.	71-72
2b.	Phosphorous content in leaf 9.	71-72
2c.	Phosphorous content in leaf 16.	71-72
2d.	Phosphorous content in different leaves.	71-72
3a.	Potassium content in leaf 2.	73-74
3b.	Potassium content in leaf 9.	73-74
3c.	Potassium content in leaf 16.	73-74
3d.	Potassium content in different leaves.	73-74
4a.	Calcium content in leaf 2.	76-77
4b.	Calcium content in leaf 9.	76-77
4c.	Calcium content in leaf 16.	76-77
4d.	Calcium content in different leaves.	76-77
5a.	Magnesium content in leaf 2.	79-80
5b.	Magnesium content in leaf 9.	79-80
5c.	Magnesium content in leaf 16.	79-80
5d.	Magnesium content in different leaves.	79-80
6a.	Iron content in leaf 2.	82-83
6b.	Iron content in leaf 9.	82-83
6c.	Iron content in leaf 16.	82-83
6d.	Iron content in different leaves.	82-83

7a.	Zinc content in leaf 2.	84-85
7b.	Zinc content in leaf 9.	84-85
7c.	Zinc content in leaf 16.	84-85
7d.	Zinc content in different leaves.	84-85.
8a.	Manganese content in leaf 2.	86-87
8b.	Manganese content in leaf 9.	86-87
8c.	Manganese content in leaf 16.	86-87
8d.	Manganese content in different leaves.	86-87
9a.	Copper content in leaf 2.	88-89
9b.	Copper content in leaf 9.	88-89
9c.	Copper content in leaf 16.	88-89
9d.	Copper content in different leaves.	88-89.

LIST OF PLATES

PLATE No.	TITLE	BETWEEN PAGES
1	Method of feeding the fertigation mixture to oil palm.	44-45.
2a & 2b	Arrangement of microtubes for feeding fertigation mixture.	44-45.
3a	Various intercrops planted at KOOL.	58-59.
3b	Oil palm alone.	58-59.
3c	Oil palm + Coffee + Banana.	58-59.
3d	Oil palm + Banana + Arecanut.	58-59.
3e	Oil palm + Arecanut.	58-59.
3f	Oil palm + Banana.	58-59.
3g	Oil palm + Sugarcane.	58-59.
3h	Oil palm + Puerarea as cover crop.	58-59.

ABBREVIATIONS

AAS	: Atomic Absorption Spectrophotometr.
APB	: At the palm basin.
AWPB	: Away from the basin.
CPCRI	: Central plantation Crops Research Institute.
CuSO ₄	: Copper Sulphate.
FeSO ₄	: Ferrous Sulphate.
FFB	: Fresh Fruit Bunches.
ICAR	: Indian Council of Agricultural Research.
KOOL	: KArnataka Oswal Oil Palm Ltd..
MgSO ₄	: Magnesium Sulphate.
MnSO ₄	: Manganese Sulphate.
MOP	: Muriate of potash.
RLER	: Relative Leaf Emergence Rate.
SSP	: Single super phosphate.
VDM	: Vegetative dry matter.
ZnSO ₄	: Znic Sulphate.

INTRODUCTION

I. INTRODUCTION

Nine cultivated annual oilseeds crops namely groundnut, sunflower, safflower, soybean, linseed, rapeseed, mustard, niger and castor contribute to 80 per cent of India's vegetable oil production of edible and non edible oils. The demand for vegetable oil during the past two decades has increased at the rate of 5 per cent per annum, while the supply has increased at the rate of 2 per cent. The production of oilseeds in the country has not been able to keep pace with the increasing demand, necessitating import of vegetable oils including palm oil or palmolein. In recent years India has been exploring the possibility of cultivating Oil Palm, the richest source of vegetable oil.

Oil palm is heavy consumer of fertilizers and of the significant research contributions to oil palm production is the recognition of adequate fertilization for maximum production. However, with increased cost of fertilizers and labor wages, the success of oil palm cultivation is being threatened.

Fertilizers in India are generally granular, prills and powder form which are applied by various methods such as: band application, broadcasting and drilling. The fertilizers applied by these methods are liable to leaching out by heavy rains, flood irrigation, and also

volatilization due to heat .This can be avoided by applying the fertilizers through drip or micro/sprinkler irrigation systems.This concept is termed as 'Fertigation'. Fertilizers applied through irrigation water reaches the site where the active roots are concentrated which enables easy absorption and thus efficient utilization can be achieved.

Fertigation which combines irrigation with fertilizer application is well recognized as the most effective and convenient means of maintaining the optimum fertility level and water supply according to the specific requirement of each crop and soil, resulting in higher yields and better quality of crop.Moreover in areas with insufficient rainfall, fertigation offers the best and sometimes the only way to ensure that nutrients enter the root zone.

The fertigation irrigation system can be had by following ways, viz, drip system, sprinklers and jets. There is a general feeling that the economy of fertilizer application could be achieved by drip system.

Drip irrigation system is modern means of irrigation system which includes fertilizers as an integral part of the system. Fertilizers and water are uniformly and simultaneously supplied to the root system in quantities required as per the plant needs. One important prerequisite for this system however, is the availability of completely water soluble fertilizers.

Among the peninsular states, command irrigated areas

of Karnataka along with Kerala, Andhrapradesh and Tamilnadu were considered suitable for the oil palm cultivation (Rethinam and Chadha, 1992). It was also recognized that irrigation and fertilizer application was most important in the successful cultivation of the oil palm.

Though intercropping is not a normal practice in oil palm plantations, there is a ample of scope for intercropping during the initial years of oil palm plantations, mainly to get income during juvenile period. Growing food crops in oil palm plantations is common in Africa. In American oil palm plantations grazing of cattle or sheep is also practiced (Nair and Nampoothri, 1992).

Intercropping with tropical tubers as well as chillies, tobacco, coffee(robusta), and banana is possible in India. From the trials conducted at CPCRI Palode, cacao was found to come up very well in oil palm plantations without any adverse effect on yield of oil palm.

With these information in background the present investigations were carried out on the farm of Karnataka Oswal Oil Palm Ltd.. Karehally, Bhadravathi(Tq), Shimoga (Dist.) Karnataka state with the following specific objectives:

1. To assess the growth and mineral nutrient status of young oil palms as influenced by the application of fertilizers to soil and through drip system (fertigation).
2. To study the effect of intercrops on growth and mineral nutrient status of oil palm.

REVIEW OF LITERATURE

11. REVIEW OF LITERATURE

The oil palm Elaeis guineensis L. Jacq., is grown commercially in Africa, Equatorial America, South East Asia and South Pacific and on a small scale in the other countries. The African oil palm was named as Elaeis guineensis by Jacquin (1763) and the name for American oil palm is Elaeis oleifera (H. B. K.) Cortes. The hybrids of E.oleifera shows dominance over E.guineensis for several characters suggesting that E.oleifera is more primitive and E.guineensis represents a derived species (Hardon, et. al., 1969).

The oil palm is newly introduced oil yielding crop in the country and hence oil palm research in India is in infant stage. Very little information is available with regards to growth, productivity and mineral nutrition under Indian conditions. The first research station for oil palm was started at Thodupuzha, Kerala during 1960. The ICAR started systematic research on oil palm at CPCRI research center with its location at Palode, Kerala during 1975. The major research activities are going on at CPCRI research center Palode, and coordinating centers (Rethinam and Chadha, 1992). Hence, whatever information is available under Indian situation right now are all originated at CPCRI, Palode, Kerala. Keeping this in view the objectives envisaged, and the literature originated both in India and also abroad are reviewed in this chapter.

Botany and morphology of oil palm

The oil palm is commercially raised in Africa, Equatorial America, South East Asia, South Pacific and other places. The center of origin appears to be Africa but exact place within Africa is not known (Hartley, 1977). The genus *Elaeis* belongs to *Palmae* and is grouped with *Cocos* and other genera under the tribe *Cocoinae* (Corley and Gray, 1976).

Oil palm has a single stem with a single vegetative growing point situated in the depression at the stem apex and is continuously active, producing leaf primordia. The mass of young leaves and leaf bases are together called 'Cabbage'. In oil palm the leaf primordia are produced in a spiral pattern at apex.

The oil palm leaf is pinnate with linear leaflets on each side of leaf stalk and are arranged laterally in upper and lower ranks, leaving a shaggy appearance. Each leaf will have about 250-300 leaflets and annually a mature palm produces about 25 leaves (Pillai and Ponnammma, 1992). The leaf takes about 2 years to develop and become photosynthetically active (Corley, 1973). In each axil, there is an inflorescence primordia and being a monoecious plant the male and female inflorescences are produced in cycles of variable duration. The female inflorescence develops into fruit after pollination and fertilization.

The fruit of oil palm is a drupe consisting of peri-

carp which is in turn made up of exocarp (skin), mesocarp (often wrongly called pericarp) and endocarp (shell) surrounding usually one, but sometimes up to four kernels. Oil is contained in mesocarp as well as in the endosperm of ripe fruit, differing in their composition, and extracted separately for commercial use. The oil content in mesocarp is highest ranging from 17-18 per cent in Dura types and 22-24 per cent in Tenera palms (Pillai and Ponnammam, 1992).

Growth of oil palm

Though oil palm is considered a humid tropical crop, it can tolerate a wide range of pedoecological conditions. It is found to grow well on a variety of soils. However, deep and well drained, medium textured soils rich in humus content are considered ideal. Oil palm requires evenly distributed annual rainfall of 2000 mm without a defined dry season since it is continuously growing and yielding all through the year. Though crop can withstand 3 to 4 months of dry period, continued moisture stress affects yield adversely, unless augmented with copious irrigation (Varghese and Cecil, 1992).

Temperature can be a limiting factor for oil palm production as it influences inflorescence production, initiation of flower primordia, sex differentiation, anthesis, floral abortion and growth rates of oil palm. Prolonged cooler temperatures with less than 19°C reduces the growth rates and leaf production considerably. More number of male inflorescences are produced under low minimum

temperature. Best oil palm yields are obtained in places where maximum average temperature of 29-33°C and minimum average temperature of 22-24°C are available. Higher diurnal temperature variation causes floral abortion in region with dry season (Verghese and Cecil, 1992) .

The crop requires 1800-2000 sunlight hours annually for production of good yield. The oil palm growth and yield will be drastically reduced when solar radiation levels fall below 350 longleys (cal/cm²/day). Constant sunlight of at least 5 hrs/day is required for better oil palm yield (Verghese and Cecil, 1992) .

A study of the growth of adult oil palm is of particular importance in view of the large differences in bunch yield found between regions where oil palm is planted as an economic crop. Accurate measurements of these organs have been made on palms of different ages in both west Africa and Malaysia and rate of dry matter production, crop growth rates and other growth parameters have been estimated from this data (Rees and Tinker ,1963 ;Corley et al, 1971a) .

For obvious reasons destructive methods can not be widely employed. But Corley et al (1971 b) evolved a non destructive method of estimating annual dry matter production which can be used in comparison of growth between progenies, environment or agronomic treatment and which make possible a considerable extension of growth analysis methods in oil palm investigations.

These methods cover only leaves, trunk and bunches but these organs were found to contribute over 96% of total annual dry matter production. High correlations between certain measurements and the actual dry matter content of various organs led to the following formulae being adopted:

Leaf area : $L = b(n \times lw)$ where 'n' , number of leaf lets, lw, mean of length x mid width for a sample of largest leaflet, and b - the correction factor i.e 0.55. This factor was found to range from 0.51 to 0.57 with age group from 1 - 2 to 8 - 11 years but for most comparison the figure 0.55 is used (Hardon et al., 1969).

Leaf dry weight (Kg) : $W = 0.1023 P + 0.202$, where P = petiole width x depth in cm^2 . The width and depth of the petiole are measured at the junction of the rachis and petiole, i.e the point of insertion of the lowest leaflet.

Trunk dry weight : $Tr = VS$ where 'v' is the volume of trunk and 's' is the density of dry trunk in g/l. The annual growth increment of trunk is represented by a cylinder, the volume of which is estimated from its diameter, after removal of all the leaf bases and its height. Thus $V = \pi \times (d/2)^2 h$. while the density $S = 7.62 T + 83$ where T is the age of the palm in years from transplanting. This method is accurate for measuring total dry weight increase and it is not directly applicable for measuring total dry weight of palm since the base is conical and the density of dry trunk has been found to increase from apex to base.

Bunch dry weight : $D = 0.5275 F$ where F is fresh bunch weight in kg (Hardon et al., 1969, Corley et al., 1971 b and Hartley 1977).

From the gross weight of the plant parts either directly measured or estimated through the above formulae and from records of bunch and leaf production and trunk height in increments, it is possible to estimate annual production of leaf, trunk and bunch dry matter.

The sum of all yield components above mentioned in terms of dry matter can be related to leaf area to give net assimilation rate (E) or to the land area to give the crop growth rate (Hartley , 1977).

Comparision between Malaysian and Nigerian data has shown that the large difference in CGR are mainly attributed to incorporation of large quantity of dry matter in bunches and that the vegetative dry matter (VDM) production is broadly similar (Ng et al., 1968; Corley et al., 1971 a).

Under the good growing condition of Malaysia, CGR increases rapidly to about 30 tonnes / ha/ annum in around seven years at usual plantations spacings, but at high density a CGR of upto 40 tonnes / ha / annum is attained (Hartley , 1977).

Nutrient requirement of oil palm:

Oil palm is a heavy consumer of fertilizers and requires rational manuring for maximizing the production and stabilizing the yields over time. Large number of manurial experiments were conducted in all parts of major oil palm growing countries of the world (Ollagnier *et al.*, 1970; Hartley 1977). However, such trials are meager under Indian situations.

Field experiments with fertilizers are the primary means of detecting and determining nutrient need, but these may be assisted by using methods of plants and soil analysis (Hartley, 1977). Leaf analysis for diagnostic purpose has been particularly useful in perennial crops including oil palm which are relatively slow growing.

Leaf tissue analysis as diagnostic tool to study the uptake pattern of individual of plant nutrient and its consequent effects on growth and yield has been possible mainly through the works of Chapman and Gray (1949), Prevot and Ollagnier (1959). In India pioneering work in this regard have been made by Nair (1981) and Nair and Sreedharan (1982).

Gradient according to the leaf:

It has been known that the element level vary with the rank of leaf: the N content increases from leaf 1 to leaf 9 and decreases ; the P and K levels decreases whilst the Ca and Mg content increases (Prevot and Peyre de Mont-

bredton, 1958). The existence of gradient necessitates sampling of leaf of known rank so as to guarantee the homogeneity of the sample. If the same rank of the leaf is always chosen it becomes possible to compare the situation, provided gradients are same from one situation to another situation (Ochs and Olivin, 1976).

Selection of Index leaf for foliar analysis:

Since the oil palm has 3/8 phyllotaxy fronds 1,9,17, 25 and 31 are beneath one another and can be readily located for routine sampling. Fronds from this series were therefore mainly used for foliar analysis. The variation in different parts of the same pinna both longitudinally transversely for the central four pinnae of 9 and 17 (Chapman and Gray, 1949).

The critical levels were established for leaf of rank at 17 and these leaves were adjusted to the leaf of rank 9 by Bachy (1964).

Foliar diagnosis can thus be used, on plants older than a year or two by sampling leaf 9 when leaf 17 does not exist or in poor condition (Ollagnier et al., 1970).

Nutrient demand by oil palm:

Sufficient data are available for the total nutrient demand of oil palm, which however vary with locality and certain crops. Based on the data obtained from Malaysia (Ng et al., 1968) and also by Ollagnier et al (1970) three types of demand were distinguished :

- a. Nutrient removed from the area entirely, as in fruit bunches,
- b. Nutrient taken up and not returned by the palm, since they are immobilized in palm itself; and
- c. All the nutrients recycled to the soil in leaf litter, dead leaves and male inflorescences.

a and b is a measure of long term depletion of soil, a+b+c are the immediate rate of supply of the roots which the soil must be able to provide. A soil must thus be able to supply some 1.3 kg N, 0.2 kg P and 1.8 kg K to each palm per year of which about 60 per cent is predominated from the soil (Tinker, 1976).

Nutrient removal by oil palm:

The nutrients removed by oil palm per annum per year vary greatly depending on soil and climatic factors. The nutrient removal by oil palm in twenty years in Nigeria was 460, 160, 340, 260 and 234 kg N, P, K, Mg and Ca per ha respectively (Tinker and Smilde, 1963) where as in Malaysia the removal was 960, 80, 1300, 290 and 40 kg N, P, K, Mg and Ca per ha respectively (Ng, 1968).

According to Ollagnier et al (1970) the nutrient removal of oil palm was 30, 7, 18, 13 and 10 kg N, P, K, Ca and Mg per ha per year respectively.

Ng (1976) estimated that the annual uptake of N, P, K and Mg by 8 to 10 years old palms was 192.5, 26.0, 251.5 and 61.3 kg per ha respectively.

Tinker and Smilde (1963) estimated the N,P,K and Mg requirement of oil palm plantation in Nigeria yielding 9.6 tones of fresh fruit bunches per ha per year and found to be 0.2, 0.04, 0.23 and 0.03 kg per palm per year respectively. Under Malaysian condition NPK and Mg requirement were 0.49,0.08,0.63 and 0.14 kg per palm per year respectively for plantations yielding 15 tons per ha (Ng and Thamboo, 1966)

The Indian experience show that application of N at 800 g, P₂O₅ at 400 g and K₂O at 1800 g per palm per year is essential for maximum production of FFB (Nair and Sreedharan, 1980). Based on the results of long duration experiments, a fertilizer schedule of 800:400:1800 g of N, P₂O₅ and K₂O respectively per palm per year was recommended for oil palm in Kerala (Nair and Sreedharan, 1981).

Effect of mineral nutrients on growth and yield of oil palm:

Nitrogen :

Nitrogen exerts a major role in controlling the growth and fruiting of oil palm and it is commonly required for rapid growth of oil palm in field (Hartley, 1977).

A higher rate of leaf production and total number of leaves per palm with increase application of Nitrogen was reported by Rosenquist (1962), Corley and Mok (1972), Nair and Sreedharan (1982).

The increased growth rate was attributed to the higher uptake from soil due to fertilization as evidenced by higher leaf nitrogen content (Nair and Sreedharan, 1982).

Vegetative dry matter (VDM), crop growth rates (CGR - which is the sum of VDM and Y), net assimilation rate (NAR) and even leaf area index (LAI) was found to be increased in response to nitrogen (Corley and Mok, 1972). Conflicting results have been reported on effect of N on reproductive growth. Female flower production was found to be decreased by nitrogen application due to high photosynthetic activity or high C/N ratio of plants (Biernaert, 1935).

Sparnaaij (1960) supported this view and opined that increase in nitrogen application reduced sex ratio. Similar results were reported stating that N application influenced male inflorescence. A high reduction in sex ratio was noticed by increased level of NPK (Nair and Sreedharan, 1982).

Warriar and Piggot (1973) observed that the number of bunches and the weight of the bunches increased in plots with N fertilization. They found that bunch number and bunch weight were highest in plots treated with 12.2 lb of N, 10.6 lb of P and 25.4 lb of K and 27.1 g of Mg.

Several workers (Van der Vossen, 1970; Green, 1972; Tan, 1976 and Nair, 1981) observed favourable responses to

nitrogen application in yield of oil palm.

Sparnaaij (1960) reported that an increase in trend in number of bunches was noticed with higher levels of N, P and K. The increased female flower production was might attributed to high ratio of carbon assimilation and N had an important role in this phenomenon. This influenced N content in tissues receiving higher levels of N.

Phosphorus;

Phosphorus manuring is pivotal in oil palm fertilization (Comhaire, 1968). Phosphorus is required for full expression of qualitative characters in oil palm (Ollagnier et al, 1970).

The experiments in Africa showed that P was needed only after several years of bearing (Hartley, 1977). Significantly higher number of fronds was noticed with rock phosphate at the rate of 1.36 kg per palm per year compared with 0.68 kg and 2.72 kg per palm per year (Tan, 1976).

Positive and relatively constant responses to phosphatic manures to the extent of 17 per cent in a 12 year old plantations and 9 per cent in 13 to 17 year old plantations was observed in Ivory Costs (Chapman and Gray, 1949). In volcanic soils of Sumatra, P application increased bunch yield to 12 to 20 tons per ha (Werkhoven, 1965). Bachy (1968) reported response to dicalcium phosphate at 2 kg per palm per year when soil P was very low.

Substantial yield increase was obtained in colonial alluvial soils of Malaysia with 3.8 kg of rock phosphate per palm per year (Mollegård, 1971). Lo et al., (1973) showed that the lowest level of P fertilization (5 lb per palm) had produced the highest yield in soils derived from granite.

Umar Akbar et al., (1976) observed a production of 34 kg bunches with 3 kg super phosphate per palm per year which was 32 per cent more than the control. Nair (1981) reported significant yield for 400 g of P_2O_5 per palm per year. The results obtained from the Cameroon soils derived from basaltic flows where P response was obtained at early growth stages (Green, 1972).

The application of P was profitable in all the soils except alluvial and peat in Malaysia (Foster and Goh, 1976). P is required in specific soil and produced large increase in yield in such soils (Hartley, 1977). However, on examination of results from Zaire, Vanderweyen (1952) noted lack of response to P due to its fixation in soils.

There was a significant increase in weight of FFB by application of 400g of P. It also increased the rate of leaf production and the number of functional leaves per palm. The higher number of leaves produced by P might have also favoured female flower production (Nair and Sreedharan, 1982).

Potassium :

Potassium is considered a fundamental element in manuring of oil palm and generally its requirement to the crops is a must under varying situations (Ollagnier et al., 1970.; Hartley, 1977).

Tan (1973) reported that in Malaysia, application of 3.63 kg of muriate of potash per palm produced highest number of leaves and also observed that maximum potash would be required for frond protection.

The Rengam soils of Malaysia recorded increase in dry matter production, leaf area index and crop growth rate by K application (Corley and Mok, 1972).

Mollegaard (1971) found that potash application increased male flower production, consequently low sex ratio. He further noted increased bunch weight and bunch number with increased K fertilization.

Response of K fertilization was also reported by others (Bachy 1968; Hew and Poon, 1973). A linear increase for K dressing upto 5 Kg potassium chloride per palm per year was noticed in Malaysia (Hew et al., 1973). Breure and Rosenquist (1976) reported that muriate of potash significantly increased the yield and the production had reached 17 per cent of FFB by fourth year of yield. Muriate of potash at 5.46 kg per palm per year produced significantly higher yields in early stages. But after 9th year

murate of potash 2.73 kg per palm gave the highest yield. Significantly increased yield was obtained with 1.8 Kg of K_2O per palm per year in an 8 year old plantations of Kerala (Nair, 1981).

Potassium application at highest level gave significant increase in weight of FFB, this could be due to the increased photosynthetic activity of palm due to K fertilization (Nair and Sreedharan, 1982).

The beneficial effect of K dressing were the increased leaf area and improved leaf angle resulting in better utilization of sunlight and ultimately more photosynthesis (Von Uex Kiill, 1971).

Calcium :

Ollagnier et al (1970) in their review on manuring of oil palm in the world mentioned that not much work has been done on calcium nutrition of oil palm. However, one experiment conducted at the united plantation in Malaysia showed that there was an increase in yield to the extent of 10 per cent by the application of calcium (Hartley, 1977). Nair (1981) however showed lack of response to calcium. in Kerala state of India.

Nair and Sreedharan (1982) reported that calcium and magnesium fertilizer did not increase the weight of FFB. The lack of response might be due to their high content in the soil (600 and 200 ppm respectively) and also it might be attributed to high foliar content of these elements

above critical levels of 0.60 percent and 0.24 per cent for Ca and Mg as suggested by Ollagnier et al (1970).

Magnesium :

Mg as a constituent of chlorophyll has an important role to play in the physiology and yield of oil palm. The frond production in oil palm increased by the application of Magnesium chloride (Breure and Rosenquist, 1976. But the female flower production was not improved by Mg application in forest soils (Chan and Rajaratnam, 1976). similar results were obtained by Nair (1981) also. Tan (1976) observed more number of aborted bunches at higher levels of Mg.

Yield improvement resulting from the application of Mg to different palms was observed by Ferwerda (1955) in Ivory Coast. Gunn (1962) found response for 3.41 kg per palm per year of Magnesium sulphate and response to the application of 1 kg of Keisierite per palm per year in oil palm was noticed by Green (1972). A cumulative yield of 35.58 tons per ha in four year with 2.72 kg MgSO₄ per palm per year was obtained in Nigeria (Anonymous, 1972).

Experiments on young pals in Peru revealed that magnesium chloride increased the yield significantly (Daniel and Ochs, 1975). However, lack of response to magnesium fertilization was also reported by many workers. A very low and irregular response to Mg application in both young and old palms were reported from Nigeria (Anonymous,

1966).

Van der vossen (1970) did not get response for magnesium sulphate at 2.72 kg per plant per year in Ghana. Hew and Poon (1973) also could not get yield response to magnesium in acid soils of Malaysia.

Micronutrients :

Very little work has been done on the role of micronutrients in oil palm, but it is likely that they are involved in similar enzyme and coenzyme systems to those in other plants. It is said that in palm, utilization of soil applied micronutrients is rather insufficient. In certain situations foliar application may correct existing deficiencies such as for copper (Ng et al., 1974), Mn (Wood et al., 1973) and boron and molybdenum (Rajaratnam, 1972).

Effect of fertilizers on tissue concentration

The applied nutrients exerts their influence on growth and productivity of oil palm through increased accumulation in leaf tissue. Leaf analysis for diagnostic purpose can be successfully made use of in perennial crops where the response of fertilizers will take a longer time (Hartley, 1977).

Prevot and Ollagnier (1959) found an increase in leaf N content by fertilization. and leaf N increased from 2.3 to 2.7 per cent by N application (Ollagnier et al 1970). Similar results were also reported by Warriar and Piggot (1973).

An increase in leaf P following N application was observed by Chapman and Gray (1949) and Ollagnier et al (1970). N fertilization at higher rates increased K level in leaf (Umar Akbar et al., 1976). Hartley (1977) stated that N application resulted in increase in K, decrease in P and Mg in leaves where as there was no marked effect on leaf Ca. However, Nair (1981) found that N fertilizer increased leaf N, P, K Ca and Mg contents and reduced leaf chlorine content. He obtained higher yields when leaf N content increased from 2.36 to 2.68 per cent.

When leaf N content reached 2.7 per cent there was a positive correlation between K levels and yield (Prevot and Ollagnier, 1959; Leyritz 1964). Ollagnier et al (1970)

reported an yield increase of over 50 per cent when the leaf N concentration was increased from 2.3 to 2.7 per cent and similar results were reported by Warriar and Piggot (1973). An yield increase of one ton per ha of FFB by an enhanced leaf N content by 0.03 to 0.5 per cent (Foster and Chang, 1976).

Forde et al., (1965) found that P application helped to increase P content of tissue. P application enabled to increase the P and Ca contents in leaf and decreased leaf K. Similar results were obtained by Nair (1981). Further he reported that P fertilization increased N and Mg contents.

Yield increments of about 32 per cent by an increase in leaf P was reported by Green (1972). The yield increased by one tonn per ha with an increase in P level from 0.003 to 0.005 per cent. But Bachy (1969) could not get any increase in yield with increased leaf P content at Ivory Cost.

In absence of potassium fertilizers very low level of leaf K was observed by Warriar and Piggot (1973). They observed an increase in leaf K content only when KCl was applied.

K fertilization even though helped to increase leaf K content, it produced an antagonistic effect on Ca and Mg. At the same time, K application showed no marked effect on leaf N and P (Hartley, 1977). Uptake of nitrogen was increased due to the application of K (Chapman and Gray, 1949).

The relation between P and K contents in leaf tissue was reported by Ochs (1965). He found that when leaf P content was less than 0.15 per cent there was correlation between leaf K and yield. When leaf P content was brought upto 0.15 per cent there was a strong correlation between K and yield. He further noted that when K level was below 1.0 per cent there was no correlation with leaf P and yield, but a strong correlation between leaf and yield was noticed when leaf K was about 1.0 per cent.

Prevot and Ollgnier (1959) noted that when leaf K was less than 1.0 per cent there was significant positive correlation between leaf N and yield. Many others reported that when leaf K content was increased, yield was also increased (Bachy, 1969; Warriar and Piggot, 1973 and Nair, 1981).

The response of K was closely linked with the K content in leaf, particularly when this level was below the critical level (Ollagnier et al, 1970). When tissue K level rose from 0.85 to 0.94 per cent the mean yield was also increased as reported by Nair (1981).

The Ca fertilization did not have any effect on N, P, Mg concentration in leaf. However, a decrease in leaf K and increase in leaf Ca was also noticed. On the other hand Mg application decreased P, K and Ca where as it enhanced the leaf Mg content. Nitrogen content of leaf was not

influenced by Mg application (Hartley, 1977). But there are some reports stating that Mg tend to increase leaf N similarly Mg application decreases leaf K to small extent, (Chan and Rajaratnam, 1976). They further observed that Mg requirement in oil palm can easily be increased by heavier application of N and P fertilizer. When the levels of Mg were in excess of 0.20 to 0.22 per cent, there was no response.

Nutrient interactions :

The studies conducted with various nutrients in oil palm revealed that full expression of one nutrient was obtained when other nutrients are supplied in adequate quantities.

A positive interaction between N and P was noticed by Dell and Arens (1957). They got 40 per cent increase in yield by application of N and P individually while 100 per cent increase in yield was recorded by N and P combination.

In the absence of K fertilizers a negative response to P in oil palm was reported by Vanderweyen (1952). Rosenquist (1962) observed that response to N was dependent on adequate supply of P and K. High P application caused the N effect to be negative and vice versa. When K was sufficient, the response to N was positive at all levels of P. He also noticed that K alone had no significant response even at the highest levels of P.

Significant yields were obtained when highest rates of P was applied in presence of K fertilization (Mollegård, 1971).

N P and PK interactions showed most favorable effect on characters like frond production and yield of oil palm (Tan, 1973). Chan and Rajarathnam (1976) found that Mg was necessary for full expression of N and K on yield. Green (1972) obtained responses to P and K in lateritic soil, with P and K interaction and a further yield increment by N and Mg.

Ratio between the elements:

The ratio between N/P is surprisingly constant for oil palm. It is about the same in seedlings, young or old trees and also it is about the same in such different conditions as Malaya and Africa and its value is 16. Similar calculations have been made for other ratios as given below :

Nutrient optimal ratios (Prevot and Ollagnier, 1954)

N:P - 16.00	P:K - 0.20	K:Ca - 2.00
N:K - 3.00	P:Ca - 0.20	K:Mg - 2.00
N:Ca - 3.00	P:Mg - 0.50-0.75	Ca:Mg - 2.00-2.50
N:Mg - 9.00		

These optimal ratios might be helpful in analyzing the deficiencies. When a ratio found in the leaf sample differ greatly from these values, the divergence may be attributed to the numerator and or denominator, and the deficiency might thus become evident (Prevot and Ollagnier, 1954).

The examination of ratios between the elements in a leaf has been well established as diagnostic procedure. The ratio N/P₂O₅, N/K₂O, K₂O/P₂O₅, CaO/K₂O and CaO/MgO were examined in leaves from trees grown in Latin square arrangement. Highly significant positive correlation with yield were obtained for certain ratios. It was concluded that the increase in yields are evidently associated with increased potash content of leaf and decreased nitrogen and phosphorus content, but the best indices of yield were the leaf nutrient ratios, particularly low N/K₂O ratios, a high K₂O/P₂O₅ ratio and a high N/P₂O₅ ratio (Thomas, 1953).

Correlation between the elements :

Strong and significant correlations were observed between yield and Nitrogen ($r=0.83$) and also between potash ($r=0.94$) while phosphate and yield were not correlated. Negative correlation between nitrogen and phosphate was found and it might be due to phosphate absorption in presence of Nitrogen and to the accompanying decreased in absorption (Chapman and Gray, 1949).

Ten possible correlation between N , P, K , Ca and Mg were calculated and a strong correlation was found in all the cases. The correlation between K and Ca or K and Mg were negative while the correlation between Ca and Mg were positive. Thus the analyzed elements were divided into two large classes. N and P could be termed as protoplasmic class while the other elements could be termed as basic

element class. It was shown that sum of $K + Ca + Mg$ for Peanut increases the yields and possibly general soil exhaustion could be estimated in available cases. In oil palm the sum of $(K+Ca+Mg)$ was constant around 2.00. It was shown that although favorable treatments increased K, the sum was changed by very small amount. This was well explained by antagonisms between Ca Mg and K (Prevot and Ollagnier, 1954)

It has been reported that Ca + Mg content was correlated (at 5 per cent level), with yield whereas Ca + Mg + K was correlated at 1.00 per cent level. Ca + Mg content was significantly correlated with leaf production, number of leaves and female inflorescence production (Nair and Sreedharan, 1980). An antagonism between K and Ca and Mg was observed when the effect of fertilizer leaf nutrient concentration of cationic elements were considered.

It was observed that the deficiency of K was expressed not only by a low concentration in leaf, but equally by Ca and Mg and concentrations above their critical levels (Ollagnier *et al.*, 1970). This fact was also substantiated by Nair and Sreedharan (1983) where in the sum of $K + Ca + Mg$ remained at 2 per cent and two way antagonism between K and Ca and Mg occurs due to fertilization of respective nutrients.

Concept of critical level:

Prevot and Ollagnier (1954) defined critical levels as the concentration of element in leaf (dry weight basis) above which yield response from the element in fertilizer is unlikely to occur. This concept is of major importance for practical use because it allows advising manures which will give the most economical returns (Ulrich, 1952).

To determine the critical levels Prevot and Ollagnier (1954) followed both direct and indirect methods. In direct methods critical levels were estimated by comparing yield responses to leaf analysis.

The work of Chapman and Gray (1949) and its continuation by I.R.H.O since 1950 have led to the formulation of critical levels that have proved themselves valid in great majority of situations. The critical level of different nutrients in 9th and 17th rank leaf for elements such as N, P, K, Ca and Mg was 2.70, 0.160, 1.25, 0.50 and 0.23 in 17th rank leaf respectively whereas 2.50, 0.150, 1.00, 0.60 and 0.24 in 9th rank leaf respectively.

Seasonal variation in nutrient concentration of foliar tissue:

In dry situation the maximum N and K levels are generally found at the end of short rainy season in November while for P there is a maximum at the end of each rainy season. During wet season N and P levels attain maximum during November though the palms received no N and P ferti-

lizer and small seasonal variation in K was noticed. This suggests that high nutrient concentration during November is not due to fertilizer that had applied but due to the availability of water (Ochs and Olivin, 1976).

Nitrogen content declined with onset of monsoon and increased following the application of fertilizers in September. Leaching of soil nitrate due to heavy rains during June, July and October may explain decline in N uptake. Unlike N and K content of leaf steadily increased upto December and decreased there after. With the fall in K level Ca and Mg level increased. Slight improvement in P was also observed during rainy season in Coconut (Wahid et al., 1981).

In oil palm it was observed that there was a reduction in N concentration of foilar tissue during January and increase during April months. This variation in N concentration in foliage could be attributed to variation in soil moisture during different seasons (Ng, 1970). Similar results on oil palm were also obtained by Smilde and Chapas (1963) in oil palm. In contrast to N there was an increase of P in foliage tissue during January and decrease during September. The increased P concentration in leaf during summer months was due to the moisture loss from the plants.

The potassium concentration of leaves also showed a trend similar to that of Phosphorus. Decreased K concentration during September could be attributed to the flowering

and fruiting of oil palm which coincides with this period (Emmert, 1959; Coulter, 1958).

Ca concentration increased during January and decreased during September; the reasons attributed for the change could be similar to that of leaf P. Mg concentration in tissue did not show definite trend (Nair and Sreedharan, 1983).

Fertigation:

Fertigation through micro irrigation system:

While it is common for crops with closer spacing to have furrow irrigation, border irrigation, corrugation irrigation with main and subsidiary channels prepared on the soil with suitable irrigation layouts, these irrigation practices have many disadvantages such as under or excess irrigation or water logging, build up of salinity and loss of water through seepage and percolation. In contrast it has been observed that widely spaced crop and other high value crops offer great scope to adopt what has now come to be known as micro irrigation system. On the whole this systems makes efficient use of available water resources through frequent application of water to the plant root zones to replenish water as in drip systems (Bruce et al, 1980).

Though the initial cost of establishment of micro irrigation system could be high, benefits in saving water, labor expenses, and the non-interference with cultural

practices and distinct possibility of saving fertilizers when given through these systems are important consideration.

Since irrigation and fertilization are regarded as very important management practices, enterprising farmers and the scientists in the past attempted to let fertilizers be distributed through irrigation with yield advantages (Goldberg and Shmueli, 1970). Subsequently a new approach of supply of fertilizer through drip or sprinklers particularly for horticultural crops was developed by scientists in a few countries (Bester et al 1977). Taking advantage of the expansion area under drip and sprinkler irrigation in India reaching upto 1.6 m.ha (Sivanappan, 1994). Indian agricultural scientists are also keen to make further advances in using these systems for supplying the costly fertilizers at the same time. This concept is termed Fertigation.

For successful fertigation system a number of prerequisites have been examined by Greef 1975 and are given in the following:

1. The system should be designed efficiently so that every emitter delivers the same amount of water.
2. The distribution of nutrients should be such that there are no blockages of fertilizers and chemical deposits.
3. There should be a constant and uniform mixing of plant nutrients with irrigation water and constant water flow throughout the system.

Fertigation is recognized to save fertilizers and labor costs. this method facilitates to supply nutrients available to plant roots more quickly than dry materials placed on soil surface. The possible disadvantages to fertigation are poor results with improperly designed irrigation system which will not give satisfactory coverage of fertilizer materials and inability to always use the least expensive materials (Koo, 1980).

Fertigation and movement of plant nutrients in the soil:

Application of fertilizers through fertigation is highly beneficial as it ensures localized additon. Movement of nutrients in the soil is largely determined by the cation exchange capacity of soil and electrostatic change particular nutrient, the water flow through soil and plant uptake. The movement of charged nutrient ions that is ammonium, potassium, calcium and magnesium is dependent on degree saturation of exchange complex of the soil and also exchange capacity of this complex. For example, sandy soil has less exchange sites than a loamy soils and loamy soils lesser than clayey soil. Therefore nutrient movement in sandy soils occur more rapidly than loamy or clay soil. Nutrient chemical molecules i.e. urea and negatively charged nutrient ions i.e. nitrate and sulfate primarily move into the profile with flow of water. thus irrigation in excess of the plant moisture could lead to much leaching of urea and nitrate (Greef, 1975).

Generally phosphate fixation occurs in most soils. High concentration of phosphate are to be found in the surface of soil layers when conventionally broadcasting fertilizers is the practice. With fertigation more uniform phosphate gradient occurs when phosphate is applied through the system is evident. Movement of an organic phosphate and glycerophosphate in the soil columns has been reported (Rolsten et al, 1974).

Effect of intercrops on growth and yield of oil palm:

Though intercropping is not a normal practice in oil palm plantations, there is ample scope for intercropping in initial years of plantation mainly to get some profits. Establishment is a temporary cultivation only and it has no effect on preparation of plantation or the spacing palms except that clearing and burning need during later stages.

Several trials on establishment of intercropping were carried out in Africa. In Zaire the planting (alone or in succession or in combination) of casava, maize, hill rice and bananas for 1, 2 or 3 years had in general a beneficial effects on oil palm yields and after 16 years no deleterious effect had appeared (INEAC, 1955).

A similar trial planted on forest land near Benin in Nigeria in 1940 included both cropping of maize, casava and yams for two years and as long as the crop could be obtained. And the results obtained from these trials showed that food cropping for 2 to 3 years may under such circum-

stances, be an attractive proportion to a small holder without affecting growth and yield of oil palm (Sparnaaij, 1957).

In both trials there was tendency for early bunch yield to be improved by intercropping, but in Nigerian trial both leaf area and early yields were significantly increased (Hartley, 1977). The early beneficial effects of establishing the intercropping systems had therefore being obtained inspite of a small reduction in top soil fertility. It was believed this was because of competition from weeds which was reduced considerably by cropping and further because cultivation makes some soil nutrients more readily available (Kowal and Tinker 1959).

In another experiments in Nigeria, the area which were degraded by food crop farming or annual burning , fertility needs to be rebuilt and on such lands even moderate yields could not be obtained without heavy fertilizer dressings, the beneficial effect of establishing intercropping was short lived and regular tillage soon become harmful (Sparnaiij, 1957).

An experiment in Malaysia on marine alluvial clay soils where soybeans were planted as an intercrop 1.8 m away from young palms for two years showed that there was no effect on growth . Early yield of oil palm was slightly impaired through root damage (Soon and Thye, 1976). Two casava crops grown in successive years as an intercrop in

oil palm severely retarded growth and reduced early yields by 14 per cent through competition for both light and nutrient, particularly N and P. However, all intercropping treatments increased yield relatively to legume cover treatment with palm age and by fourth bearing year differences were very small.

Recently in India, intercropping in oil palm plantation were introduced. Intercropping with tropical tubers were possible in India and annuals like tobacco and chillies are being successfully grown in young plantation of Andhrapradesh and Karnataka. From trails conducted at CPCRI, Palode, Cacao was found to come up very well in oil palm plantation without any adverse effect on growth and yield (Varghese and Cecil, 1992).

Vanderweyen (1952) and Marynen (1960) from different trials at Africa and Zaire suggested that robusta coffee can be planted along with oil palm and may be removed after seven years.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

Oil palm is a heavy consumer of mineral nutrients. Obviously significant research contributions to oil palm production is possible by adequate fertilization for maximizing the production.

Keeping in view the envisaged objectives two experiments were conducted and the details of which are given in this chapter. Both these experiments were conducted on the farm of Karnataka Oswal Oil Palm Ltd (KOOL) ., Karehally, Bhadravathi taluk, Shimoga District, Karnataka State.

Experiment I : Response of oil palm to application of fertilizers and micronutrients on growth and mineral nutrient status

The experiment was conducted in B-Block of KOOL Karehally. This area falls under agroecological transition zone -7, Region - 4 and receives about 700-1500mm of rainfall annually. The soils are generally black clayey (pH 7.81 and Available N,P,K of 304.6, 18.48, 255.5 Kg/ha respectively). Already existing one and a half year old young oil palm (Tenera) cv. IRHO (date of planting : 7.4.1995) were utilized for the study. There were about 136 palms planted in a triangular fashion with a spacing of 9m x 9m. These young palms were receiving irrigation through drip system and the system was laid out in such a way that it divided the experimental plot into two portions of which one region had four palms and the other had 7-8 palms. Before the imposition of treatments all the 136

palms received equal split dose of fertilizers (200g Urea, 300g Super phosphate, 200g Muirate of potash and 100g Magnesium sulfate per palm). Of the 136 palms, 112 palms in the experimental area were made use of, to layout different treatments. Altogether there were 10 treatments of which 4 constituted soil application treatments and the remaining 6 constituted fertigation treatments.

The treatment details were as follows:

- T1 - Recommended NPK to soil (800:400:800g/palm/year)
- T2 - Enhanced NPK to soil (1000:500:1000g/palm/year)
- T3 - Recommended NPK + Mg + Zn + B to soil (T1 + 400:60:60g of MgSO₄, ZnSO₄, Boric acid/palm/year respectively).
- T4 - Enhanced NPK + Mg + Zn + B to soil (T2 + 400:60:60g of MgSO₄, ZnSO₄, Boric acid/palm/year respectively).
- T5 - Recommended NPK through drip (800:400:800g/palm/year)
- T6 - Enhanced NPK through drip (1000:500:1000g/palm/year)
- T7 - Recommended NPK + Mg + Zn + B through drip (T5 + 400:60:60g of MgSO₄, ZnSO₄, Boric acid/palm/year respectively).
- T8 - Enhanced NPK + Mg + Zn + B through drip (T6 + 400:60:60g of MgSO₄, ZnSO₄, Boric acid/palm/year respectively).
- T9 - Recommended N & K + Zn + B through drip and P and Mg to soil (T5 + 400:60:60g of MgSO₄, ZnSO₄, Boric acid/palm/year respectively).
- T10 - Enhanced N & K + Zn + B through drip and P and Mg to soil (T6 + 400:60:60g of MgSO₄, ZnSO₄, Boric acid/palm/year

respectively).

The details of dose and source fertilizer and other nutrients applied through soil and drip are shown in the Table 1.

Generally the fertilizers were applied in split doses. The schedule and time of application of various nutrients under different treatments are also detailed in Table 2a and 2b.

Protocol for preparation of fertigation mixtures.

Preparation of Macro I

Calculated quantities of urea, super phosphate and muriate of potash (Table 1a) required for a month or two (depending on the treatment) were dissolved in tap water separately and kept overnight to allow sedimentation of undissolved materials. The clear supernatant was carefully decanted by suction leaving behind the precipitated material and inert particles in the container. The decanted supernatant was further filtered through a double layered cloth. To this filtered solution, citric acid at the rate of 10g /liter was added to avoid turbidity and clogging of the micro tubes of the drip system. The fertilizers were mixed in such a proportion that the final solution would have 10:5:10 ratio of NPK that is 100 ml of this solution had 10g of N, 5g of P, 10g of K.

Finally this clear solution was used to feed the young palms. Macro 1 was used to feed the palms under the treatments T5 and T7 at the rate of 800ml per palm and

Table 1 : Amount of fertilizers and other nutrient sources applied to soil and through drip system.

Fertilizer dosage	N	P	Super Po4	K	Mg	Zn	B
	Urea	Super	Po4	MOP	MgSO4	ZnSO4	Boric Acid
Recommended Dose							
g / palm/ Year	1740	2500		1320	400	60	60
g / palm/ month	145	210		110	033.3	5	5
Enhanced dose							
g / palm/ Year	2160	3120		1680	400	60	60
g / palm/ month	180	260		140	033.3	5	5

Note:

Recommended dose
800:400:800, N:P:K g /palm/ Year.

Enhanced dose
1000:500:1000, N:P:K g/ palm/ Year.

Table 1a : Preparation of fertigation mixture per palm having 10:5:10 ratio of N:P:K.

Amount of fertilizers used to get fertigation solution of 10:5:10 ratio.		
Urea (g)	SSP (g)	MOP (g)
165.0	265.0	132.0

Note : Urea, super phoshate (SSP), Muriate of potash (MOP) have to be dissolved in 925 ml of water to get 660 ml of fertigation sloution per palm having 10:5:10 ratio of N:P:K.

**Table 2a : Schedule and time of application of various nutrient sources for different treatments
(g /palm/ time) in soil application.**

January 1995(13:1:1995)												
Treatment		Urea	SSP	MOP	MgSO4	ZnSO4	Boric Acid	March 1995 (11:3:1995)				
		Urea	SSP	MOP	MgSO4	ZnSO4	Boric Acid	Urea	SSP	MOP	MgSO4	Boric Acid
T1		290	420	220	-	-	-	145	210	110	-	-
T2		360	520	280	-	-	-	180	260	140	-	-
T3		290	420	220	66.6	10	10	145	210	110	33.3	5
T4		360	520	280	66.6	10	10	360	920	280	33.3	5

August 1995 (12:8:1995)												
T1		580	840	440	-	-	-	580	840	440	-	-
T2		720	1040	560	-	-	-	720	1040	560	-	-
T3		580	840	440	133	20	20	580	840	440	133	20
T4		720	1040	560	133	20	20	720	1040	560	133	20

Table 2b. : Schedule and time of application of various nutrient sources for different treatments (g /palm/ time) in Fertigation.

January 1995 (13:1:1995)						March 1995 (11:3:1995)						
Treatment	Urea	SSP	MOP	MgSo4	ZnSo4	Boric Acid	Urea	SSP	MOP	MgSo4	ZnSo4	Boric Acid
T5	290	420	220	-	-	-	145	210	110	-	-	-
T6	360	520	280	-	-	-	180	260	140	-	-	-
T7	290	420	220	66.6	10	10	145	210	110	66.6	10	10
T8	360	520	280	66.6	10	10	180	260	140	66.6	10	10
T9	290	*420	220	66.6	10	10	145	210	110	66.6	10	10
T10	360	*520	280	66.6	10	10	180	260	140	66.6	10	10

April 1995 (12:4:1995)						May 1995 (11:5:1995)						
Treatment	Urea	SSP	MOP	MgSo4	ZnSo4	Boric Acid	Urea	SSP	MOP	MgSo4	ZnSo4	Boric Acid
T5	145	210	110	-	-	-	145	210	110	-	-	-
T6	180	260	140	-	-	-	180	260	140	-	-	-
T7	145	210	110	-	-	-	145	210	110	66.6	10	10
T8	180	260	140	-	-	-	180	260	140	66.6	10	10
T9	145	*1680	110	*266	-	-	145	-	110	-	10	10
T10	180	*3680	140	*266	-	-	180	-	140	-	10	10

Note: * -> Applied to soil.
 SSP -> Super phosphate.
 MOP -> Muriate of potash.

42

Table 2b: Scheduled and time of application of various nutrient sources under different treatments (g /palm/ time) in Fertigation.

June 1995 (8:6:1995)										
Treatment	Urea	SSP	MOP	MgSo4	ZnSo4	Boric Acid	Urea	SSP	MOP	Boric Acid
T5	145	210	110	-	-	-	145	210	110	-
T6	180	260	140	-	-	-	180	260	140	-
T7	145	210	110	-	-	-	145	210	110	66.6
T8	180	260	140	-	-	-	180	260	140	66.6
T9	145	-	110	-	-	-	145	-	110	-
T10	180	-	140	-	-	-	180	-	140	-

August 1995 (12:8:1995)										
Treatment	Urea	SSP	MOP	MgSo4	ZnSo4	Boric Acid	Urea	SSP	MOP	Boric Acid
T5	145	210	110	-	-	-	290	420	220	-
T6	180	260	140	-	-	-	360	520	280	-
T7	145	210	110	-	-	-	290	420	220	66.6
T8	180	260	140	-	-	-	360	520	280	66.6
T9	145	-	110	-	-	-	290	-	220	-
T10	180	-	140	-	-	-	360	-	280	-

October 1995 (20:10:1995)										
Treatment	Urea	SSP	MOP	MgSo4	ZnSo4	Boric Acid	Urea	SSP	MOP	Boric Acid
T5	145	210	110	-	-	-	290	420	220	-
T6	180	260	140	-	-	-	360	520	280	-
T7	145	210	110	-	-	-	290	420	220	66.6
T8	180	260	140	-	-	-	360	520	280	66.6
T9	145	-	110	-	-	-	290	-	220	-
T10	180	-	140	-	-	-	360	-	280	-

November 1995 (19:11:1995)										
Treatment	Urea	SSP	MOP	MgSo4	ZnSo4	Boric Acid	Urea	SSP	MOP	Boric Acid
T5	145	210	110	-	-	-	290	420	220	-
T6	180	260	140	-	-	-	360	520	280	-
T7	145	210	110	-	-	-	290	420	220	66.6
T8	180	260	140	-	-	-	360	520	280	66.6
T9	145	-	110	-	-	-	290	-	220	-
T10	180	-	140	-	-	-	360	-	280	-

Note:

SSP

-> Super phosphate.

MOP

-> Muriate of potash.

under the treatments T6 and T8 at the rate of 1000ml per palm per month. Excess quantity of fertigation mixture was used while feeding the palms to avoid inadequate quantities in the container that might arise due to unforeseen problems.

Preparation of Macro 2

Calculated amounts of urea and muriate of potash were dissolved in calculated quantity of tap water in a big container and kept over night to allow sedimentation of undissolved materials. Similar protocol was followed to get a clear solution as with Macro 1. The amount of macro 2 was used to feed the palms under the treatments T9 and T10 at the rate of 800ml and 1000ml per palm for one month respectively and similar precaution as above was taken to avoid left over solution in the container.

Preparation of Micro 1 (secondary and micronutrients)

Calculated quantities of MgSO_4 (1600g) and micronutrient such as ZnSO_4 (240g), FeSO_4 (77g), MnSO_4 (48g), CuSO_4 (48g), Boric acid (240g) and Ammonium molybdate (5g) were dissolved in five liters of water and this solution was kept overnight to allow sedimentation of undissolved materials. Only supernatant solution was decanted by suction. This supernatant was again filtered through double layered cloth and to this Citric acid at the rate of 10 g per liter was added. Citric acid was added to avoid turbidity and also clogging of microtubes of drips system. Micro 1 was used to feed the palm under the treatments T7 and T8 at the rate of 200ml per palm bimonthly.



Plate 1: Method of feeding fertigation mixture to oil palm.

2a



2b



Plate 2a & 2b: Arrangement of microtubes for feeding fertigation mixture

Preparation of Micro 2 (Micronutrients)

Calculated quantities of ZnSO_4 (240 g), MnSO_4 (48 g), CuSO_4 (48 g), FeSO_4 (77 g), Boric acid (240 g) and Ammonium molybdate (5 g) were dissolved in five liters of water and kept over night. Similar protocol was followed to get clear solutions as in case of Micro 1. Micro 2 was used to feed the palms under the treatments T9 and T10 at the rate of 200ml per palm bimonthly.

Protocol to feed the fertigation mixture

The measured quantities of clear fertigation mixture for the treatment was poured into a plastic container. The amount of fertigation mixture used per palm and for the total number of palms in a treatments are shown in Table 3. The plastic container with measured quantity of fertigation mixture was then tied to the pole at a measured height (1 to 1.5 m) depending on the pressure existing in the micro tubes of drip system (Plate 1). This operation was done to create a high pressure which pushed the solution towards the microtubes and for easy movement of fertigation mixtures along with the water towards the root zone in equal amounts in Plates 2a and 2b.

Experimental layout:

The experiment was laid as RCBD with ten treatments and three replications and each replication had four palms.

Table 3 : Amount of Fertigation mixture used per palm and total number of palms in a treatments (ml/month).

*Treatment	Fertigation Mixture(ml/palm)	Type of Mixture	Total Number of palms	Total Quantity of Fertigation Mixture
T5	800	Macro 1	4	3200
			8	6400
T6	1000	Macro 1	4	4000
			8	8000
T7	800	Macro 1	4	3200
			8	6400
T8	1000	Macro 1	4	4000
			8	8000
T9	800	Macro 2	4	3200
			8	6400
T10	1000	Macro 2	4	4000
			8	8000

Note:*

T5 ---> Recommended NPK thro' drip
 T6 ---> Enhanced NPK thro' drip
 T7 ---> Recommended NPK thro' Drip
 T8 ---> Enhanced NPK thro' drip
 T9 ---> Recommended N K + Zn + B thro' drip
 and P + Mg to soil.
 T10 ---> Enhanced N K + Zn + B thro' drip
 and P + Mg to soil.

Method of fertilizer application:

Fertilizers were applied to the soil by band method and care was taken to cover the applied fertilizer with waste bunches to avoid evaporation and volatile losses.

Observations recorded

Normally growth is reflected in leaves that is number of leaves emerged, number of leaflets in a palm, length and width of largest leaflet and also length of frond. Hence, to see the effect of various fertilizer treatments on growth of young oil palms, the following observations were recorded.

- a. Total no. of fronds per palm
- b. No. of leaflets in 9th frond
- c. Length and width of largest leaflet in 9th frond
- d. Length of 9th frond
- e. Leaf area

Observations were recorded on the above mentioned growth parameters at bimonthly intervals during the experimental period lasting from January 1995 to November 1995.

All the palms in a treatment were used for recording observation on total number of fronds per palm and averaged out per replication and the treatment. However, the other parameters were recorded from the representative palms in each replication of a treatment at the end of the experiment that in November 1995. From these observations leaf area per frond was estimated by nondestructive indirect

method as suggested by Hardon et al., (1969) by using a formula $L = b (n \times lw)$ where L is the leaf area per frond in m^2 , b is the correction factor (0.55), n is the number of leaflets in the 9th frond and lw is the mean length and width of largest leaflet in 9th frond.

Leaf area per palm:

This was estimated by multiplying total number of fronds with leaf area during at the end of the experiment (November 1995) and expressed in m^2 per palm.

Relative leaf emergence rate (RLER) :

RLER per month was computed from bimonthly observations on total number of fronds by following RGR formula:

$$\frac{\log_e A_2 - \log_e A_1}{t_2 - t_1}$$

where A_1 and A_2 are frond number at two consecutive months t_1 and t_2 .

This was estimated for every two months as well as for five months and ten months from the commencement of the experimental period.

Mineral Nutrients

Plant or leaf tissue analysis technique:

Tissue analysis is a tool for assessing the nutritional requirements and status of any crop plants. In oil palm leaf tissue analysis has been widely used to know the nutritional status. In the present study, the mineral nutrient elements estimated in oil palm were N, P, K, Ca,

Mg, Fe, Mn, Cu and Zn. The leaf lets were sampled from the representative palms in a treatment.

Protocol for leaf sampling :

The leaves selected for sampling were second and ninth during January, March, May 1995 and second, ninth and sixteenth during July and November 1995. From the selected palms three leaflets on either side of approximately mid point of fronds were sampled. From the sampled leaflets center portion of about 10 to 20 cm was taken for analysis. The leaflets thus sampled was thoroughly washed in distilled water to remove the dust and other materials adhering to the leaf surface and then rubbed with filter paper to remove water. The midrib and leaf margin of 2 cm were removed and the laminar portion was dried at 60-70 ° C for 2 days and powdered in a mixer grinder to get a fine powder. The powdered material was used for chemical analysis of all the above mentioned nutrients.

Nitrogen

The total nitrogen content in plant samples were determined by micro kjeldahl method (Piper 1957).

Known quantity of powdered sample (0.5 g) was digested with concentrated sulphuric acid (10 ml) in presence of digestion mixture by heating in a flame chamber. After the completion of digestion, the volume was made up to 50 ml. From this 10 ml of aliquot was taken in a distillation unit and 10 ml of 40% NaOH was added. The ammonia liberated was trapped in 4% Boric acid (25 ml) with mixed indicator.

This was back titrated with 0.025 N standard H_2SO_4 . From the titer value obtained, the nitrogen content was calculated by using the formula:

$$\% \text{ N} = \frac{\text{TV} \times \text{N of acid} \times 0.014 \times \text{vol. of digested sample}}{\text{Weight of sample} \times \text{aliquot taken}} \times 100$$

Nitrogen content in plant was expressed in per cent of leaf dry matter.

The other elements such as P, K, Ca, Mg, Fe, Zn, Mn and Cu were estimated following wet oxidation method by using diacid mixture. The acids used were nitric acid and perchloric acid at a ratio of 10:4. The digested sample was made to 50ml with triple distilled water. Adequate aliquots were drawn for the estimation of various elements as mentioned above.

Phosphorus

P content in leaf tissue was estimated by following Vanado molybdo phosphoric yellow colour in nitric acid system (Piper 1957).

Protocol for Reagent preparation :

Phosphate standard: From 50 ppm of P solution different standards were prepared and respective absorbance were recorded at 430 nm and plotted on a graph.

Vanadomolybdic acid :

a) solution A : Dissolved 25g of Ammonium molybdate in 400 ml of distilled water.

b) Solution B: Dissolved 125 g of Ammonium metavanadate in 300 ml of boiling distilled water. The contents

were cooled and 250 ml of concentrated nitric acid was added. Finally, solution A and B were mixed and diluted to 1000 ml with distilled water.

Procedure :

5 ml of digested sample was drawn into a 25 ml of volumetric flask and 10 ml of reagent was added and the volume was made upto 25 ml. The yellow colour was read at 430 nm and graph ppm was calculated from the standard. Then the P content in leaf tissue was calculated by using the formula:

$$P = \frac{\text{graph ppm} \times \text{vol. of digested sample} \times \text{vol. made}}{10^6 \times \text{wt. of sample} \times \text{Aliquot taken}} \times 100$$

Potassium

Potassium content in leaf tissue was estimated by using flame photometer (Piper 1957). From 50 ml of the digested sample 1ml of aliquot was drawn and diluted by 50 times. This sample was fed to flame photometer and the readings were plotted on to graph and percent K was calculated by using the formula :

$$K = \frac{\text{graph ppm} \times \text{vol. of digested sample} \times \text{vol. made}}{10^6 \times \text{wt. of sample} \times \text{Aliquot taken}} \times 100$$

Potassium content in plant was expressed in percentage.

Calcium and Magnesium

The calcium and magnesium in plant samples were determined by using 'Polarized Zeeman Atomic Absorption Spectrometer' (AAS-Z - 6100). From 50 ml of the sample 1ml

of aliquote was drawn and diluted by 50 times with triple distilled water. This diluted sample was then fed to AAS and the readings were recorded to compute Ca and Mg content. Before feeding the samples to the AAS, suitable standards were prepared and fed to instrument and a standard graph was fit. To this standard curve the sample readings were compared and then computed. The Ca and Mg content in plant leaves was expressed as per cent leaf dry weight.

Micronutrients

Micronutrients such as Iron, Manganese, copper and Zinc in leaf tissue was estimated by AAS.

From the same 50 ml of digested sample the micro nutrients were estimated in AAS after feeding the standard solutions of a particular element and a suitable graph was fit. The unit of expression of these micro nutrients was ppm per gram dry weight of leaf.

Soil analysis

Soil analysis is being generally used as tool to asses the nutritional requirement and/or fertilizer recommendations. In the present investigation soil analysis was carried out to see the nutritional status of soil and the nutrient availability as influenced by treatments. Samples for soil analysis was done at two depths namely 0-15cm and 15-30cm and at two spots namely at the palm basin and away from the plant basin.

Initially that is before imposing the treatments (January 1995) soil samples were drawn at random from six spots at the basin and also away from the palm basin at two depths as mentioned earlier.

Again at the end of the experimental period (November 1995) soil samples were drawn at the palm basin of all the representative palms in a replication of each treatment. Pooled samples from four spots away from the palm basin were also drawn. These samples were shade dried and powdered with a wooden pestle and mortar. The powdered samples were used for estimation of different elements such as N, P, K, Ca, Mg, Fe, Mn, Zn, and Cu (Jackson, 1967).

Protocol for nutrient estimation in soils

Nitrogen

Available Nitrogen in soils was estimated by the alkaline potassium permanganate method (Jackson 1967).

Reagents:

1. 0.32 % KMnO_4 was prepared by dissolving 3.2 g of KMnO_4 in distilled water and made up the volume to one liter.
2. 2.5 % NaOH was prepared by dissolving 25 g of NaOH flakes in distilled water and finally volume made up to one liter.
3. 4.0 % Boric acid was prepared by dissolving 40.0 g of boric acid in distilled water and finally volume made up to one liter.

Procedure:

20 g of soil was weighed and distilled in Kjeldahl distillation assembly after adding 0.32 % KMnO_4 and 2.5 % NaOH . Ammonia released from distillation flask after heating was trapped in 25 ml of 4.0 % Boric acid with mixed indicator. The contents were then back titrated with 0.05 N standard H_2SO_4 . From the titer value nitrogen content in soil was calculated by using the formula:

$$X \text{ (\% N)} = \frac{\text{TV} \times \text{N of acid} \times 0.014}{\text{Weight of soil}} \times 100$$

$$\text{N (ppm)} = X \times 10000$$

Phosphorus

Available phosphorus in soils was determined by Olsen's method (Jackson 1967).

There are two distinct phases in soil P determination namely : 1) Extraction .

2) Measurement.

For the extraction of P from the soil of the experimental site the Olsen's method was used since the pH of the soil was 7.8 to 8.6.

Olsen's method (Olsen et al 1954) :

Reagents for Olsen's method : 1) 0.5 N NaHCO_3 (extractant) was prepared by dissolving 42g of NaHCO_3 in distilled water and pH was adjusted to 8.5. Finally the volume was to one liter with distilled water.

$$\text{Avail. P} = \frac{\text{Graph ppm} \times \text{Vol. of extractant} \times \text{Vol. made}}{\text{weight of sample} \times \text{aliquot}}$$

Unit of expression : ppm.

Potassium

The exchangeable K in soil refers to that adsorbed on the clay matrix. Although the neutral normal ammonium acetate extracts both extractable and water soluble K, a prolonged extraction is a safe estimate of exchangeable K in soils.

Reagents :

Neutral normal ammonium acetate : 77.09 g of ammonium acetate was dissolved in distilled water and made up the volume to one liter. The pH Of the solution was adjusted to neutral using pH meter.

Standard K solution : 1000 ppm Std. K solution was prepared and suitable dilutions were made to get std. solutions ranging from 0 to 10 ppm.

Procedure : 5 g of soil was treated with 25 ml of neutral normal ammonium acetate and the contents were shook for 30 min. The contents were then filtered and suitable dilutions made with triple distilled water.

The flame photometer reading was adjusted to 0 with ammonium acetate and 100 with 10 ppm K solution. The diluted samples were fed to the flame photometer and the readings were plotted on to the std. graph to get standard curve. Finally the exchangeable K in soil was estimated by

using formula:

56

$$X \text{ (K ppm)} = \frac{\text{Graph ppm} \times \text{vol. of extractant} \times \text{vol. made}}{\text{weight of soil} \times \text{aliquote}}$$

$$\text{Exch. K (meq./100g)} = \frac{X}{10^4 \times \text{meq. wt. of K}}$$

meq./100g can also be expressed as C mol(P⁺)/Kg.

Calcium and Magnesium

The same neutral normal ammonium acetate extract done in K was used for the estimation of both Ca and Mg in Polarized Zeeman Atomic Absorption Spectrometer (AAS) with suitable dilutions (1 in 100ml and from this 1 in 25ml). The Ca and Mg content in soil was expressed as C mol (P⁺)/Kg.

by using formula :

$$X = \frac{\text{Graph ppm} \times \text{vol. of extractant} \times \text{vol. made} \times \text{vol. made}}{\text{wt. of soil} \times \text{aliquote} \times \text{aliquote}}$$

$$\text{Avail. Ca (C mol(p}^+) \text{) /Kg} = \frac{X}{10^4 \times \text{meq. wt. of Ca}}$$

Mg in soil was estimated as like Ca in AAS with same diluted extract and the contents were expressed as earlier.

Micronutrients

Micronutrients such as Fe, Mn, Zn and Cu were estimated in soils by using DTPA extractant:

Reagents :

149 g of triethanolamine, 19.67 g of DTPA and 14.79 g

of CaCl_2 in 200 ml of distilled water and diluted to 9 lit. and adjust the pH to 7.3 .

Suitable standard solutions were prepared for each elements and fed to AAS, a standard graph was fit.

Procedure :

10 g of soil and 25 ml of the extractant were continuously shook for 2 hrs. and the contents were filtered. The filtered solution was then diluted (10 times) with triple distilled water. The diluted solution was fed to AAS and readings were calculated for the content of each element. The available micronutrient content of the soil was expressed as ppm.

EXPERIMENT 2 : Effect of intercrops on growth and mineral nutrient status of oil palm .

Among the peninsular states the command irrigated parts of the Karnataka along with Kerala and Andhrapradesh were considered for oil palm cultivation. Among the irrigated areas, Bhadra project in Karnataka is actively considered for propagation of oil palm cultivation.

This area falls under agroecological transition zone (zone 7 of region 1V) of the state. This narrow strip of 45 km sandwiched between hilly zone in the western side and plains on eastern zone is characterized by assured rainfall of 700 - 1500 mm annually. Traditionally the important crops grown in this area are areca, paddy, tobacco etc. In recent years areca is being priced highly in the market. Thus it is always not possible to motivate farmers to

takeup oil palm cultivation in preference to areca. Under such circumstances intercropping with oil palm with the other cash crops of the region may be possible during the initial periods of the plantations and probably would act as incentive to the farmer to cultivate oil palm.

The experiment was conducted in 'A' and 'C' block of KOOL, karehally, Bhadravathi, Shimoga (Dist.). Already existing 3 - 3.5 year old (date of planting 31.4.93) palms cv. Costarica with Puerarea as cover crop in 'A' block and 2 - 2.5 year old (date of planting 7.10.93) palms cv. Palode with coffee, banana, arecanut and sugarcane as inter crops were selected for the study. Block 'A' consisted of 601 palms and block 'B' with 524 palms planted in a triangular fashion with a spacing of 9 x 9 mt. and all the palms were receiving irrigation through drip. All the palms were fertilized with equal split dose of recommended NPK and MgSo₄ through band application to soil and mulching with waste bunches. All the inter crops also received recommended dose of NPK fertilizers separately and the inter crops were planted in between the palms and also between the two rows of oil palm.

For the purpose of laying out the experiment the following treatments containing various inter crops were included. (Plates 3a - 3h).



Plate 3c: IC 1 - Oil palm + Coffee + Banana



Plate 3d: IC 2 - Oil palm + Banana + Arecanut



Plate 3e: IC 3 - Oil palm + Arecanut



Plate 3f: IC 4 - Oil palm + Banana



Plate 3g: IC 5 - Oil palm + Sugarcane



Plate 3h: IC 6 - Oil palm + Pueraria

Treatment details :

IC 0 : area with oil palm alone was taken as control

IC 1 : oil palm + Coffee + Banana

[area with 5 rows of oil palm, 2 rows of coffee and 2 rows of banana planted alternately in between the rows and 2 banana plants were planted between oil palm plants] .

IC 2 : oil palm + Banana + Arecanut

[area with 3 rows of oil palm and 2 rows of banana and a row of arecanut planted in between the rows and 2 banana plants were planted between oil palm plants.

IC 3 : oil palm + Arecanut

[area with 2 rows of coffee and 2 rows of banana planted alternately in between the rows and 2 banana plants were planted between oil palm plants] .

IC 4 : Oil palm + Banana

[area with 2 rows of coffee and 2 rows of banana planted alternately in between the rows and 2 banana plants were planted between oil palm plants] .

IC 5 : Oil palm + Sugarcane

[area with 2 rows of coffee and 2 rows of banana planted alternately in between the rows and 2 banana plants were planted between oil palm plants] .

IC 6 : Oil palm + Pueraria as cover crop.

Adequate fertilization was done to individual palms and individual intercrops with recommended NPK in split doses.

Observations recorded

Growth parameters :

Growth parameters were recorded in November 1995, from four representative palms in each treatment and the following observations were recorded :

Total number of fronds

Length of 17th frond

Number of leaflets in 17th frond

Mean length of largest leaflet in 17th frond

Mean width of largest leaflet in 17th frond

Number of male and female inflorescence

Leaf area per frond was calculated from the observation on no. of leaflet, length and width of largest leaflet as mentioned in experiment 1.

Leaf area per palm was calculated by multiplying leaf area per frond with total no. of fronds (Hardon et al 1969).

Mineral nutrition

Leaf tissue analysis :

Leaf tissue analysis was done for the elements such as N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, in the leaflets of index leaves such as 3rd, 17th and 31st from the representative palms in a treatment.

Processing of leaflets was done before the chemical

analysis as mentioned in experiment 1. The protocol for estimation of different elements in leaves was followed as mentioned in experiment 1 and the same method of expression was used.

Soil analysis :

Soil sampling was done during November 1995 at two different depths namely 0 -15cm and 15 -30cm at the palm basin and also away from the basin (in between the plants). Soil samples were sampled from four different spots representing four replications in a treatment. The protocol for the processing of soil samples, estimation of different elements in soil and method of expression was followed similar to that of Experiment. 1.

Statistical Analysis:

All the data were subjected to statistical analysis. Analysis of variance was used to assess the treatment differences (Snedecor and Cochran, 1960).

RESULTS

IV. RESULTS

The results obtained on growth and mineral nutrient content in the leaflets of young oil palm crop as influenced by varying doses of fertilizers applied to soil and through fertigation as well as due to effect of intercrops are presented in this chapter.

EXPERIMENT. 1 : Response of oil palm to application of fertilizers and micronutrients on growth and mineral nutrient status.

Growth parameters :

The plants chosen for the study were only one and a half year old. Prior to imposition of the treatments, the crop received the recommended dose of fertilizers. It is known the characteristics like the number of fronds (leaves) per palm, number of leaflets on leaf, length and width of largest leaflets have direct relationship with growth and productivity of oil palm. The effect of enhanced dose of fertilizers both applied to soil as well as through drip system on growth characteristics were recorded during the experimental period. The data pertaining to these and other growth parameters as influenced by varying fertilizers are presented in Table 4.

Total number of fronds per palm :

Initially at the time of imposition of treatments, the average leaf number was 15.1 which steadily increased till May to 18.8, followed by a sharp increase in July

Table 4 : Progressive leaf number (No./palm) and RLER during different periods of observation (no./no./month $\times 10^{-2}$)

Treatment	Leaf no. J	RLER J-M	Leaf no. M	RLER M-MY	Leaf no. MY	RLER MY-J1	Leaf no. J1	RLER J1-N	Leaf no. N
T1	15.2	6.93	17.4	5.90	19.5	6.65	22.3	5.20	29.7
T2	14.9	3.44	16.0	6.02	18.1	10.53	22.3	5.48	29.7
T3	16.3	1.31	16.7	7.07	19.2	7.32	22.3	5.74	30.0
T4	16.0	1.28	16.4	6.95	18.2	9.48	22.8	2.49	28.7
T5	14.2	6.65	16.1	4.7	17.8	10.22	21.8	5.16	29.0
T6	14.9	2.80	15.8	8.85	18.8	9.47	22.8	5.17	30.3
T7	15.3	2.15	16.0	9.03	19.1	9.18	23.0	5.79	30.7
T8	15.3	1.94	15.8	8.87	18.9	9.45	22.9	5.60	31.3
T9	14.2	2.42	15.9	11.48	18.9	9.43	22.7	5.22	30.7
T10	14.6	1.93	15.1	10.63	18.5	9.00	22.2	5.70	31.3
Mean	15.1	3.08	16.0	7.95	18.8	9.07	22.5	5.15	30.1
Soil mean	15.6	3.24	16.6	6.48	18.8	8.50	22.4	4.73	29.5
Fert. Mean	14.8	2.98	15.8	8.43	18.7	9.46	22.6	5.44	30.6
CD 5%	NS	1.19	NS	1.70	NS	1.73	NS	0.99	NS

Note : Observations were recorded on January(J), March(M), May(MY), July(J1) and November(N).

(22.5) and November (30.1). During the entire experimental period no significant difference was observed in total number of fronds per palm among the treatments. However a slight advantage was noticed in respect of fertigation treatments in general (30.6) as against soil application of fertilizers (29.5) respectively at the end of experimental period.

Leaf emergence rate :

The mean relative leaf emergence rate (RLER) on the otherhand increased from intital value of 3.08 to 9.07 (No./ No./ Month $\times 10^{-2}$) by July, which fell off sharply by November to 5.15. This observation indicates that the rate of leaf emergence is highest during summer month prior to monsoon and slowed down during cooler months of active monsoon as well as in post monsoon seasons. As against the leaf number, RLER was significantly affected by various fertilizer treatments. Generally fertigation treatments showed significantly higher RLER values than soil application treatments, throughout the experimental period both during early (January - March) and later phase of experimentation (July - November).

Leaf and related leaf characters :

The data collected in November 1995 in respect of number of frond per palm, leaf area per frond as well as leaf area per palm, number of leaflets, length and width of largest leaflets in 9th frond and length of 9th frond are presented in Table 5.

Table 5 : Growth characteristics as influenced by increased levels of nutrients to soil and through drip (Nov, 1995).

Treatment	Total no. of fronds	* LA/frond (m ²)	LA/palm (m ²)	No. of Leaflets	Length & Width of leaflet (cm.)	Length of 9th frond (m)
T1	29.7	1.79	53.7	142	55.0	4.2
T2	29.7	2.35	69.8	162	62.7	4.1
T3	30.0	1.81	54.9	154	57.7	3.7
T4	28.7	2.01	57.9	149	56.3	4.4
T5	29.0	2.10	60.9	154	54.3	4.4
T6	30.3	2.04	61.5	162	56.0	4.0
T7	30.7	2.14	66.0	158	57.8	4.3
T8	31.3	2.57	81.1	166	63.2	4.5
T9	30.7	2.05	63.0	157	56.8	4.2
T10	31.3	2.44	76.2	173	61.0	4.2
Mean	30.1	2.13	64.5	158	58.1	4.2
Soil mean	29.5	1.99	59.2	152	57.9	4.1
Fert. Mean	30.6	2.22	68.1	162	58.2	4.3
CD 5%	NS	NS	NS	NS	NS	NS

Note: * Leaf area.

All these parameters registered non significant differences among various treatments throughout experimental period. However the fertigation treatments in general (T5 to T10) were found superior over soil applied fertilizer treatments (T1 to T4) irrespective of enhanced rates over recommended rates as well as due to application of micronutrients.

Mineral nutrient status in leaves :

The mineral content was estimated during bimonthly intervals from January to November 1995. Till May, only leaflets in 2nd and 9th leaf were sampled while in July and November, due to increased growth of leaflets on 16th leaf was also sampled in addition for analysis. The data on contents of various elements namely, nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc, manganese and copper are presented in Tables 6 to 14 and also the leaf nutrient content of different leaves (2nd, 9th and 16th) as influenced by the increased application of fertilizers to soil and also through drip (fertigation) were depicted in Figures 1 to 9.

Nitrogen :

Considering the mean values of all the treatments, it was observed that the leaf N content was relatively higher in lower leaves (9th) and decrease in upper leaves (2nd) at any given time observation Table 6. The leaf nutrient content generally increased and reached its peak in

Table 6 : Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Nitrogen' content (% DW) in leaflets at different leaf positions of young oil palms.

Treatment N:P:K and (Mg + Zn + B) * (g / Palm / year)	2nd leaf					9 th leaf					16 th leaf				
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
T1-800:400:800 (Rec.) to soil	2.12	2.54	2.23	2.53	2.30	2.20	2.46	2.80	2.68	3.07	-	-	-	2.45	2.72
T2-1000:500:1000 (Enh.) to soil	2.64	2.54	2.36	2.12	2.49	2.70	2.52	2.84	2.66	2.45	-	-	-	2.09	2.56
T3-T1 + Mg + Zn + B to soil	2.23	2.29	2.27	1.88	2.34	2.26	2.32	2.49	2.53	2.60	-	-	-	2.09	2.56
T4-T2 + Mg + Zn + B to soil	2.35	2.52	2.46	2.37	2.53	2.40	2.71	2.43	2.68	2.69	-	-	-	2.70	2.57
T5-800:400:800 thro' drip	2.62	2.75	2.22	2.33	2.70	2.62	2.62	2.78	2.20	3.02	-	-	-	2.42	3.24
T6-1000:500:1000 thro' drip	2.49	2.26	2.42	2.31	2.78	2.44	2.68	2.70	2.11	3.44	-	-	-	2.24	2.74
T7-T5 + Mg + Zn + B thro'drip	2.55	2.67	2.50	2.21	2.59	2.49	2.97	2.83	2.53	2.91	-	-	-	2.58	2.63
T8-T6 + Mg + Zn + B thro' drip	2.38	2.43	2.44	2.25	2.30	2.39	2.78	2.67	2.37	2.57	-	-	-	2.60	2.91
T9-Rec. N K Zn & B thro' drip and P & Mg to soil.	2.49	2.39	2.43	2.31	2.41	2.52	2.53	3.13	2.62	2.89	-	-	-	2.36	3.00
T10-Enh. N K Zn & B thro'drip and P & Mg to soil.	2.67	2.56	2.50	2.34	2.38	2.62	2.37	2.80	2.68	3.22	-	-	-	2.86	2.82
Mean	2.45	2.50	2.38	2.26	2.48	2.46	2.60	2.75	2.51	2.89	-	-	-	2.45	2.78
CD at 5%	NS	NS	NS	NS	NS	NS	0.36	NS	NS	0.47	-	-	-	0.34	NS

* Mg as MgSO 4 : 400 g /palm /year
 Zn as ZnSO 4 : 60 g /palm /year
 B as Boric acid : 60 g /palm /year.

November, in all the three leaf positions on plant. At all the months the average nitrogen content was well within the limits of reported values (2.29% to 3.01%) in all the leaves analyzed.

The N content in upper most leaf (2nd from top) did not differ among the treatments throughout the experimental period. On an average the highest content of 2.5 per cent was observed in March which decreased to relatively lower values of 2.26 per cent in July followed by a spurt in its increase to 2.42 per cent in November. As against this trend, the mean N content in 9th leaf was its highest in November (2.89%) with no particular pattern in other months (ranging from 2.51 in July to 2.75 in May). During the months of March and November the N content did not significantly vary among the treatments. In March a significantly higher N content of 2.98 per cent was obtained in T7 compared to 2.46 per cent in T1 (control, recommended N:P:K dose). On the other hand during November relatively higher N content was obtained in T2 (2.45%), T3 (2.6%) and T8 (2.59%) which other treatments were at par.

The N content in 16th leaf significantly differed during July month only. However, on an average the leaf registered relatively higher N content of 2.61 per cent in November and 2.37 per cent in July. In July significantly higher N content of 2.86 per cent was observed in T10 over 2.45 per cent of T1. Among the soil application treatments significantly lower N content of 2.09 per cent was obtained in T3.

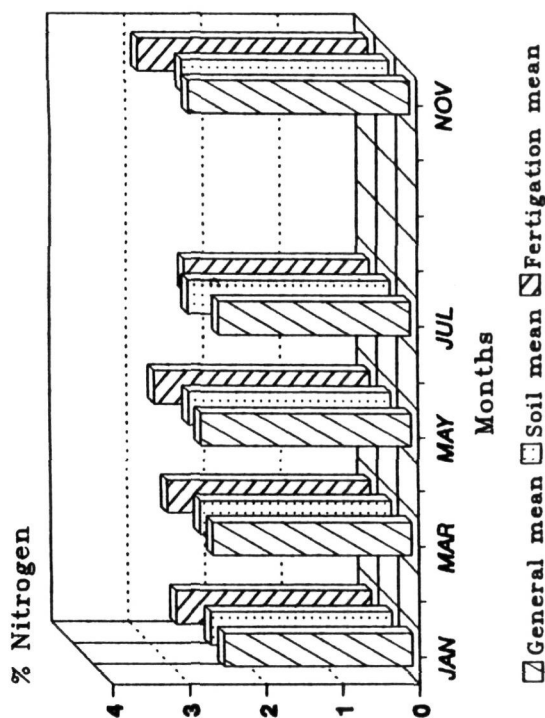


Fig. 1b : Nitrogen content in leaf 9

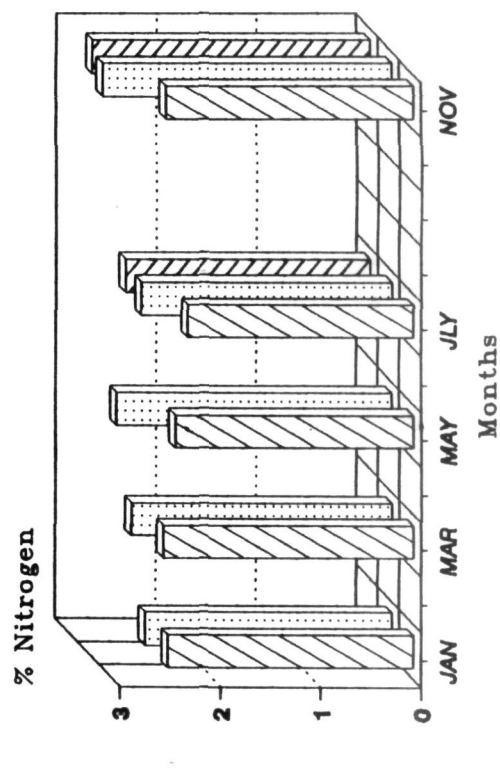


Fig. 1d : Nitrogen content in different leaves

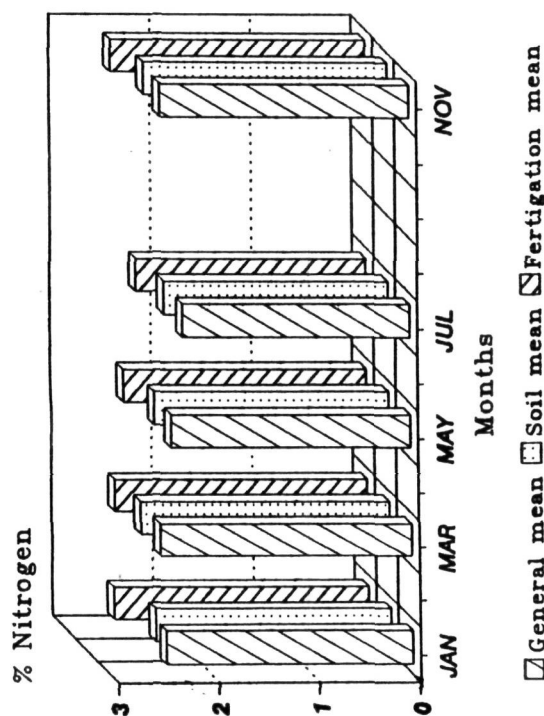


Fig. 1a : Nitrogen content in leaf 2.

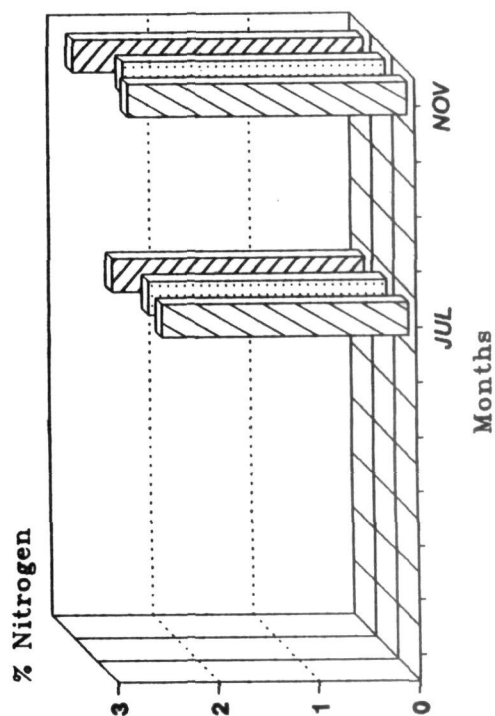


Fig. 1c : Nitrogen content in leaf 16

In general, at all months of sampling relatively higher N content was observed in the leaves of fertigation treatments than that of soil application of fertilizers (Figures 1a to 1d).

Phosphorus :

The P content in 2nd, 9th and 16th leaves varied considerably with decreasing in trend from top to bottom position on plant (Table 7). The mean content of all the treatments indicated a gradual decrease in P content of both 2nd and 9th leaf from January to November. The P content in 16th leaf was relatively higher in July than in November. The mean content of P varied from 0.200 to 0.252 per cent in 2nd leaf ; 0.180 to 0.208 per cent in 9th leaf and 0.184 to 0.171 per cent in 16th leaf indicating that they were well within range of reported values for young palms.

The P content in 2nd leaf did not vary among the treatments in all the months of sampling except that in July. In July the P content among the treatments significantly ranged from 0.183 per cent (T10) to 0.263 per cent (T4 and T5). In comparison to T1 (0.206%), T2, T3, T4 and T5 had significantly higher percentage of P (0.25 and 0.263 respectively). It was also noticed that fertigation treatments with the exception of T5 had relatively lower P content (ranging from 0.183 to 0.224 per cent in T6 to T10) compared to T1 and other soil application treatments (T2 to

Table 7 : Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Phosphorous' content (% DW) in leaflets at different leaf positions of young oil palms.

Treatment N:P:K and [Mg + Zn + B]* (g / Palm / year)	2 nd leaf					9 th leaf					16 th leaf				
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
T1-800:400:800 (Rec.) to soil	0.281	0.204	0.195	0.206	0.215	0.195	0.221	0.187	0.147	0.184	-	-	-	0.201	0.163
T2-1000:500:1000 (Enh.) to soil	0.288	0.259	0.197	0.251	0.218	0.202	0.195	0.179	0.173	0.187	-	-	-	0.209	0.168
T3-T1 + Mg + Zn + B to soil	0.240	0.194	0.215	0.251	0.206	0.234	0.184	0.165	0.152	0.160	-	-	-	0.181	0.173
T4- T2 + Mg + Zn + B to soil	0.214	0.223	0.189	0.263	0.215	0.210	0.192	0.198	0.173	0.181	-	-	-	0.187	0.173
T5- 800:400:800 thro' drip	0.221	0.241	0.203	0.263	0.217	0.273	0.195	0.179	0.184	0.195	-	-	-	0.192	0.176
T6- 1000:500:1000 thro' drip	0.253	0.217	0.192	0.224	0.220	0.184	0.195	0.195	0.184	0.206	-	-	-	0.181	0.165
T7- T5 + Mg + Zn + B thro' drip	0.310	0.230	0.184	0.220	0.218	0.172	0.195	0.184	0.200	0.187	-	-	-	0.171	0.171
T8- T6 + Mg + Zn + B thro' drip	0.265	0.213	0.197	0.206	0.197	0.191	0.181	0.192	0.260	0.189	-	-	-	0.176	0.179
T9- Rec.N K Zn & B thro' drip and P & Mg to soil.	0.212	0.242	0.206	0.210	0.220	0.217	0.165	0.197	0.201	0.195	-	-	-	0.195	0.176
T10- Enh. N K Zn & B thro' drip and P & Mg to soil.	0.242	0.267	0.218	0.183	0.211	0.183	0.195	0.209	0.182	0.206	-	-	-	0.151	0.170
Mean	0.252	0.226	0.200	0.230	0.214	0.208	0.192	0.188	0.180	0.189	-	-	-	0.184	0.171
CD at 5%	NS	NS	NS	0.043	NS	NS	0.023	0.022	0.037	NS	-	-	-	0.014	NS

* Mg as MgSO 4 : 400 g/palm /year
 Zn as ZnSO 4 : 60 g/palm /year
 B as Boric acid : 60 g/palm /year.

T4). However, considering the mean of all soil and fertigation treatments, P content did not vary much between themselves.

Significant difference in P content of 9th leaf among the treatments was observed in the month of March, May and July, while non-significant difference was observed during January to November months. In March the 9th leaf of T1 had significantly higher P content (0.221%) over all other treatments (varying from 0.184 to 0.195%). On the other hand in May higher P content was observed in all the fertigation treatments, compared to control (T1) with significant increase in T10 (0.209%). Among the soil application treatments significant reduction was observed in T3 (0.165%) in comparison to control T1 (0.187%). Continuing this trend, the July month showed a significant increase in P content of almost all the fertigation treatments (0.184 to 0.206%) barring T10 over T1. Thus, with mean low values during January and March fertigation helped to build up P content in 9th leaf as against soil application of fertilizers.

The P content of 16th leaf in July registered considerable differences among the treatments with significant reductions over control in T3, T4, T6, T7, T8 and T10 (0.151% to 0.187%). The reduction was generally more in fertigation treatment than in soil application treatments. Thus the mean values were low for P content in fertigation treatments (0.178%) than for soil application

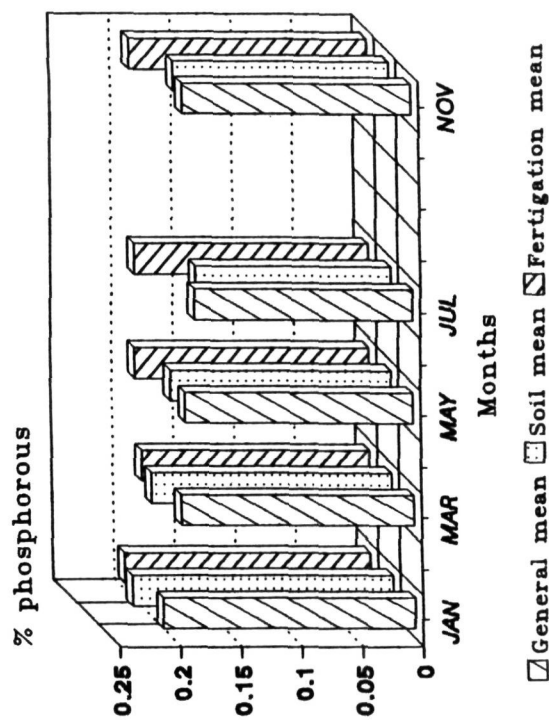


Fig. 2b : Phosphorous content in leaf 9

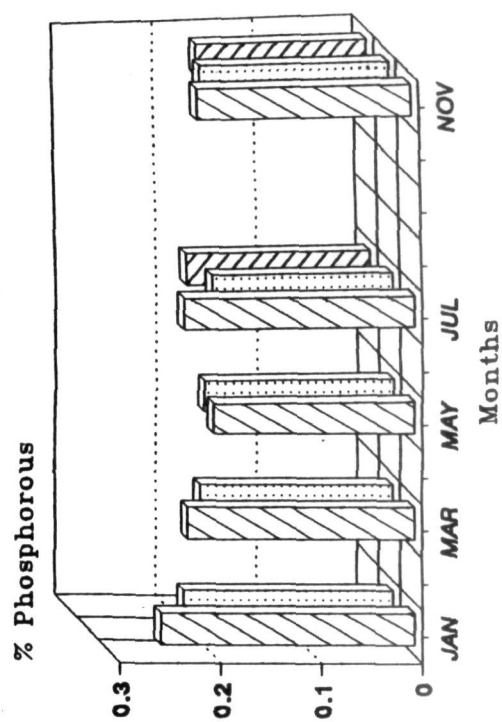


Fig. 2d : Phosphorous content in different leaves

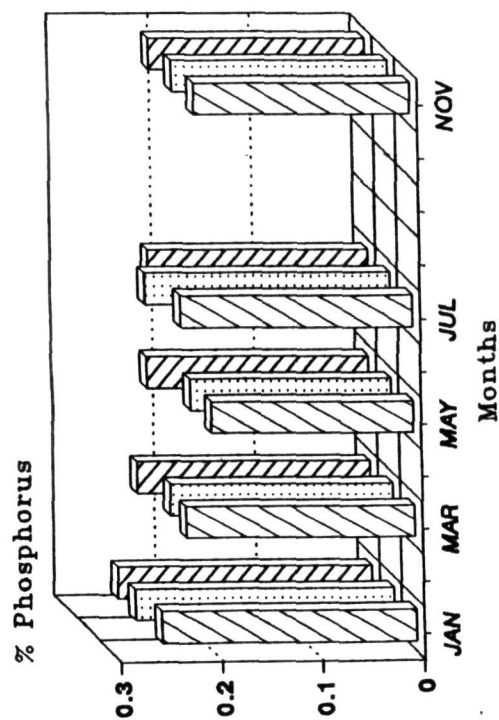


Fig. 2a : Phosphorous content in leaf 2

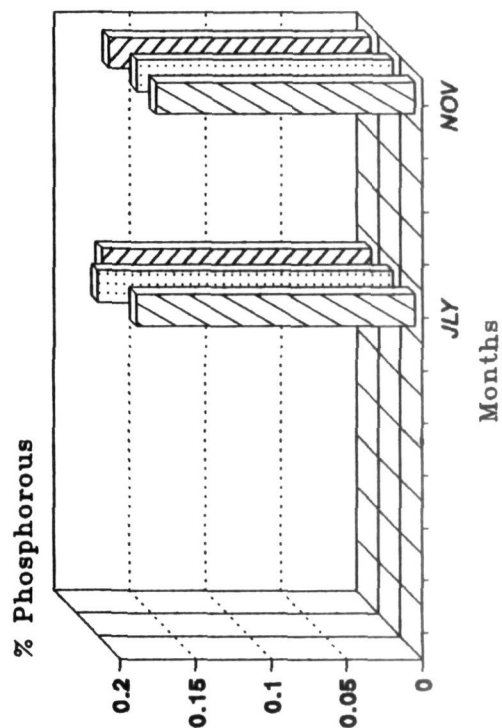


Fig. 2c : Phosphorous content in leaf 16

treatments (0.195%). Although non-significant differences were observed in P content of 16th leaf in November, the trend decreased with fertigations having slightly higher P content (0.173%) than the soil application treatments (0.169%) (Figures 2a to 2d).

Potassium :

The potassium content in different leaves over a period of time showed a decreasing trend from top to bottom. Generally, there was a gradual increase in leaf K content of all the leaves from January to November 1995 (Table 8). The K content was generally high in 2nd leaf, while that in 9th leaf and 16th leaf were lower but well within the range as reported for young palms.

significant differences due to different fertilizer treatments was noticed in all the months except July for 2nd leaf, January and March for 9th leaf. Non-significant differences were apparent for 16th leaf in both July and November months. Fertigation in general caused a decrease in K content of 2nd leaf in all the months upto July, whereas reverse was the case in November, with the soil application treatments generally having lower K content. The 9th leaf had higher content of K due to fertigation, in all the months of sampling. As against this, during both July and November, soil application caused a higher K content in 16th leaf.

Table 8 : Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Potassium' content (% DW) in leaflets at different leaf positions of young oil palms.

Treatment N:P:K and (Mg + Zn + B)* (g / Palm / year)	2 nd leaf					9 th leaf					16th leaf				
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
T1-800:400 (Rec.) to soil	2.03	1.83	2.21	1.67	2.27	0.43	0.68	0.80	1.15	1.49	-	-	-	0.57	1.02
T2-1000:500:1000 (Enh.) to soil	1.39	1.49	1.82	2.58	1.85	0.46	0.61	0.71	1.29	1.67	-	-	-	0.64	1.12
T3-T1 + Mg + Zn + B to soil	1.29	1.50	2.22	2.44	1.82	0.36	0.37	0.57	1.20	1.49	-	-	-	0.67	1.15
T4-T2 + Mg + Zn + B to soil	1.06	1.13	1.27	2.24	2.00	0.40	0.49	0.55	1.10	1.54	-	-	-	0.65	0.85
T5-800:400 thro' drip	1.09	1.22	1.32	2.54	2.02	0.46	0.61	0.82	1.39	1.94	-	-	-	0.50	1.04
T6-1000:500 thro' drip	1.28	1.41	1.42	1.55	1.64	0.48	0.64	0.79	1.19	1.89	-	-	-	0.52	0.74
T7-T5 + Mg + Zn + B thro' drip	1.09	1.07	1.30	1.94	2.80	0.68	0.83	0.92	1.25	1.60	-	-	-	0.65	0.97
T8-T6 + Mg + Zn + B thro' drip	1.07	1.15	1.40	1.55	2.55	0.55	0.62	1.07	1.10	1.49	-	-	-	0.79	0.77
T9 Rec. N K Zn & B thro' drip and P & Mg to soil.	1.12	1.30	1.40	1.87	2.60	0.52	0.79	0.95	1.02	1.65	-	-	-	0.70	0.99
T10 Enh. N K Zn & B thro' drip and P & Mg to soil.	1.14	1.30	1.58	1.84	2.44	0.42	0.93	1.07	1.15	1.83	-	-	-	0.50	1.08
Mean	1.26	1.34	1.60	2.02	2.30	0.47	0.66	0.82	1.18	1.66	-	-	-	0.62	0.97
CD at 5%	0.19	0.42	0.40	NS	0.45	0.11	0.28	NS	NS	NS	-	-	-	NS	NS

* Mg as MgSO 4 : 400 g /palm /year
 Zn as ZnSO 4 : 60 g /palm /year
 B as Boric acid : 60 g /palm /year.

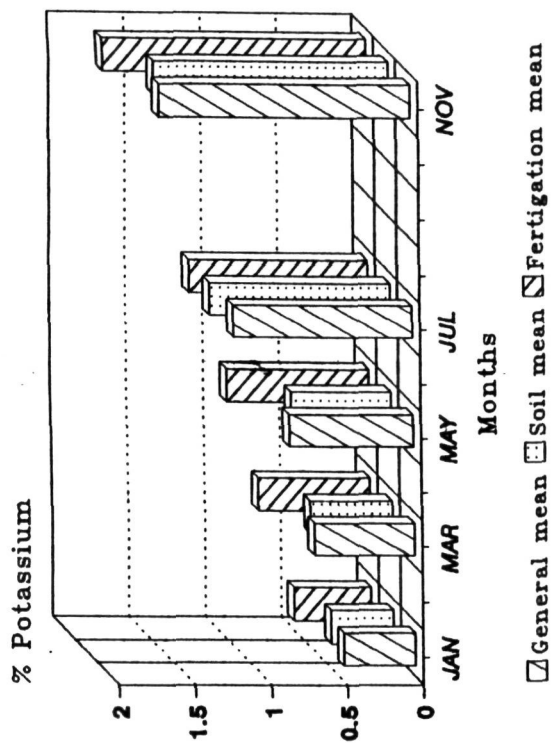


Fig. 3b : Potassium content in leaf 9

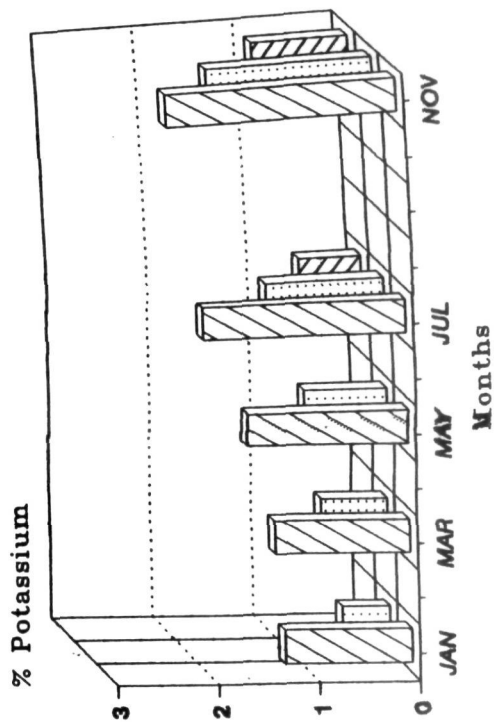


Fig. 3d : Potassium content in different leaves

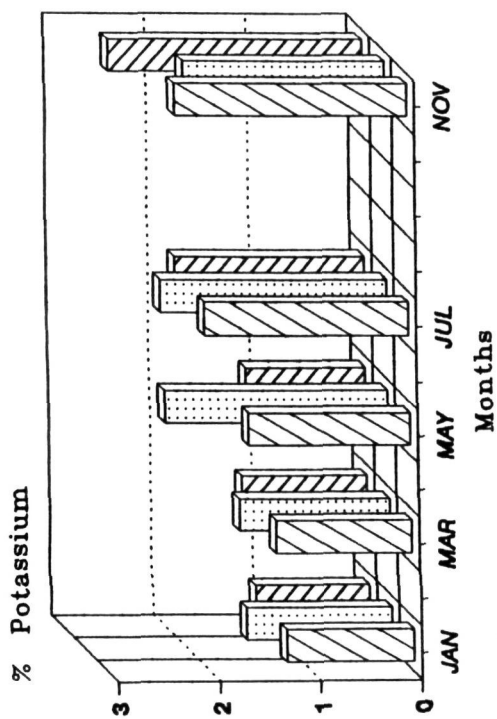


Fig. 3a : Potassium content in leaf 2

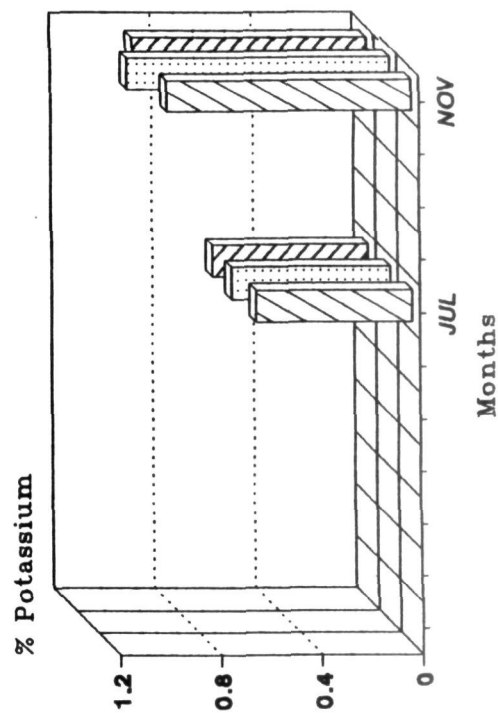


Fig. 3c : Potassium content in leaf 16

The K content in the month of January, March and May was significantly higher in T1 than in other treatments. Generally all the fertigation treatments caused a significant reduction in K content over control during these months. In contrast, in November there was a tendency for accumulation of more K in the leaves of fertigation treated plants than in soil application treatments. Among the fertigation treatments significant K content of 2.80 per cent was noticed in T7 as compared to T1 (2.27%).

Significant differences in K contents of 9th leaf was observed in the initial months only, namely that in January and March. Since the treatments were imposed after sampling in January the observed significant values was probably due to the variation among the plants themselves. Incidentally the mean K content of all the treatments was only 0.47 per cent with a range from 0.36 (T3) to 0.68 per cent (T7) indicating somewhat lower values than those reported for young palms. Although the treatment effect was significant in March, almost all were at par with the exception of T3 which recorded significantly lower K content (0.37 %) compared to control (0.68 %) (figures 3a to 3d).

Calcium :

In general the calcium content showed an increasing trend from upper to lower leaves. Fertigation enhanced the calcium content of 2nd leaf in later months (July and

November); throughout the experimental period in 9th leaf and during November in 16th leaf (Table 9).

There was no significant difference in calcium content of 2nd leaf among various treatments from January to November. As far as 9th leaf was concerned the treatment difference was apparent in the months of March, May and November only. The calcium contents in 16th leaf significantly differed among the treatments in both July and November months.

There was a tendency for more accumulation calcium in all the leaves particularly during later stage of sampling than those reported for the young palms. In both the months of March and May soil application treatments especially T3 and T4 recorded significantly lower calcium content than in control. All the other treatments were at par with slightly higher contents in fertigation treatments. During November the calcium content of 9th leaf was significantly higher in T3, T4, T5, T6, T7 and T8 compared to control T1 (0.97%) indicating enhanced accumulation of calcium due to both soil application of fertilizers and fertigation.

The lower 16th leaf in July month of sampling showed a significantly lower calcium content in all the treatments as compared to control T1 (1.40 %). In November, the calcium content among the treatments significantly differed. No particular trend was observed so far, as application of fertilizers either to soil or through drip system. Never-

Table 9 : Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Calcium' content (% DW) in leaflets at different leaf positions of young oil palms.

Treatment N:P:K and (Mg + Zn + B)* (g / Palm / year)	2nd leaf					9th leaf					16th leaf				
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
T1-800:400:800 (Rec.) to soil	0.50	0.46	0.65	0.62	0.58	0.39	0.50	0.68	0.91	0.99	-	-	-	1.40	1.38
T2-1000:500:1000 (Enh.) to soil	0.43	0.36	0.49	0.52	0.71	0.39	0.40	0.53	0.83	1.07	-	-	-	1.06	1.18
T3-T1 + Mg + Zn + B to soil	0.49	0.42	0.59	0.59	0.55	0.44	0.36	0.48	0.95	1.64	-	-	-	1.05	1.69
T4-T2 + Mg + Zn + B to soil	0.52	0.41	0.58	0.66	0.76	0.42	0.35	0.47	0.90	1.60	-	-	-	0.93	1.52
T5-800:400:800 thro' drip	0.43	0.38	0.53	0.63	0.77	0.38	0.44	0.60	0.93	1.54	-	-	-	1.01	1.93
T6-1000:500:1000 thro' drip	0.40	0.36	0.46	0.50	0.83	0.38	0.46	0.62	0.84	1.59	-	-	-	1.02	1.69
T7-T5 + Mg + Zn + B thro' drip	0.40	0.36	0.46	0.69	0.77	0.44	0.55	0.74	0.93	1.68	-	-	-	1.15	1.72
T8-T6 + Mg + Zn + B thro' drip	0.41	0.35	0.43	0.61	0.50	0.33	0.42	0.57	1.04	1.51	-	-	-	1.07	1.61
T9-Rec.N K Zn & B thro' drip and P & Mg to soil.	0.54	0.43	0.57	0.82	0.86	0.41	0.56	0.76	1.01	1.29	-	-	-	0.95	1.50
T10-Enh. N K Zn & B thro' drip and P & Mg to soil.	0.48	0.46	0.62	0.65	0.77	0.46	0.53	0.71	0.99	1.14	-	-	-	1.16	1.35
Mean	0.46	0.40	0.54	0.63	0.71	0.40	0.46	0.62	0.94	1.41	-	-	-	1.08	1.56
CD at 5%	NS	NS	NS	NS	NS	NS	0.13	0.17	NS	0.36	-	-	-	0.20	0.41

* Mg as MgSO 4 : 400 g /palm /year
 Zn as ZnSO 4 : 60 g /palm /year
 B as Boric acid : 60 g /palm /year.

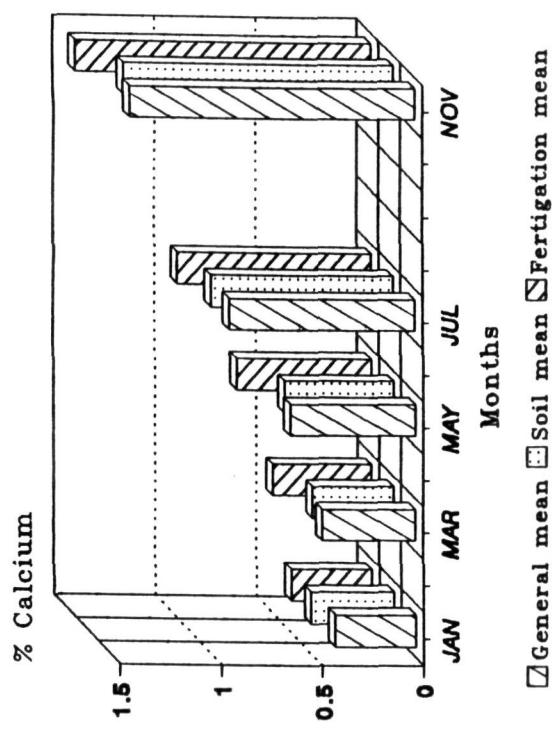


Fig. 4a : Calcium content in leaf 2

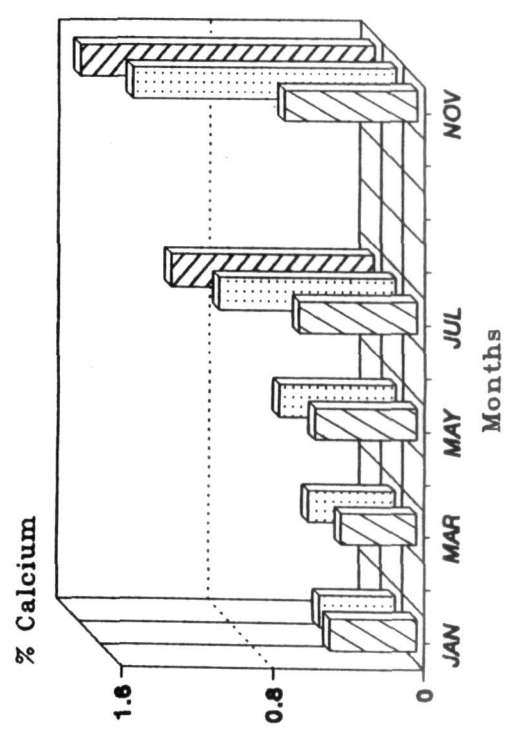


Fig. 4b : Calcium content in leaf 9

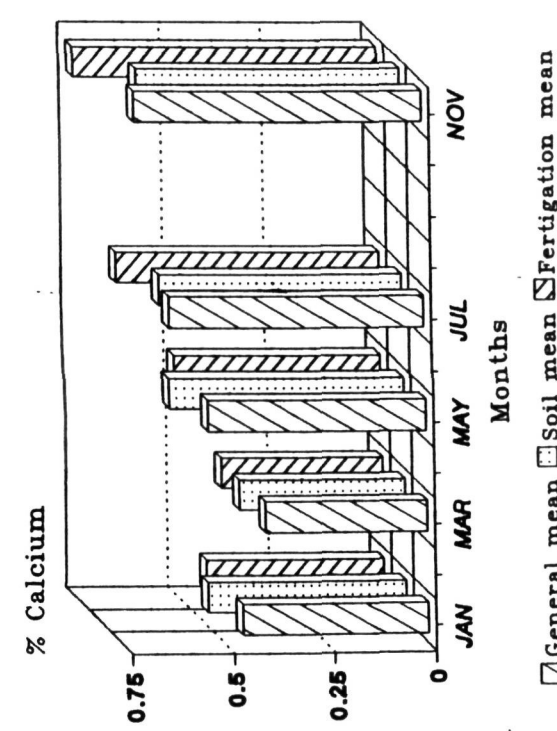


Fig. 4c : Calcium content in leaf 16

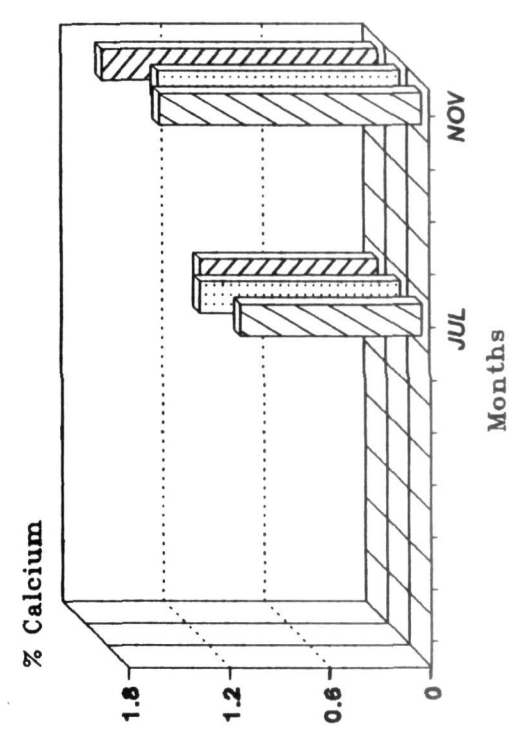


Fig. 4d : Calcium content in different leaves

theless, a general increased concentration was observed for fertigation treatments (1.50 to 1.93 %) as against control T1 (1.38%). Significantly higher calcium content was noticed in T5 (1.93 %) (figures 4a to 4d).

Magnesium :

As with calcium, the magnesium content also showed an increasing trend from top to bottom leaves, in all the months of observation (Table 10). The fertigation treatments generally lowered the Mg content of 2nd leaf in all the months except November where it was higher in fertigation treated plants. However in contrast the 9th leaf had relatively higher Mg content due to fertigation.

Magnesium content of 16th leaf July was generally higher in soil application treatments while that in November was more in fertigation treatments (figures 5a to 5d).

Significant differences due to treatments were observed in all the months except March for 2nd leaf; March, May and November for 9th leaf. The differences in Mg content of 16th leaf in both July and November was not apparent. In both the months of May and July a decreased trend in Mg content of 2nd leaf in all the plants under fertigation was apparent with significant reduction over control was observed in T5, T7, T8 and T9 in May and T6, T7, T8 and T9 in July.

In contrast, the November month saw a renewed of trend with fertigation showing an increased content of Mg

Table 10 : Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Magnesium' content (%DW) in leaflets at different leaf positions of young oil palms.

Treatment	2 nd leaf					9 th leaf					16 th leaf				
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
N:P:K and (Mg + Zn + B)* (g / Palm / year)	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
T1-800:400:800 (Rec.) to soil	0.385	0.435	0.469	0.527	0.325	0.364	0.397	0.420	0.529	0.399	-	-	-	0.533	0.813
T2-1000:500:1000 (Enh.) to soil	0.362	0.336	0.373	0.462	0.305	0.324	0.304	0.314	0.446	0.390	-	-	-	0.504	0.700
T3-T1 + Mg + Zn + B to soil	0.383	0.393	0.445	0.372	0.300	0.299	0.212	0.228	0.474	0.648	-	-	-	0.425	0.849
T4- T2 + Mg + Zn + B to soil	0.318	0.363	0.386	0.516	0.339	0.280	0.244	0.263	0.514	0.619	-	-	-	0.326	0.669
T5- 800:400:800 thro' drip	0.304	0.260	0.262	0.438	0.332	0.307	0.319	0.328	0.484	0.672	-	-	-	0.324	0.697
T6- 1000:500:1000 thro' drip	0.316	0.359	0.385	0.307	0.435	0.351	0.336	0.373	0.491	0.671	-	-	-	0.399	0.872
T7- T5 + Mg + Zn + B thro' drip	0.362	0.273	0.286	0.411	0.386	0.363	0.362	0.395	0.438	0.692	-	-	-	0.421	0.833
T8- T6 + Mg + Zn + B thro' drip	0.271	0.300	0.236	0.338	0.330	0.318	0.260	0.274	0.458	0.481	-	-	-	0.333	0.601
T9- Rec.N K Zn & B thro' drip and P & Mg to soil.	0.350	0.347	0.321	0.402	0.418	0.300	0.401	0.424	0.496	0.667	-	-	-	0.343	0.601
T10- Enh. N K Zn & B thro' drip and P & Mg to soil.	0.332	0.335	0.376	0.440	0.365	0.283	0.417	0.448	0.528	0.633	-	-	-	0.455	0.815
Mean	0.338	0.340	0.354	0.429	0.353	0.319	0.325	0.347	0.486	0.619	-	-	-	0.406	0.767
CD at 5%	0.053	NS	0.120	0.113	0.058	NS	0.088	0.104	NS	0.220	-	-	-	NS	NS

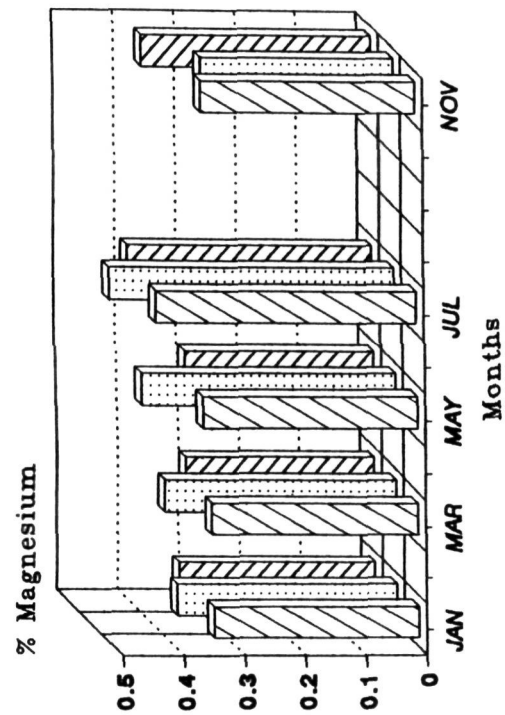
* Mg as MgSO 4 : 400 g /palm /year
 Zn as ZnSO 4 : 60 g/palm /year
 B as Boric acid : 60 g/palm /year.

in 2nd leaf. Significantly higher content of 0.435, 0.386 and 0.418 per cent was seen in T6, T7 and T9 as against 0.325 per cent in T1.

The Mg content in 9th leaf in March was relatively higher in T1 (0.397%) and decreased significantly in T2, T3, T4 (all soil application) and T8 (0.212 to 0.304 %).

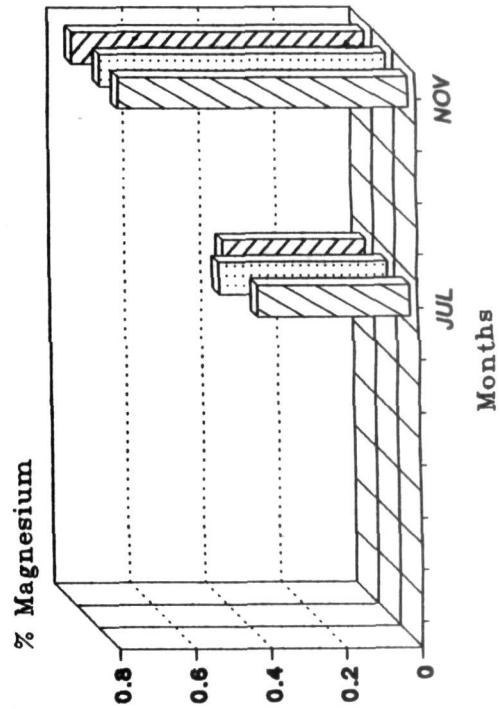
In November, the Mg content decreased sharply in T1 (0.399 %) over the period of month, while there was a subsubstantial increase in other treatments especially T3 and T4 (both soil application), as well as in T5, T6, T7, T9 and T10 (fertigation), the content ranging from 0.633 to 0.692 per cent.

In 16th leaf, on an average almost doubled the Mg content was noticed from July to November with nonsignificant differences among the treatments in both the month. The contents ranged from 0.324 (T4) to 0.533 (T1) per cent during July ; from 0.601 (T8) to 0.872 (T6) per cent during November respectively.



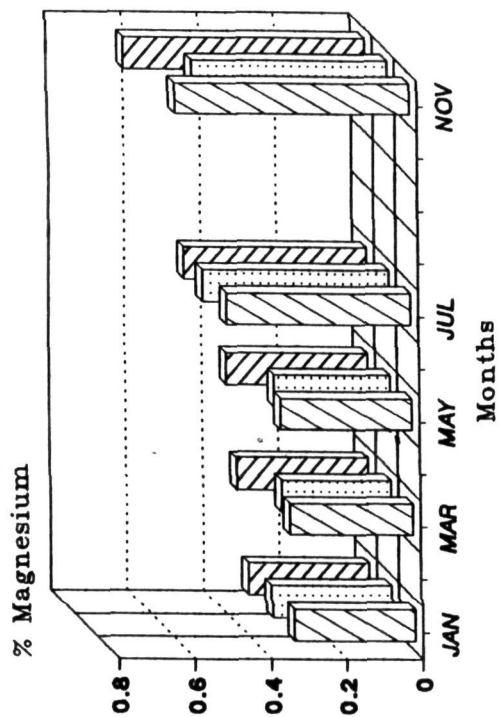
□ General mean □ Soil mean □ Fertigation mean

Fig. 5a : Magnesium content in leaf 2



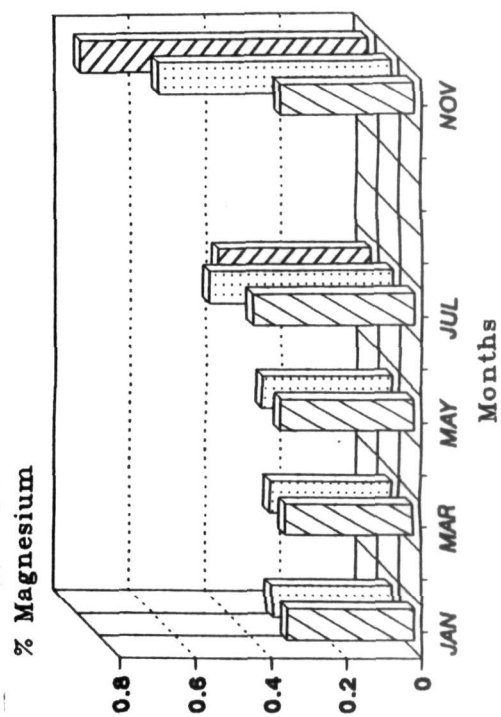
□ General mean □ Soil mean □ Fertigation mean

Fig. 5c : Magnesium content in leaf 16



□ General mean □ Soil mean □ Fertigation mean

Fig. 5b : Magnesium content in leaf 9



□ % Mg in 2nd leaf □ % Mg in 9th leaf □ % Mg in 18th leaf

Fig. 5d : Magnesium content in different leaves

Iron

The iron content during different months was more or less similar in the leaves irrespective of their position on the plant (Table 11). The mean higher content was 253 and 281 ppm for 2nd and 9th leaf respectively. The 16th leaf showed a slightly high iron content (215 ppm) in July. Generally the iron content in the leaves were slightly on higher range as against the values reported for young palms within 6 years of age. Further the iron contents in 2nd and 9th leaves were relatively higher in fertigation treatments as compared to those of soil application. The reverse was true for 16th leaf in both months of observations. Significant differences due to treatment were observed in May and November for 2nd leaf as well as in July and November for 16th leaf. In none of the months the contents differed significantly among the treatments in 9th leaf.

In 2nd leaf during May significantly higher Fe content was noticed in T10 (434 ppm) as against control T1 (240 ppm). All the other treatment were at par with control.

The Fe content in 2nd leaf during November also differed significantly with fertigation treatments such as T7 and T8 registering higher Fe content (280 ppm and 265 ppm respectively) over control T1 (142 ppm). Other fertigation treatments (T5, T6, T9 and T10) also registered a non-significant increase in Fe content.

Table 11 : Effect of application of increased levels of nutrients to soil and through drip irrigation on Iron (ppm) content (DW) in leaflets at different leaf positions of young oil palms.

Treatment N:P:K and (Mg + Zn + B) * (g / Palm / year)	2 nd leaf					9 th leaf					16 th leaf				
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
	189	133	240	190	142	195	147	246	153	195	-	-	-	217	189
T1-800:400:800 (Rec.) to soil	189	133	240	190	142	195	147	246	153	195	-	-	-	217	189
T2-1000:500:1000 (Enh.) to soil	241	145	156	187	135	120	154	249	142	231	-	-	-	299	204
T3-T1 + Mg + Zn + B to soil	187	133	251	208	182	156	163	310	207	211	-	-	-	151	254
T4-T2 + Mg + Zn + B to soil	159	150	295	163	136	208	237	261	136	147	-	-	-	194	182
T5-800:400:800 thro' drip	144	145	169	308	161	175	248	301	136	137	-	-	-	158	266
T6-1000:500:1000 thro' drip	165	149	236	142	177	159	195	310	139	152	-	-	-	176	143
T7-T5 + Mg + Zn + B thro' drip	238	172	243	130	280	148	192	292	187	253	-	-	-	142	144
T8-T6 + Mg + Zn + B thro' drip	175	209	256	147	265	233	175	308	189	188	-	-	-	196	135
T9-Rec. N K Zn & B thro' drip and P & Mg to soil.	215	183	251	171	205	242	238	233	137	179	-	-	-	136	153
T10-Enh. N K Zn & B thro' drip and P & Mg to soil.	162	155	434	145	199	238	232	298	156	170	-	-	-	256	142
Mean	188	157	253	179	188	188	198	281	158	186	-	-	-	192	181
CD at 5%	NS	NS	129.1	NS	91.5	NS	NS	NS	NS	NS	-	-	-	60.7	89.4

* Mg as MgSO 4 : 400 g /palm /year
Zn as ZnSO 4 : 60 g /palm /year
B as Boric acid : 60 g /palm /year.

The iron content of 9th leaf were at par in all the treatments in all the months. However, upto May there was an increasing trend, which were relatively higher as compared to that in soil treatments. Both July and November saw a decreased content in all the treatments with fertigation treatments recording lower Fe content than with soil application treatments.

The iron content in 16th leaf during July and November differed significantly among the treatments. In comparison to control T1 (217 ppm), T2 (125% of recommended fertilizers) recorded higher (299 ppm) iron content. However, most of the treatments under fertigation had lower iron content. Significantly reduced Fe content was observed in T7 (142 ppm) and T9 (136 ppm) respectively.

During November although all the treatments, affected the iron content in 16th leaf, significant difference was not observed between control T1 (189 ppm) and other treatments. However in other treatments it ranged from 142 ppm (T10) to 266 ppm (T5). The fertigation treatments in general had a tendency to accumulate lower iron content than soil application treatments (Figures: 6a to 6d)

Zinc :

In general the average zinc content all through the experimental period was higher in 2nd leaf than 9th and 16th leaf. The exceptional month was July during which the average was higher in 9th followed by 16th leaf than in 2nd

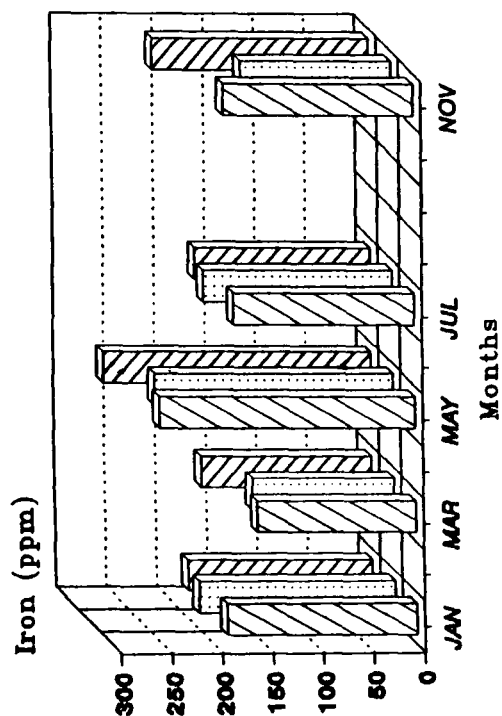


Fig. 6a : Iron content in leaf 2

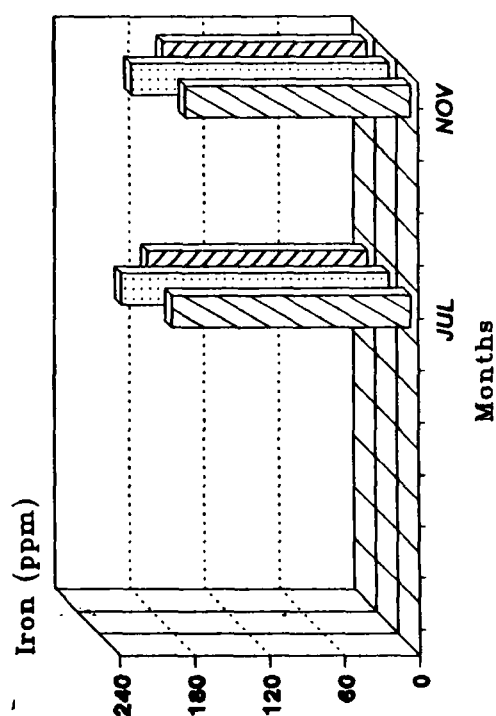


Fig. 6c : Iron content in leaf 16

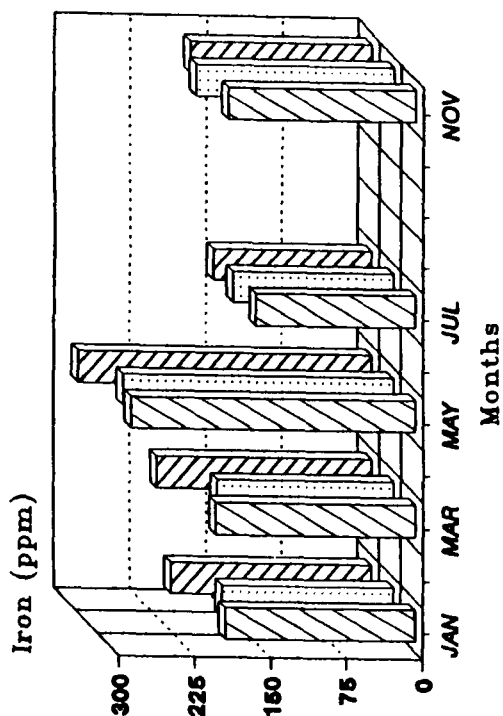


Fig. 6b : Iron content in leaf 9

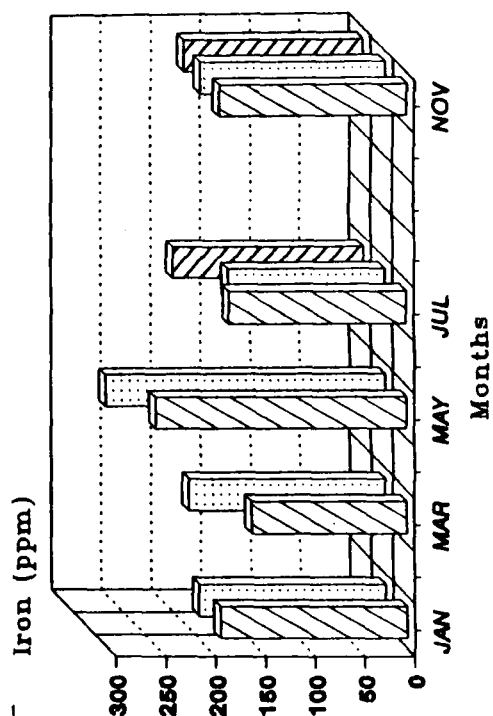


Fig. 6d : Iron content in different leaves

Table 12 : Effect of application of increased levels of nutrients to soil and through drip irrigation on 'King N' (ppm)' content (DW) in leaflets at different leaf positions of young oil palms.

Treatment N:P:K and [Mg + Zn + B]* (g / Palm / year)	2 nd leaf					9 th leaf					16 th leaf				
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
T1-800:400:800 (Rec.) to soil	29.7	27.8	21.3	17.3	45.6	28.5	27.7	17.4	37.1	35.9	-	-	-	35.6	46.4
T2-1000:500:1000 (Enh.) to soil	22.8	25.4	18.3	24.8	43.4	27.7	24.1	16.2	32.5	39.4	-	-	-	36.1	44.7
T3-T1 + Mg + Zn + B to soil	22.8	29.5	23.3	23.0	46.8	25.4	23.7	16.1	41.2	40.7	-	-	-	36.2	47.6
T4-T2 + Mg + Zn + B to soil	27.9	29.3	25.0	22.6	46.6	26.1	25.0	20.0	44.6	41.4	-	-	-	38.0	43.4
T5-800:400:800 thro' drip	24.5	29.0	20.7	29.1	62.8	25.4	25.6	15.3	44.3	41.2	-	-	-	39.7	48.0
T6-1000:500:1000 thro' drip	26.0	31.1	20.0	23.4	82.5	25.1	22.8	15.7	42.8	45.6	-	-	-	41.9	45.0
T7-T5 + Mg + Zn + B thro'drip	21.7	37.4	18.2	20.7	75.5	27.3	27.8	17.0	42.9	45.0	-	-	-	36.3	45.7
T8-T6 + Mg + Zn + B thro' drip	27.5	38.9	21.1	18.3	66.3	26.0	27.4	15.6	38.0	47.4	-	-	-	42.7	50.1
T9-Rec. N K Zn & B thro' drip and P & Mg to soil.	23.5	35.7	18.8	21.2	57.6	20.7	31.0	15.7	42.1	46.1	-	-	-	37.3	44.4
T10-Enh. N K Zn & B thro'drip and P & Mg to soil.	27.1	29.1	19.3	32.5	61.7	25.8	28.4	24.1	40.1	48.0	-	-	-	32.7	42.3
Mean	25.4	31.3	20.6	23.3	58.9	25.8	26.4	17.3	40.6	43.1	-	-	-	37.7	45.8
CD at 5%	4.5	NS	NS	6.1	10.7	NS	NS	NS	5.9	4.2	-	-	-	5.4	NS

* Mg as MgSO 4 : 400 g /palm /year
Zn as ZnSO 4 : 600 g /palm /year
B as Boric acid : 600 g /palm /year.

* Mg as MgSO 4 : 400 g /palm /year
 Zn as ZnSO 4 : 60 g /palm /year
 B as Boric acid : 60 g /palm /year.

leaf. The values obtained were more less similar to those reported for young palm with probable exception of 2nd leaf during November month which was on higher side. The average zinc content reached its peak in November in all the leaves. The zinc content was generally higher in fertigation treatment from January to November, irrespective of the leaf position on palm. Significant difference in zinc content of 2nd and 9th leaf was observed in July and November, while it was significant in 16th leaf only during July. The zinc content was highly varying among the palm even before the imposition of the treatments in January especially in 2nd leaf (Table : 2 and Figures : 7a to 7d).

In 2nd leaf during July significantly higher zinc content was noticed in T2 (24.80 ppm), T5 (29.10 ppm), T6 (23.40 ppm) and T10 (32.50 ppm), indicating fertigation treatments influencing relatively more accumulation of zinc in 2nd leaf. This was clearly brought in November with significantly higher content in all the fertigation treatments (57.60 to 82.50 ppm) as compared to control (45.60 ppm). However, these concentrations were considerably higher than reported in literature.

The zinc content in 9th leaf significantly differed among the treatments in July and November months. As compared to control (37.10 ppm), the zinc content in July was significantly higher in T4 (44.60 ppm) and T5 (44.30 ppm) with other fertigation treatment also showing non-

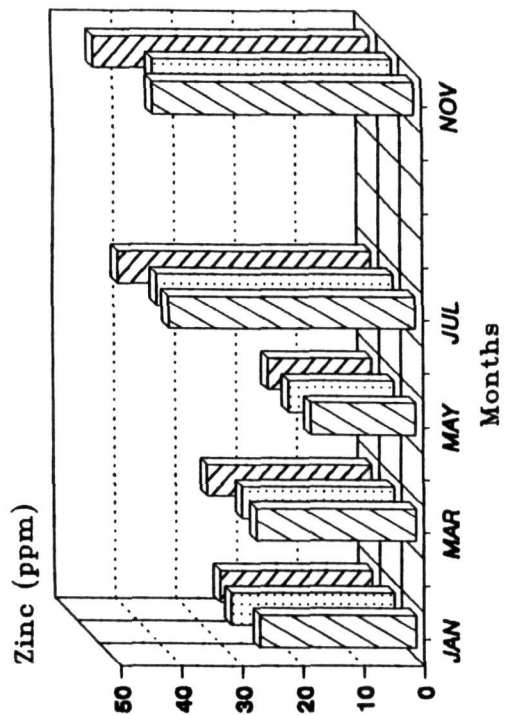


Fig. 7b : Zinc content in leaf 9

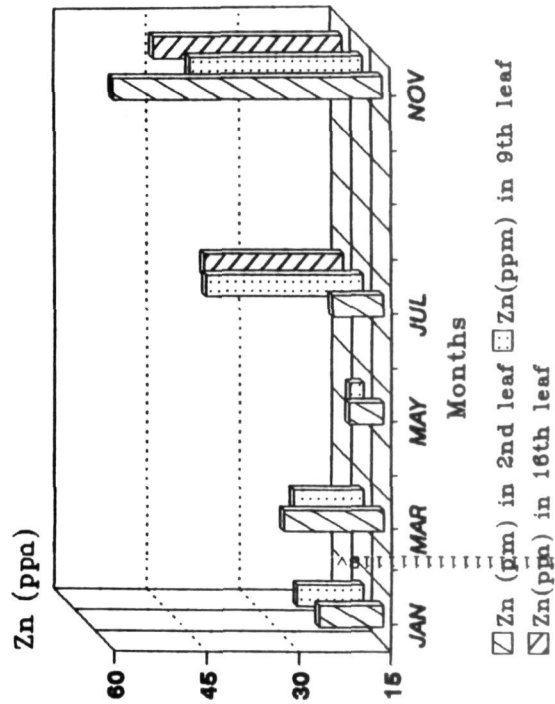


Fig. 7d : Zinc content in different leaves

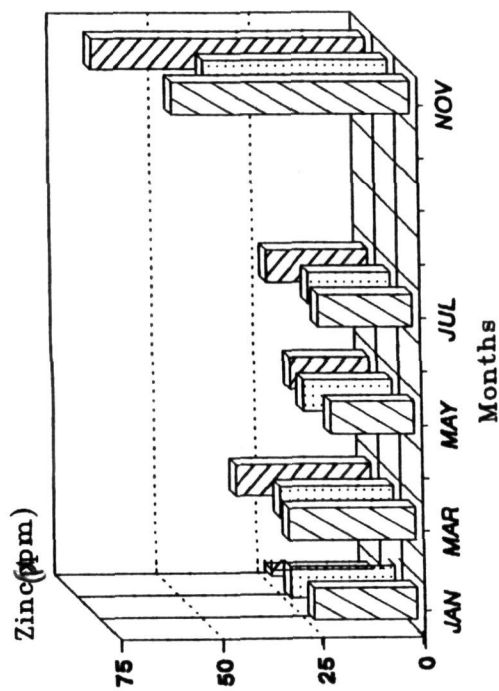


Fig. 7a : Zinc content in leaf 2

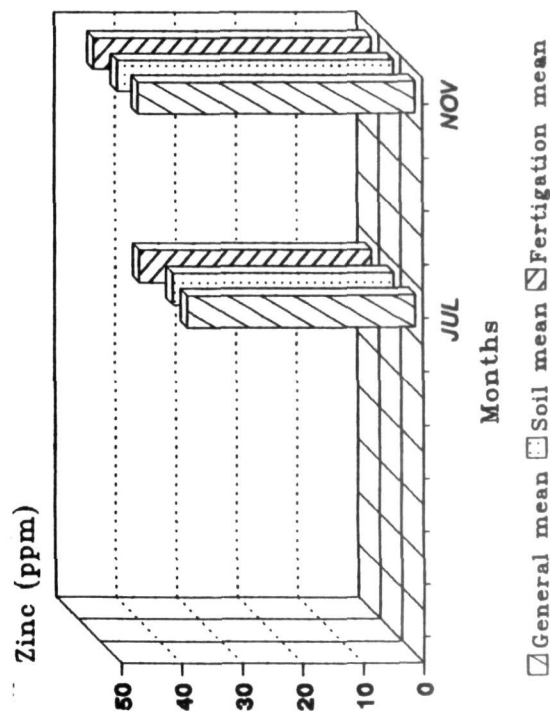


Fig. 7c : Zinc content in leaf 16

significant increase over control. Similarly significantly higher content was obtained in all the fertigation treatment (41.20 to 48.00 ppm) during November in comparison to control T1 (35.90 ppm). The other soil application treatments such as T3 and T4 also recorded significantly higher concentration of zinc (40.70 and 41.40 ppm respectively).

The zinc content in 16th leaf differed significantly among the treatment in July only. However, relatively higher contents were observed in T6 (41.90 ppm) and T8 (42.70 ppm) over control T1 (35.60 ppm). In November the zinc content was at par in all the treatments ranging from 42.3 ppm in T10 to 50.10 ppm in T8.

Manganese :

The manganese content was generally lower in top leaves and higher in bottom leaves. The lower leaves especially 16th leaf recorded very high contents in November. Barring these, all through the experimental period the manganese content was within the range of values reported for young palms (Table 13).

On an average the manganese content was at its highest in July for 2nd leaf (56.90 ppm) and November month for 9th leaf (78.10 ppm) and 16th leaf (88.50 ppm).

In none of the months manganese differed significantly among the treatments in 2nd, 9th and 16th leaf. Generally fertigation enhanced contents of manganese in 2nd and 9th leaf till July, while in November the content was

Table 13 : Effect of application of increased levels of nutrients to soil and through drip irrigation on 'Mangnese (ppm)' content [DW] in leaflets at different leaf positions of young oil palms.

Treatment N:P:K and [Mg + Zn + B]* (g / Palm / year)	2 nd leaf					9 th leaf					16 th leaf				
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
T1-800:400:800 (Rec.)to soil	51.0	44.9	51.8	55.9	57.7	58.0	67.4	56.5	53.9	76.2	-	-	-	81.0	75.5
T2-1000:500:1000 (Enh.)to soil	44.6	58.1	40.7	54.4	58.1	63.6	74.5	64.4	56.2	86.1	-	-	-	74.4	91.8
T3-T1 + Mg + Zn + B to soil	56.5	49.1	43.0	59.7	54.9	62.7	77.8	54.3	56.0	71.1	-	-	-	72.6	84.4
T4-T2 + Mg + Zn + B to soil	69.0	58.9	56.6	57.3	57.0	81.4	90.1	61.0	58.7	78.9	-	-	-	78.4	102.5
T5-800:400:800 thro' drip	54.8	62.5	44.8	47.8	51.0	82.8	77.6	64.1	64.0	71.4	-	-	-	84.3	96.8
T6-1000:500:1000 thro' drip	46.0	71.2	49.7	55.4	66.2	74.8	82.3	65.1	65.7	69.8	-	-	-	74.3	129.7
T7-T5 + Mg + Zn + B thro'drip	43.6	66.7	60.1	48.9	47.9	55.9	93.4	80.3	79.1	77.0	-	-	-	74.5	120.1
T8-T6 + Mg + Zn + B thro' drip	79.0	63.5	46.5	84.0	46.9	73.6	61.4	57.2	66.9	57.8	-	-	-	73.1	72.2
T9-Rec.N K Zn & B thro' drip and P & Mg to soil.	68.0	54.2	52.3	58.8	39.9	66.8	73.5	72.3	67.6	68.1	-	-	-	81.8	88.7
T10-Enh. N K Zn & B thro'drip and P & Mg to soil.	49.0	49.5	47.0	59.1	39.7	80.4	79.8	60.2	63.8	73.1	-	-	-	67.8	96.5
Mean	56.2	57.9	49.2	58.1	51.9	70.0	77.8	63.6	63.3	73.0	-	-	-	76.2	95.8
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-	NS	NS

* Mg as MgSO 4 : 400 g /palm /year
 Zn as ZnSO 4 : 60 g /palm /year
 B as Boric acid : 60 g /palm /year.

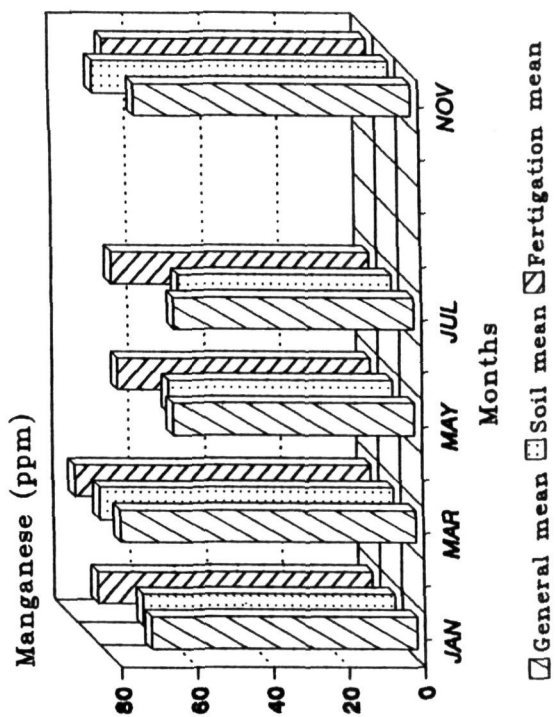


Fig. 8b : Manganese content in leaf 9

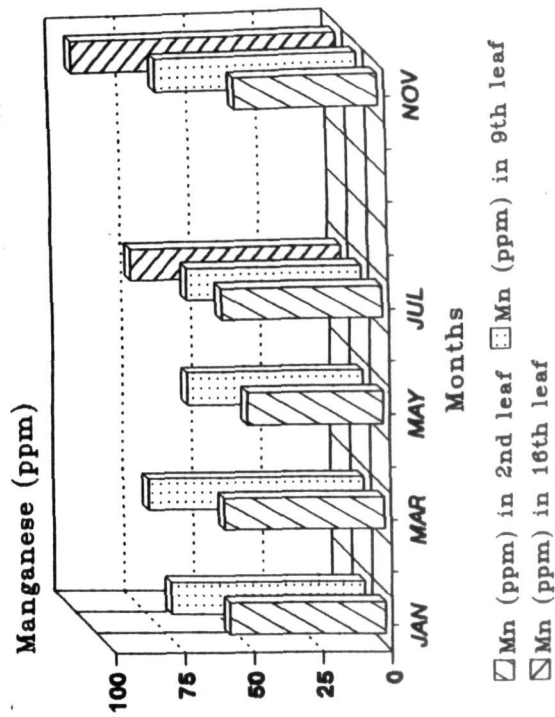


Fig. 8d : Manganese content in different leaves

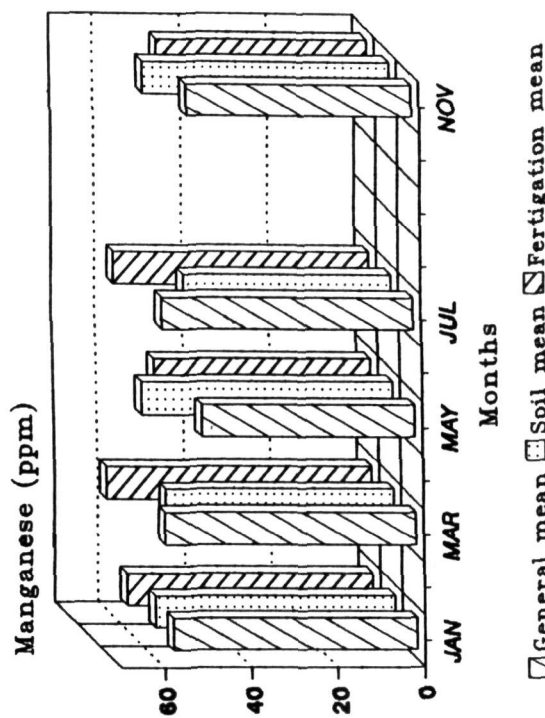


Fig. 8a : Manganese content in leaf 2

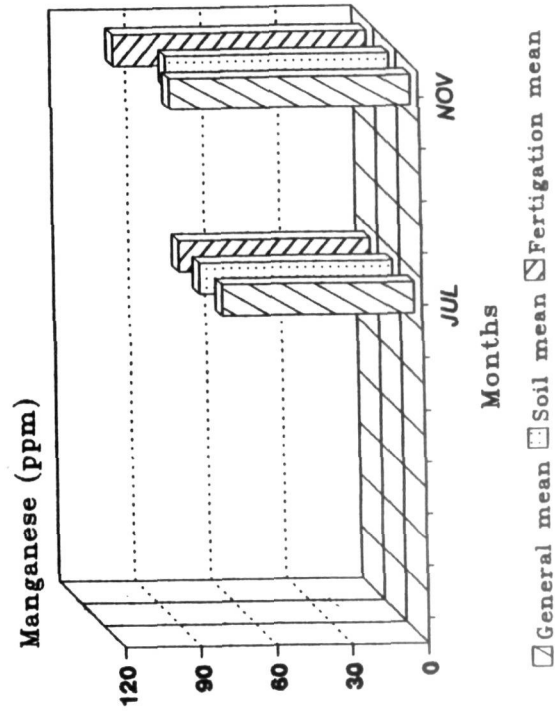


Fig. 8c : Manganese content in leaf 16

considerably less in these treatments, as compared to that in soil application treatments. Even in 16th leaf during November the content was higher under fertigation (Figures : 8a to 8d).

Copper :

The Cu content in general was higher in 2nd leaf and gradually decreased in 9th and 16th leaf. Cu content in all the leaves was within the range of limits reported for palm of less than 6 year age. As against other nutrients, Cu was not affected either by soil application or fertigation treatments throughout. In general, the Cu content reached its peak in May for 2nd and 9th leaf, while in 16th leaf the peak was reached in November. As regards the effect of various treatments significant differences were obtained in respect of 2nd leaf only. The Cu content in 9th and 16th leaf did not differ significantly among the treatments in any of the months observed (Table : 14 and Figures :9a to 9d).

In March the Cu content in 2nd leaf was significantly higher in T3 (18.70 ppm) and T10 (17.60 ppm) as compared to control T1 (13.80 ppm).

In May it was 18.00 ppm in T1 which was significantly higher than in T2 (13.40 ppm) but lower than in T3 (22.10 ppm). In July as against T1 (10.80 ppm), T2, T3, T4, T5, T6, T7 and T9 recorded significantly higher Cu content ranging from 14.00 to 17.10 ppm. In November T9 and T10

Table 14: Effect of application of increased levels of nutrients to soil and through drip irrigation on Copper (ppm) content [DW] in leaflets at different leaf positions of young oil palms.

Treatment (g / Palm / year)	2 nd leaf				9 th leaf				16 th leaf						
	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov	Jan	Mar	May	Jul	Nov
T1-800:400:800 (Rec.)to soil	9.90	13.8	18.0	10.8	9.90	9.20	12.0	13.5	9.60	10.6	-	-	-	7.90	9.40
T2-1000:500:1000 (Enh.)to soil	9.70	11.7	13.4	17.1	8.60	9.20	11.8	12.1	10.5	10.5	-	-	-	8.20	8.90
T3-T1 + Mg + Zn + B to soil	8.40	18.7	22.1	15.0	10.5	8.60	11.5	11.9	11.2	9.70	-	-	-	9.10	11.2
T4-T2 + Mg + Zn + B to soil	9.10	13.1	15.9	14.3	11.8	8.00	11.3	13.3	10.6	11.5	-	-	-	8.30	10.9
T5-800:400:800 thro' drip	8.60	12.9	15.2	15.5	10.2	8.40	10.9	12.0	10.3	11.2	-	-	-	8.10	13.7
T6-1000:500:1000 thro' drip	9.20	13.5	15.1	14.0	9.50	7.90	12.5	12.2	9.50	12.0	-	-	-	9.00	7.50
T7-T5 + Mg + Zn + B thro'drip	10.6	12.7	14.8	14.3	11.7	9.20	12.2	13.2	8.70	9.60	-	-	-	8.40	7.80
T8-T6 + Mg + Zn + B thro' drip	113.	13.9	16.7	12.8	12.2	10.0	11.3	12.3	10.3	9.30	-	-	-	8.80	9.40
T9-Rec.N K Zn & B thro' drip and P &Mg to soil.	12.1	14.3	16.8	14.6	16.3	11.1	10.4	12.2	9.60	10.3	-	-	-	8.50	12.0
T10-Enh. N K Zn & B tho'drip and P & Mg to soil.	9.90	17.6	18.2	12.2	13.4	9.50	9.50	11.4	8.00	9.80	-	-	-	7.10	8.30
Mean	9.90	14.2	16.6	14.1	11.4	9.10	11.3	12.4	9.80	10.5	-	-	-	8.30	9.90
CD at 5%	1.2	3.6	3.9	3.0	2.6	1.1	NS	NS	NS	NS	-	-	-	NS	NS
* Mg as MgSO 4 : 400 g /palm /year Zn as ZnSO 4 : 60 g /palm /year B as Boric acid : 60 g /palm /year.															

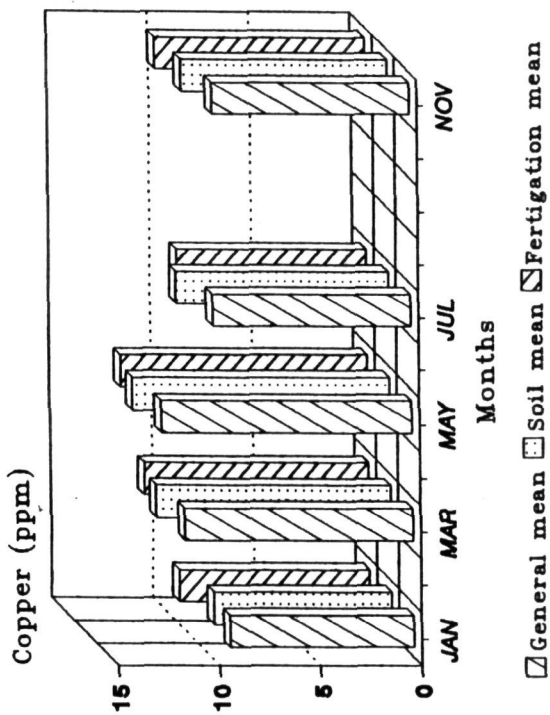


Fig. 9b : Copper content in leaf 9

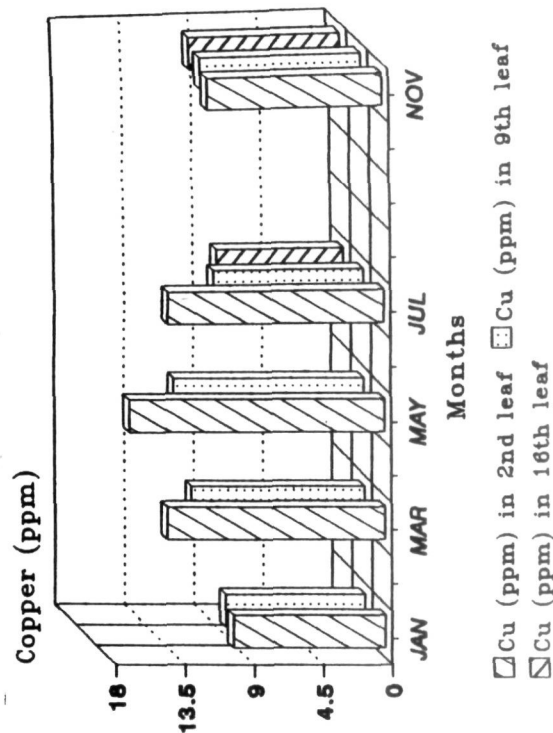


Fig. 9d : Copper content in different leaves

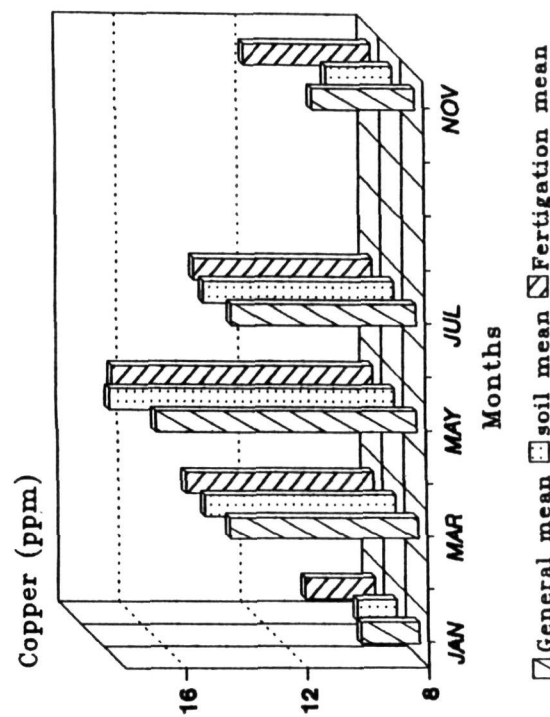


Fig. 9a : Copper content in leaf 2

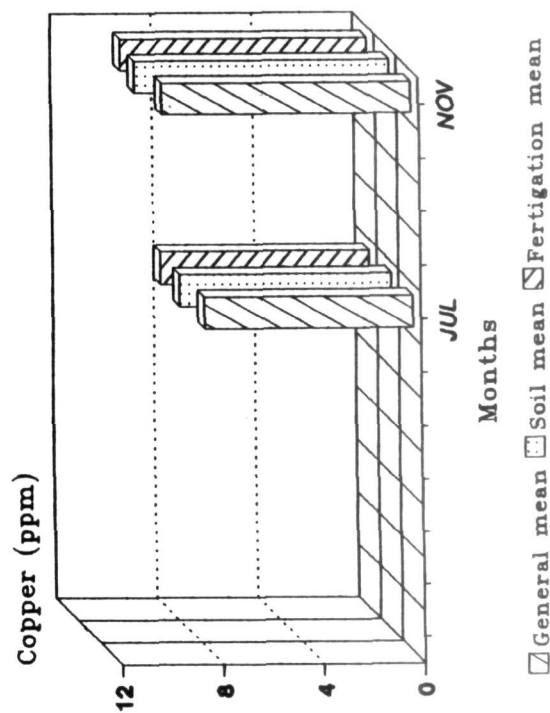


Fig. 9c : Copper content in leaf 16

had significantly higher content of 16.30 and 13.40 ppm as compared to 9.90 ppm in control (T1).

Soil nutrient status :

The soil samples were collected at two depths (0-15 and 15-30 cm) initially and at the end of experimental period at different distances from the palm namely at the basin and away from the basin. The soil samples at the basin were collected in all the treatments replication wise, whereas that away from the basin was collected randomly at four spots in the entire experimental area.

The mean data on available nutrients initially and at the end of experimental period at and away from the palm basin presented in Table 15, to assess the overall availability of nutrients. The data pertaining to individual treatments at the basin are dealt separately in more detailed manner.

The data presented in Table 15 indicated that initially the available nutrients occurred adequately in black soil of the farm. Slight variation was observed between the available nutrients at the palm basin and away from the palm basin, at both the depths studied. The available K, Zn and Cu were more or less similar in both the regions, while that of P, Ca and Fe was more in the region away from the basin. This suggests that K, Zn and Cu were rather in excess in their availability, whereas P, Ca and Fe were continuously taken up by the palm causing a certain

Table 15 : Soil nutrient status of young oil palm garden as influenced by increased application of fertilizers applied to soil and through fertigation.

Available	Initial				At the end of experiment							
					APB				AWPB			
	**	T	M		T	M			T	M	T	M
Nitrogen (ppm)		186	174	168	104	8.23	7.60	213	220	246	198	
Phosphorus (ppm)		7.13	6.70	8.27	8.23	7.60	5.40	6.50	5.70			
Potassium C mol (P)/Kg	+	0.29	0.23	0.29	0.22	1.82	1.52	1.41	0.42			
Calcium C mol (P)/Kg	+	32.30	36.80	42.70	40.20	42.20	45.20	46.40	47.70			
Magnesium C mol (P)/Kg	+	7.38	11.40	9.90	10.60	10.80	11.50	11.50	11.50			
Iron (ppm)		3.52	3.18	5.95	4.45	4.75	4.85	4.17	3.77			
Zinc (ppm)		0.26	0.32	0.26	0.32	0.74	0.73	0.27	0.32			
Manganese (ppm)		8.13	6.62	9.80	6.88	3.86	4.11	3.44	3.60			
Copper (ppm)		0.23	0.19	0.26	0.18	0.49	0.47	0.33	0.30			

Note : * location APB ----> At the palm basin

AWPB ----> Away from the palm basin.

** Soil depth T : 0-15cm
M : 15-30cm.

depletion which did not heavily dropped to a deficiency level. The available N was more in the basin, indicating of being replenished frequently and through organic matter from waste bunches. Mg at surface level and Mn at both the depths were slightly of lower availability at the palm basin.

All the nutrient showed at the end of experimental period a substantial increase in their availability at the palm basin at both depths, presumably due to application of enhanced N, P and K fertilizers as well as due to additional dose of Mg, Zn and B. Even in the region away from the basin also the nutrient availability enhanced considerably especially in case of N, K, Ca, Cu and Mg. This is suggestive of movement of nutrients both horizontally and vertically down. On the other hand, available nutrient such as P, Fe and Mn tended to reduced further from the initial values from the region away from the basin.

At the end of experimental period soil collected at the basin of individual treatments at the depth viz., 0-15 and 15-30 cm were also analyzed for available nutrients. With the exception of available N at both the depths, and Ca and Mn at 0-15 cm depth, all the other nutrient availability significantly differed due to treatments. The available N remained more or less same at both depths with a tendency to increase at lower depths (213 ppm at 0-15 cm, 220 ppm at 15-30 cm). It ranged from 190 to 248 ppm at 0-15

cm and 186 to 270 ppm at 15-30 cm depths respectively (Table 16a and 16b). At both the depths the available N relatively higher in T1 than other treatments. However at 0-15 cm depth fertigation caused a slight increase in availability as against soil treatments (208 ppm). At lower depths reverse was the true with the soil treatments showing an enhanced N availability (241 ppm) as against fertigation (212 ppm).

Phosphorus :

The available P also remained constant at both depths studied (10.19 ppm at 0-15 cm and 10.10 ppm 15-30 cm). The available P significantly differed among the treatments at both the soil depths (Table 16a). The available P at 0-15 cm was higher in T1 (13.90 ppm) differing with other treatments, except T10 where a further increase in its availability was noticed (21.74 ppm). All other treatments especially those of fertigation caused significantly lower availability of P ranging from 6.44 ppm (T8) to 7.44 ppm (T5). A similar trend was observed at 15-30 cm depth. All the treatments barring T10 caused a significant reduction in P availability more so under fertigation.

Potassium :

There was a reduction in exchangeable K with depth (1.82 at 0-15 cm and 1.52 C mol (P⁺)/Kg at 15-30 cm). At both the depths exchangeable K differed significantly among the treatments, with fertigation treatments generally causing a reduction (Table 16a). At 0-15 cm T3 and T4

(both soil application treatments) the exchangeable K was significantly higher (3.08 and 3.04 C mol (P⁺)/Kg respectively) as against control (2.31 C mol (P⁺)/Kg). All other fertigation treatments significantly lowered exchangeable K ranging 0.1 (T6) to 1.37 (T7) C mol (P⁺)/Kg. Similar trend was noticed at 15-30 cm. However, the fertigation treatment T10 was found to be on par with control.

Calcium :

In contrast to K, the available Ca tended to increase with depth (42 and 45 C mol (P⁺)/Kg at 0-15 cm and 15-30 cm respectively). The available Ca did not differ significantly among the treatments (Table 16a). However numerically its availability was higher in T1 (47.30 C mol (P⁺)/Kg). As compared to the mean of soil treatments (41.0 C mol (P⁺)/Kg), the mean of fertigation treatments showed slight increase in Ca availability (43.0 C mol (P⁺)/Kg). At lower depths of 15-30 cm, Ca availability significantly differed among the treatments. In comparison to control, T1 (47.10 C mol (P⁺)/Kg) significant increase in available Ca occurred in T5 (58.50 C mol (P⁺)/Kg). However, generally a slight decrease in Ca availability at 15-30 cm depth was obtained in fertigation treatments (44.44 C mol (P⁺)/Kg) as against that of soil application treatments (46.40 C mol (P⁺)/Kg). This was partially attributed to the reduction obtained in T10 (36.80 C mol (P⁺)/Kg).

Magnesium :

The Mg availability at both depths remained constant at around 10.65 C mol (P^+)/Kg. Similar to Ca, available Mg did not significantly differ among the treatments at 0-15 cm depths, while that at 15-30 cm did. The available Mg ranged from 9.04 to 12.15 C mol (P^+)/Kg, with general tendency for enhanced availability due to fertigation (11.17 C mol (P^+)/Kg) in contrast to that of soil application (9.77 C mol (P^+)/Kg).

Irrespective of mode of application of fertilizers, the available Mg at 15-30 cm depths in various treatments did not differ significantly. As compared to control (9.38 C mol (P^+)/Kg) T3, T5 and T8 showed higher available Mg of 12.15, 12.15 and 11.81 C mol (P^+)/Kg respectively indicating applied Mg caused its increased availability (Table 16a).

Iron :

The available Fe in soil at both the depths studied significantly differed among the treatments (Table 16b). There was a tendency for its reduced availability under fertigation at both the depths. At 0-15 cm the availability was significantly more T3 a soil application treatment (6.99 ppm) as against control T1 (4.48 ppm). At 15-30 cm, available Fe reduced substantially in three fertigation treatments, namely T5, T6 and T10 with values of 3.60, 4.29 and 4.21 ppm respectively. The control (5.62 ppm) along

Table 16a. : Effect of application of increased levels of nutrients to soil and drip irrigation on soil nutrient availability (at the end of expt. period).
Major and secondary nutrients.

Treatments		0 - 15 cms					15 - 30 cms				
NPK and [Mg +Zn + B]* (g / palm / year)		N (-ppm-)	P (-ppm-)	K ⁺ [C mol(P ⁺)/ Kg]	Ca ⁺⁺ [C mol(P ⁺)/ Kg]	Mg ⁺⁺ [C mol(P ⁺)/ Kg]	N (-ppm-)	P (-ppm-)	K ⁺ [C mol(P ⁺)/ Kg]	Ca ⁺⁺ [C mol(P ⁺)/ Kg]	Mg ⁺⁺ [C mol(P ⁺)/ Kg]
T1-800:400:800(Rec.) to soil		248	13.97	2.31	47.3	9.73	270	15.77	2.53	47.1	9.38
T2-1000:500:1000(Enh.) to soil		198	8.57	2.10	38.7	10.07	253	8.80	2.53	42.1	10.77
T3-T1 + Mg + Zn + B to soil		190	8.98	3.08	39.1	10.24	222	8.68	2.10	52.2	12.15
T4-T2 + Mg + Zn + B to soil		197	15.81	3.04	38.8	9.04	271	19.04	2.61	44.2	10.07
T5-800:400:800 thro' drip		218	7.40	1.54	43.0	10.77	186	10.69	0.68	58.3	11.81
T6-1000:500:1000 thro' drip		200	5.43	0.51	43.4	11.46	211	5.10	0.59	43.4	12.15
T7-T5 + Mg + Zn + B thro' drip		213	6.76	1.37	39.4	10.07	192	5.59	1.02	44.7	11.29
T8-T6 + Mg + Zn + B thro' drip		195	6.44	1.20	43.8	12.15	225	7.09	1.07	42.8	11.81
T9-Rec N K Zn and B thro' drip and P & Mg to soil		246	6.86	0.94	43.0	11.46	262	6.95	0.94	40.4	9.38
T10-Enh N K Zn and B thro' drip and P & Mg to soil		224	21.74	2.10	45.4	11.11	197	13.26	1.11	36.8	8.73
Mean		213	10.19	1.82	42.2	10.61	220	10.10	1.52	45.2	10.75
CD at 5 %		NS	5.32	0.44	NS	NS	NS	4.49	0.49	8.3	2.09

* Mg as MgSO4 : 400 g/palm/year
Zn as ZnSO4 : 60 g/palm/year
B as Boric acid : 60g/palm/year

with other soil application treatments maintained higher Fe availability ranging from 4.51 to 5.26 ppm.

Zinc :

The mean values indicated that the available Zn decreased with depth of the soil with surface had greater availability (0.736 ppm) then at lower depth (0.713 ppm). At both depths treatment differences were significant. Generally fertigation resulted in enhanced Zn availability at both the depths (Table 16b). Among the treatments T4, T7 and T10 at 0-15 cm had available Zn of 1.696, 1.108 and 2.083 ppm respectively as against 0.308 ppm observed in control (T1). The applied Zn in combination with other micronutrients at enhanced NPK dose might have resulted in its increased availability. The same treatments at 15-30 cm depths also enhanced available Zn significantly.

Manganese :

The available Mn increased with depth, 3.86 and 4.11 ppm at 0-15 and 15-30 cm respectively. The available Mn differed significantly at both the depths studied among the treatments. Fertigation resulted in its decreased availability, in comparison to soil application of nutrients. A significant increase was also observed in soil treatments T3 (6.62 ppm) and T2 (6.15 ppm) at 0-15 cm and 15-30 cm depths. Significantly lower available Mn was noticed in T5 (2.81 ppm), T7 (2.57 ppm), T9 (2.28 ppm) and T10 (1.98 ppm) at 0-15 cm, T3 (3.01 ppm), T5 (2.18 ppm) and T6 (3.39 ppm) at 15-30 cm (Table 16b).

Copper :

The available Cu in soil was more or less similar at both the depths with a tendency for reduced availability at lower depths (0.489 ppm at 0-15 cm, 0.471 ppm at 15-30 cm). Although in general, fertigation treatments resulted in enhanced availability inconsistently among the treatments was obtained (Table 16b). At 0-15 cm T9 had significantly lower availability (0.286 ppm), while T10 had greatly enhanced availability (1.029 ppm). At 15-30 cm depth significantly higher available Cu was obtained in T7 (0.683 ppm) in comparison to control (0.468 ppm).

EXPERIMENT II : Effect of intercrop on growth and mineral nutrient status of oil palm.

Growth characteristics :

Since plant characteristics namely leaf number per palm, leaf area per palm and leaf area per frond and other related leaf characters are reflection of growth and productivity the data on these were collected in the maturing palms grown together with various intercrops. The data are presented in Table 17. Considerable differences in various growth parameters were apparent due to presence of various intercrops, except in such parameters as leaf area per frond and leaf area per palm, length of leaf 17, number of leaflets in a largest leaf and number of female inflorescences at the time of observation.

Significant reduction in all the growth parameters

Table 17 : Growth characteristics of oil palm as influenced by different inter crops during November 1995.

Treatment	Total no. of fronds	LA/frond m ²	LA/palm m ²	No. of Leaflets	Length & Width (L) (W) of leaflet (cm.)	Length of frond (m)	No. of inflo.
IC 0	50.3	2.44	118.6	181	61.1 4.0	2.42	0.5 4.0
IC 1	46.8	2.70	126.8	163	69.8 4.3	2.82	0.5 6.3
IC 2	52.8	2.42	127.0	178	62.3 4.0	2.71	0.0 5.0
IC 3	45.5	2.74	124.5	171	66.9 4.3	2.64	1.0 7.0
IC 4	47.0	2.67	117.0	186	62.5 3.7	2.42	0.5 5.3
IC 5	39.0	1.81	70.6	162	60.3 3.4	2.13	0.3 1.8
IC 6	37.5	2.07	77.1	199	60.5 3.1	2.65	2.8 1.3
Mean	45.6	2.41	108.8	177	63.3 3.8	2.54	0.8 4.39
CD 5%	8.3	NS	45.1	NS	NS 0.8	0.42	1.5 NS

Note: * LA : Leaf area.

Inflo. : Inflorescence

Treatments: IC0 : Oil palm alone (control)

IC1 : Oil palm + Coffee + Banana

IC2 : Oil palm + Banana + Areaca

IC3 : Oil palm + Areacanut

IC4 : Oil palm + Banana

IC5 : Oil palm + Sugarcane

IC6 : Oil palm + Puerarea as cover crop.

studied was observed in respect of those oil palm plants which were grown along with either sugercane as intercrop or Puerarea as cover crop. Interestingly at the time of observation the number of male inflorescence in oil palm plant was significantly more (2.8) when Puerarea was taken as cover crop, as compared to those of pure oil palm crop (0.5). On the other hand other intercrop such as coffee + banana, banana + areca, areca, banana had stimulating effect on growth parameter such as total number of leaves per palm and leaf area per palm, although on a non-significant scale.

Leaf nutrient status :

The leaves at different positions on the plant namely 3rd, 17th and 31st from the top for various nutrient content of oil palm as affected by intercrop are presented in Table 18a and 18b. All most all the nutrients barring P (at all leaf positions), K and Mg (17th and 31st leaf) varied significantly among the treatments. With the exception of Fe and Cu all other nutrients decreased in concentration from 3rd to 31st leaf. All the intercrops (single as well as double) had increasing effect on N content of 3rd leaf while it is reduced in 17th leaf. The N content in 31st leaf was significantly higher in IC4 (oil palm + banana) and IC6 (oil palm + Puerarea) over control (pure oil palm crop).

The P content did not vary in all the leaf position under any set of intercrops. The K content in 3rd leaf was

Table 18b. : Leaf nutrient status of maturing oil palm as influenced by the intercrops
(Micro nutrients)

Inter crops *	Iron (ppm)			Manganese (ppm)			Zinc (ppm)			Copper (ppm)		
	1st	17th	31st	3rd	17th	31st	3rd	17th	31st	3rd	17th	31st
IC 0	139	149	203	96.1	83.0	83.2	13.4	19.0	18.4	11.9	10.1	7.6
IC 1	172	141	256	85.3	95.0	84.1	18.8	19.3	20.9	9.1	9.0	8.1
IC 2	197	411	245	54.9	88.4	73.7	26.7	17.6	22.1	13.1	7.7	7.6
IC 3	288	240	313	71.4	75.0	82.0	27.3	16.4	19.2	14.0	11.9	8.7
IC 4	330	247	252	59.5	101.5	72.2	27.2	16.0	20.0	14.6	11.4	8.1
IC 5	172	171	130	41.0	63.6	68.0	29.0	15.1	23.1	9.3	11.1	8.8
IC 6	257	271	298	96.4	98.3	76.6	26.2	16.9	24.6	8.0	12.8	12.4
Mean	222	233	242	72.1	86.4	77.1	24.1	17.2	21.2	11.4	10.6	8.7
CD at 5%	58	34	35	14.8	7.4	7.7	2.4	1.4	1.1	1.3	2.6	2.4

Note *

IC 0	Oil palm alone (control)
IC 1	Oil palm + Coffee + Banana
IC 2	Oil palm + Banana + Areca nut
IC 3	Oil palm + Areca nut
IC 4	Oil palm + Banana
IC 5	Oil palm + Sugarcane
IC 6	Oil palm + Puer area as cover crop

significantly lower in IC4 (2.49%) and IC6 (2.16%) as compared to control (2.80%).

A significant increase over control (0.72%) was observed in Mg of 31st leaf of control plot, in IC2 (oil palm + banana + areca) and IC3 (oil palm + areca).

Fe content with all the intercrops barring IC5 (oil palm + sugarcane) significantly increased on 3rd, 17th and 31st leaf.

Zn content of 3rd and 31 st leaf significantly increased while that in 17th leaf the content was significantly reduced , when intercrops were present.

Mn content of all the leaves substantially got reduced in most of the intercrop treatments. However IC1, IC4 and IC5 had a stimulatory effect on Mn content of 17th leaf.

The Cu content was significantly higher in 17th and 31st leaf of IC5 plants, compared to control. However Cu content was considerably higher in 3rd leaf in IC3 and IC4. Other intercrop treatments IC1, IC5 and IC6 significantly reduced the Cu content.

Available soil nutrient status :

The data pertaining to available nutrients at two depths namely 0-15 and 15-30 cm both at the basin and away from the basin under different intercrop treatments vis a vis that in pure crop in oil palm are presented in Table 19a to 19d. The nutrient availability was generally on the

higher side in top soil at both the basin and away from the basin for N, P, K, Ca, Mg, Fe, Zn, Cu and Mn. The available Mn and Cu were almost equal at both the soil depths, only available Mg was found to more at lower depths. Almost all the nutrients were at their higher availability at the basin than away from it.

As compared to pure crop of oil palm, the presence of intercrop tended to reduce the available nutrients at the basin, especially in respect of N, P, K and Fe. On the other hand availability of other mineral nutrients enhanced both at and away from the basin.

Table 19a : Soil nutrient status of maturing oilpalm garden as influenced by intercrops (avail. N and P).

** Treatments:		Available Nitrogen (ppm)				Available phosphorous			
V	* Location	Soil depth				Soil depth			
		0-15cm		15-30cm		0-15cm		15-30cm	
		APB	AWPB	APB	AWPB	APB	AWPB	APB	AWPB
IC 0		319	262	224	238	16.0	5.4	16.4	4.6
IC 1		262	233	271	210	7.60	5.4	6.5	5.7
IC 2		171	191	300	276	5.60	4.4	10.8	5.9
IC 3		319	262	262	243	9.60	10.3	12.1	10.1
IC 4		314	286	214	138	11.1	4.9	13.1	4.9
IC 5		191	191	248	205	10.1	9.2	10.0	9.1
IC 6		300	276	200	205	8.1	5.9	7.7	9.0
Mean		268	230	243	253	9.7	6.5	10.9	7.0

note : * location APB ----> At the palm basin
AWPB ----> Away from the palm basin

**** Treatments :**

IC 0 ----> Oil palm alone (control)
IC 1 ----> Oil palm + Coffee + Banana
IC 2 ----> Oil palm + Banana + Areca nut
IC 3 ----> Oil palm + Areca nut
IC 4 ----> Oil palm + Banana
IC 5 ----> Oil palm + Sugarcane
IC 6 ----> Oil palm + Puer area as cover crop

Table 19b. : Soil nutrient status of maturing oilpalm garden as influenced by intercrops (exch. K and avail. Ca and Mg).

** Treatments		Exchangeable Potassium				Available Calcium				Available Magnesium			
						C mol (P)/Kg							

Table 19c : Soil nutrient status of maturing oilpalm garden as influenced by intercrops (avail. Fe and Mn).

** Treatments	Available Iron (ppm)		Available Manganese (ppm)			
	Soil depth		Soil depth			
	0-15cm	15-30	0-15cm	15-30cm	0-15cm	15-30cm
* Location	APB	AWPB	APB	AWPB	APB	AWPB
IC 0	16.4	10.1	13.7	9.1	8.1	10.1
IC 1	7.0	5.2	7.5	6.6	6.6	7.8
IC 2	8.6	9.1	7.5	7.6	7.7	8.2
IC 3	12.3	11.4	9.1	8.1	8.2	8.1
IC 4	10.8	12.0	7.8	8.5	10.9	9.8
IC 5	12.8	7.8	9.1	5.8	10.9	7.8
IC 6	11.9	12.2	7.9	11.7	6.2	8.9
Mean	11.4	9.7	8.9	8.2	8.4	8.6

Note * Location : APB ----> At the palm basin
AWPB --> Away from the palm basin

** Treatments :
 IC 0 ----> Oil palm alone (control)
 IC 1 ----> Oil palm + Coffee + Banana
 IC 2 ----> Oil palm + Banana + Areca nut
 IC 3 ----> Oil palm + Areca nut
 IC 4 ----> Oil palm + Banana
 IC 5 ----> Oil palm + Sugarcane
 IC 6 ----> Oil palm + Puer area as cover crop

Table 19d : Soil nutrient status of maturing oilpalm garden as influenced by intercrops (Cu and Zn).

** Treatments		Available Copper (ppm)		Available Zinc (ppm)			
	Location	Soil depth		Soil depth		Soil depth	
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
		APB	AWPB	APB	AWPB	APB	AWPB
IC 0		0.8	0.8	1.0	1.1	0.35	0.66
IC 1		0.7	0.6	0.8	0.8	0.43	0.43
IC 2		0.8	0.8	0.8	0.8	0.38	0.55
IC 3		1.1	1.1	1.0	0.9	0.50	0.43
IC 4		1.1	1.0	0.8	0.7	0.33	0.41
IC 5		0.6	0.5	0.9	0.5	0.40	0.31
IC 6		0.8	0.7	0.7	1.0	0.55	0.38
Mean		0.8	0.8	0.9	0.8	0.42	0.44

Note * Location : APB -----> At the palm basin
AWPB ----> Away from the basin

** Treatments :
 IC 0 -----> Oil palm alone (control)
 IC 1 -----> Oil palm + Coffee + Banana
 IC 2 -----> Oil palm + Banana + Areca nut
 IC 3 -----> Oil palm + Areca nut
 IC 4 -----> Oil palm + Banana
 IC 5 -----> Oil palm + Sugarcane
 IC 6 -----> Oil palm + Puerarea as cover crop

DISCUSSION

V. Discussion

Among the oil yielding plants, oil palm gives the highest yield per hectare. It is also heavy consumer of fertilizers. Since oil palm is recently introduced crop in India, there is considerable scope for its cultivation. Oil palm requires a rational manuring for maximizing production and stabilized yield. Although extensive studies on oil palm nutrition have been made in all major oil palm growing countries of world, not much progress has been made in this direction in India (Nair and Sreedharan, 1980). Therefore, current investigations were carried out to gain first hand knowledge on mineral nutrition of young oil palms, with particular influence to Karnataka, where the information is totally lacking.

Experiments were carried out to assess the effect of application of enhanced dose of fertilizers in combination with secondary and micronutrients, as applied to soil and through drip system (fertigation). In addition, the effect of intercrops on growth and mineral nutrition were also studied since there is a growing apprehensions among the farmers to adopt this crop, either as a competitive or alternate crop to other cash crops mainly Areca.

The results obtained from these studies are discussed in this chapter experimental wise.

Experiment 1 : Response of oil palm to application of fertilizers and micronutrients on growth and mineral nutrient status.

Growth :

Normally the physiological growth analysis of a crop is based on the data obtained on leaf area and dry matter at various growth stages. However, it is not always possible to follow up this at various times during the growth of oil palm by destructive samplings for obvious reasons. Indirect methods to obtain this information by non - destructive methods have been suggested, which gives approximately accurate values (Hardon,et al, 1969 ; Corley et al, 1971b).

In the present study which lasted for eleven months commencing from January 1995 to November 1995, growth in terms of number of leaves emerged during the experimental period was assessed by bimonthly observation. The treatment effect was non significant at any time of observation. However, the rate of leaf emergence as assessed by Relative leaf emergence rates (RLER) was generally influenced by enhanced dose of fertilizers as applied to soil well as through fertigation in comparison to control (recommended dose). At the end of the experimental period data collected on leaf characters including leaf area also showed non - significant differences. However it was noticed that fertigation treatments tend to increase all the growth characters studied. Obviously the readily available nutrients in the basin region under fertigation caused the

enhanced effects. It is reported that 80 per cent of water soluble fertilizers thorough fertigation is equally effective as those of 100 per cent normal fertilizers through soil + drip irrigation in producing most of the growth and yield characters of oil palm (Shivashankar and Khan, 1995).

It is known that the enhanced dose of nutrients particularly N and K increase both the rate of leaf production and number of functional leaves (Nair and Sreedharan, 1982) as well as leaf area (Corley and Mok, 1972).

Plant nutrient status :

Foliar analysis to detect mineral element deficiencies as an aid for interpretation of the agronomic experiments is generally practiced in all the perennial crops, where response to fertilizers will take a long time (Hartley, 1977). Foliar analysis can be considered as a diagnostic tool to study the uptake pattern of individual plant nutrients and its consequent effect on growth and yield. From time to time studies on leaf nutrient concentrations in oil palm under various conditions have been reviewed (Chapman and Gray, 1949; Prevote and Ollagnier, 1954; Tan, 1973 and Nair and Sreedharan, 1983).

Selection of index leaf for foliar analysis :

The important aspect of foliar analysis is the selection of standard leaf. Usually in matured palms leaf 17 is recommended for sampling (Chapman and Gray, 1949). In young palms with less than 20 functional leaves, generally

leaf 9 is sampled, since this leaf is said to be at right stage of maturity, being not too old or not too young (Foster, 1976).

In the present study leaf 2, 9, and 16 were sampled for assessing the nutrient status of palm as the palm chosen for the study was only one and a half year old. All the elements followed a gradient depending on the position on the trunk. The N content increased from leaf 2 to 9 and then decreased, Ca, Mg and Mn increased for leaf 2 to leaf 16, while P, K, Fe, Zn and Cu decreased.

Existence of gradient has long been known and the current observation only confirm to the general trend (Prevot and Pyre de Montebreton, 1958; Ochs and Olivin, 1976). The existence of gradient necessitates leaf sampling, because it facilitates to compare the situations. It is generally sufficient to sample single rank of leaf. The data from the present study on young palms it is clear that leaf 9 can be used as an index leaf for the analysis of the above mentioned elements.

Seasonal variation :

The mean content of nutrients (analyzed for all the treatments) in 9th leaf was considered for the seasonal variation wherein nitrogen, potassium, calcium and magnesium were lowest in their concentration and reaching the peak in November. The micronutrients iron, Manganese and copper were lowest in their concentration in July where as

Zinc was lowest in its concentration in May. The peak content of iron and copper was observed in July with that of zinc and manganese in November. In contrast to these elements phosphorus was at its highest concentration in January, which continuously decreased through November. These results pertaining to the seasonal variation in N, P, K, Ca and Mg are similar to those reported for Kerala. It was observed that there is a reduction in nitrogen concentration in foliar tissue in summer months and increase during rainy seasons. But a reverse trend was noticed in phosphorus, potassium and calcium while magnesium concentration show any definite pattern (Nair and Sreedharn, 1983). Seasonal variation could thus be attributed to seasonal factors, such as rainfall pattern, irrigation facility, site factor and probably the genotype. Similar views were reported for seasonal variation in leaf nutrient concentration in coconuts (Wahid et al, 1981).

Optimal / Critical concentration :

The critical leve of nutrient is defined as the concentration of element in the leaf above which the yield responses from the element in fertilizer is unlikely to occur (Prevot and Ollagnier, 1954). The concept is of major importance for practical use it allows advising manures which will give the most economic returns (Ulrich, 1952). The work of Chapman and Gray (1949) and its continuation by I.R.H.O since 1950 have led to the foundation of critical levels that have proved themselves valid in

Table 20 : Comparative Optimum Nutrient status for Oil Palm leaves.

Element	Optimum range of Nutrient concentration reported	Optimum concentrations (Leaf 9) obtained in current study (mean).
N	2.60 - 2.90 %	2.89 %
P	0.16 - 0.19 %	0.19 %
K	1.10 - 1.30 %	1.66 %
Ca	0.50 - 0.70 %	1.41 %
Mg	0.30 - 0.45 %	0.62 %
Fe	100 - 200 ppm	186.00 ppm
Zn	15 - 20 ppm	43.00 ppm
Mn	200 ppm	73.00 ppm
Cu	5 - 7 ppm	10.00 ppm

Source : Abraham (1994)----> for N, P, K, Ca, Mg for young palms (below 6 years).

Rajaratnam (1976)--> for micronutrients (Fe, Zn, Mn, Cu.) in 17th leaf.

greater majority of situation (Ollgnier et al,1970). The suggested nutrient concentration ranges associated with optimal concentration for leaf was given by Abraham (1994) for young palms, while Rajarathnam (1976) gives the optimal concentration for micronutrients in leaf 17. The concentration of the nutrients in leaf 9 during November for the present study given in the table 20 for comparative purposes. Abraham (1994) gave optimal concentration for N, P, K, Ca and Mg, while for the micronutrients (Fe, Mn, Zn and Cu) in leaf 17 of machure palms was given by Rajaratnam (1976). The results of present study indicates that with exception of nitrogen and phosphorus all the other elements were in excess in concentration. In contrast Mn appears to be considerably lower than the reported optimum concentration. These figures are indicative of scheduling of fertilizer doses and application in the farm where the experiment was carried out.

Inter relations of the elements :

While the critical levels are of major importance they do not tell the whole story. In order to understand the experimental results in a more detailed manner it is necessary to consider the interrelationships of the different elements.

Correlations were worked between such growth characteristics as leaf area in November, leaf increment during January-July and January-November, RLER during January-July and July - November and leaf nutrient contents in the

Table 21 : Relationship between growth parameters and leaf (9th) nutrient content.

Growth Parameters	Leaf 9 nutrient content during Jan/Jul/Nov.								
	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
leaf increment (Jan-Jul)	0.167	0.352	-0.750*	-0.018	-0.037	-0.059	0.061	-0.467*	-0.116
RLER (Jan-Jul)	-0.066	0.420	-0.306	0.079	0.036	-0.267	0.304	0.321	-0.014
Leaf increment (Jan-Nov)	0.227	0.120	0.229	0.046	-0.168	-0.067	0.338	0.065	-0.096
RLER (Jul-Nov)	0.098	-0.084	0.047	-0.257	-0.126	0.337	0.155	0.195	-0.352
Leaf area (Nov)	-0.108	0.161	0.094	-0.182	0.083	0.064	0.430*	0.062	-0.106
RLER (Jan-Nov)	0.161	0.145	0.311	-0.230	0.004	0.028	0.254	0.076	-0.095

Note * Significant at 0. 05 P

9th leaf in July and November. The data are presented in Table 21 generally indicated a significant negative association ($r = -0.750$) between leaf K content and leaf increment during January - July. Similarly RLER during January - July had a weak but positive correlation with P content ($r = 0.420$). Interestingly leaf area during November was found to have positive association (significant at 0.05 p) with leaf zinc content in November. Barring these, none of the elements had any significant association with the growth characteristics either during mid way or at the end of the experimental period. However, in mature palms, the relationship between major nutrients and number of leaves and their rate of production is apparent (Nair and Sreedharan (1980)).

The inter relationship of various elements in leaf 9 was also worked out and the data are presented in Table 22. Significant positive correlation was obtained between nitrogen and phosphorus, nitrogen and potassium, phosphorus and potassium, potassium and calcium, and calcium and magnesium. The other relations were non-significant. This observation is in contrast to those of Prevot and Ollagnier (1954). He stated that of all inter relationships, those between K and Ca, Mg or K and Ca + Mg have assumed greater importance, in relation to its positive relation with yield. Generally K, Ca and Mg alone or in combination are antagonistic. Thus if K uptake is more, Ca and Mg decreases. On the other hand if all the three

Table 22 : Nutrient interrelations in 9th leaf of young oil palms

	Nl	P	K	Ca	Mg	Fe	Zn	Mn	Cu
N		0.547**	0.398*	-0.018	0.253	-0.282	0.213	-0.136	0.420 *
P			0.729**	-0.010	0.089	-0.126	0.353	0.086	0.420*
K				-0.006	-0.007	-0.040	0.164	0.126	0.509**
Ca					0.365*	0.008	0.138	-0.098	-0.079
Mg						-0.034	-0.124	0.052	-0.077
Fe							-0.160	0.029	-0.176
Zn								-0.220	-0.085
Mn									0.025
Cu									

Note: * Significant at 0.05 p.

cations increase in their concentration in cell sap, it is favorable for the growth and yield of oil palm (Nair and Sreedharan, 1980). The beneficial association of K + Ca + Mg with yield was first shown in pea nut by Prevot and Ollagnier (1954). In the present study a positive association was noticed between combination of three base cations and leaf area ($r = 0.388$; are significant at 0.05 p). However, Prevot and Ollagnier (1954) observed that the sum of K + Ca + Mg is fairly constant, around 2.00. This is in variance with observations made in present study on young palms where the values ranged from 2.44 to 4.86. Grundur (1960) and Bachy (1964) were of the opinion that for optimum growth of oil palm the sum of K + Ca + Mg should be around 2.7 per cent of the dry matter.

Another aspect in the inter relationship of element in leaf is their ratios (Prevot and Ollagnier, 1954). The best suggested ratios along with those obtained in the present study are presented in Table 23.

The values indicate that with the exception of N:P and Ca:Mg ratios, all other were considerably lower for the present study. When the ratio in a leaf sample differ greatly from the suggested values, the divergence may be attributed to both the elements in question. Prevot and Ollagnier (1954) further emphasised that the values are the means of checking the conclusion drawn from the critical level values. They are especially useful in regions where no experimental fertilization data are available. The

Table 23 : Estimates of best element ratios in oil palm.

Element Ratios	Ratios according to Prévot and Ollagnier, (1954)	Ratios obtained (leaf 9th) in curen study (1995).		
		Gen.mean	Soil mean	Fert. mean
N:P	16.00	15.38	15.15	15.38
N:K	3.00	1.74	1.74	1.73
N:Ca	3.00	2.05	2.03	2.06
N:Mg	9.00	4.67	5.25	4.73
P:K	0.20	0.11	0.12	0.11
P:Ca	0.50-0.75	0.13	0.13	0.13
P:Mg	0.20	0.31	0.35	0.31
K:Ca	2.00	1.18	1.17	1.19
K:Mg	2.00	2.68	3.02	2.74
Ca:Mg	2.0-2.5	2.27	2.59	2.30

observations are highly relevant to the present situation, where no earlier information on fertilization was not generated.

Response to Fertilizer and Fertigation :

Fertilizers applied in the present study was based on the earlier recommendation emanated from CPCRI, Palode. Response to enhanced dose (125 % of recommended dose) was studied in comparison with recommended dose of fertilizers as applied to soil directly and through fertigation with or without secondary and micro-nutrients.

Considering the growth in terms of leaf area and other leaf characteristics, a definite beneficial effect was observed in fertigation treatments in general as against the soil application treatments, although on a non-significant scale. Fertigation i.e. application of solubilised fertilizers through micro-irrigation system is gaining importance in recent years, primarily because of its cost effectiveness and ready availability of nutrients in the root zone. In the present study the improved performance of young palms could be attributed to the enhanced levels of nutrients in leaf particularly with fertigation treatments. It is also claimed that fertigation to oil palm results in savings of 20 per cent of fertilizers (Shivashankar and Khan, 1995). It appears that response to nitrogen and potassium are universal and they exert a major role in the growth and production of oil palm (Nair and Sreedharan, 1981).

Further it is also observed that magnesium requirement of oil palm can easily be increased by heavier application of nitrogen and phosphorus fertilizers (Chan and Rajarathnam, 1976). Application of nutrients such as Magnesium sulfate, zinc sulfate and boron in the form of boric acid in the present study increased their concentration in leaves although their direct role in growth enhancement was not evident as judged by the correlations.

As already observed, the enhanced nutritional status of leaf in particular of micro-nutrients was in fact on higher side as against those reported for young palms. Hence their application as additional dose appears to be rather redundant and palms in future have to be watched carefully for phytotoxic symptoms, if any.

Nutrient Availability in the Root Zone :

In general nitrogen, calcium, magnesium and iron increased with soil depth while phosphorus, potassium, zinc and copper decreased. Significant differences in the nutrient availability were noticed mostly at lower (15-30cm) depths in case of N, P, K, Ca and Mg while such differences were apparent for micronutrients at both the depths (Table 6a and 6b). It was further noticed that nutrient availability was greater in basin region although there was a considerable improvement in soil nutrient status in the region away from the basin, indicating a

lateral and downward movement, probably along the root spread and depth, as the plant grew in stature. Available nutrient level is shown to be enhanced by the application of fertilizers in particular of N,P, and K (Zaharah et al, 1985; Ng , 1976; and Singh, 1989).

Experiment II : Effect of intercrops on growth and mineral nutrient status of oil palm.

The agroecological southern transition zone of Karnataka (zone 7 and region IV) is actively considered for propagating the cultivation of oil palm. This region which adjoins the hilly zone on the western side is a potential area for growing Areca. Presently it is enjoying high market price and thus activating farmers to take up its cultivation. Any crop which can replace Areca should be competitive and fetch better market price over Areca. In order to convince the farmers who are somewhat skeptical in taking up oil palm cultivation, it becomes necessary to demonstrate that inter cropping of various food and cash crops in oil palm, would not affect economic returns atleast in the initial years of establishment.

Intercropping in oil palm is not generally practiced. However, there is ample of scope for introducing a few annual crops particularly during early phase of oil palm growth. Several such studies in recent past within in India and Africa have shown a distinct possibility of raising such inter crops as, tobacco, chillies, coffee, Dioscorea, Colocasia etc.. during the initial establishment

period of oil palm, without affecting the latter growth (Hartley, 1977; Nair and Nampoothiri, 1992). As the oil palm increases its canopy with age the root spreads beyond basin region, drawing nutrients from different places than near the trunk. Oil palm being a heavy feeder of nutrients it would be highly competitive and perhaps would hinder and slowdown the inter crops.

In the farm of Karnataka Oswal Oil Palm Ltd., inter-cropping systems have been established including various crops such as banana, coffee, areca and sugarcane with oil palm as a demonstration plots to encourage the farmers to take up oil palm cultivation. These plots were made use for observations on growth and mineral nutrition of oil palm as well as nutrient availability in soil.

A small but unequivocal effect on oil palm growth in terms of leaf area and leaf characteristics, was noticed in inter cropping of oil palm with coffee + banana, banana + areca, areca while depressing effect was noticed when sugarcane as an inter crop and Puerarea as a cover crop were present. The female inflorescence which was developing into fruit, bunches were also numerically higher in number in the oil palm with other inter crops.

The mineral elements in leaves also showed marked influence due to various inter crops. The nutrient availability in the basin as well as away from the basin showed considerable differences, with depletion in the top soil

than in lower depths with various inter crops, in comparison to that in oil palm as sole crop.

The beneficial effects of intercrops on oil palm was largely due to the application of fertilizers to intercrops separately. The reduction in top soil fertility may be attributed to the utilization of nutrients which are present abundantly. In addition, beneficial effects of intercrops can also be traced to lack of weeds in intercropping system of oil palm (Kowal and Tinker, 1959).

During the experimental period, yellowing of leaves of was noticed in oil palms with Puerarea cover crop. Consequently growth characteristics of oil palm were significantly affected. The Nigerian experience in this regard has shown a general reduction in soil fertility as judged by total exchangeable cations, indicating that the cultivation needed to establish the ground cover. Hartley, (1977) concluded that cropping can be practiced on fertile, water retentive soil for 1 to 2 years without substantial loss of crop if the crops are not allowed to compete for light, nutrients and water. Thus inter crops such as sugarcane, areca should carefully be monitored in oil palm plantations.

SUMMARY

VI. SUMMARY

Oil palm is newly introduced crop in India. It is well known that oil palm is heavy feeder of nutrients, the availability of which determine the yield and productive. Information on mineral nutrition of oil palm under varying agroclimatic conditions of India is very little. Hence study was initiated on young oil palms with varying doses of fertilizers as applied to soil and also through fertigation. Experiments were also conducted to study the effect of intercrops on growth, productivity and mineral nutrition of oil palm. This study was taken up, since this new crop is seen as a poor rival for areca a most popular cash crop particularly in Bhadra command area. Therefore both these were conducted on the farm of Karnataka Oswal Oil palm Ltd., situated near Bhadravathi.

Experiment I : Response of Oil Palm to application of fertilizers and micronutrients on Growth and Mineral Nutrient Status.

Growth as measured in terms of leaf emergence at bimonthly intervals was not affected by enhanced rate of fertilizers either applied to soil or applied fertigation. However, the Relative leaf emergence rate (RLER) was strongly influenced by fertigation.

Other growth parameters collected at the end of the experimental period viz., leaf area per palm, and also per leaf, length of 9th leaf, Length and width of largest

leaflet in 9th leaf, although were numerically superior under fertigation treatments, but the overall differences were non significant.

The mineral nutrient contents (N, P, K, Ca, Mg, Fe, Mn, Zn and Cu) in bimonthly samples collected from leaf positions such as 2nd, 9th upto May and 2nd, 9th, and 16th from July onwards upto the end of the experimental period (November).

The status of available soil nutrients were also collected at two depths viz., 0-15 and 15-30cm, initially and at the end of the experimental period, both at the palm basin and away from it.

The mineral nutrients in general followed a definite pattern of gradient in different leaves. The nitrogen content increases from leaf 2 to leaf 9 and declined in leaf 16; calcium, magnesium and manganese, increases from leaf 2 to leaf 16 ; while phosphorus, potassium, iron zinc and copper decreased.

Seasonal variation was also apparent. The peak concentrations of N, K, Ca and Mg was observed in November, while that of phosphorus which decreased throughout the experimental period. The micronutrients such as iron manganese and copper lowest in their concentration during July, while zinc was at its lowest in May.

Considering the mineral nutrient content during November, it was observed that the mean concentration of almost all elements were in excess, with exception of nitrogen and phosphorus, in comparison to the published data.

Correlations recorded a significant negative association between leaf K (July) and leaf increment during January-July ($r = -0.750$) and appositive association between P in July ($r = 0.420$) and RLER (January-July). Leaf area was found to be positively correlated with zinc (November). None of the other nutrients bore any significant association with growth parameters. However, a sum of K + Ca + Mg (during November) was positively related to leaf area ($r = 0.388$).

The fertilizers applied particularly through fertigation showed a definite and better response, as compare to soil application in terms of growth. Fertigation also resulted in increased contents of mineral nutrients, in particular that of micronutrients.

The soil nutrient availability significantly increased in basin region, but the improvement was also seen in the region away from the basin. Fertigation in general was generally helpful in enhancing the nutrient availability.

Experiment II : Effect of intercrops on growth and mineral nutrient status of oil palm.

Intercrops in alone or in combination such as Banana + Areca, Banana + Coffee with oil palm were found to stimulate growth. However, sugarcane as an intercrop and Puerarea as a cover crop significantly reduced leaf area and other growth characteristics. The beneficial effect of intercrop on oil palm was attributed to repeated application of fertilizers to individual intercrops. The nutrient content in oil palm also enhanced due to intercropping generally the nutrients in top soil was depleted in the intercropping area than in pure crop of oil palm.

REFERENCES

VII REFERENCES

- ABRAHAM, V.K. 1994. Manuring - key to higher yields in oil palm. Indian Oil Palm Journal. 4 : 17-22.
- ANONYMOUS. 1966. Annual Report 1966-67. Nigerian Institute for Oil palm Research, Benin city, Nigeria. pp.39.
- ANONYMOUS. 1972. Annual Report For 1968-69. Nigerian Institute for Oil Palm Research, Benin city, Nigeria.
- *BACHY, A. 1964. Diagnostic foliaire du palmier a huile - niveau critique chez les jeunes arbres. Oleagineux. 19 : 253-256.
- *BACHY, A. 1968. Principaux resultat acquis par I.R.H.O. Sur la fertilization du palmier a huile. Oleagineux. 23 : 9-14.
- *BACHY, A. 1969. A propos d'un cas typique de carence potassique du palmier a huile en cote d's Ivoire. Oleagineux 24 : 533-540.
- BESTER, D.H., FOUCHE, P.S. and VELDMAN, G.H., 1977. Fertigation through drip irrigation system on orange trees. Proc. Int. Citriculture. 1 : 46-49.
- *BIERNAERT, A. 1935. Introduction a'la biologie florae du palmier a huile. Rev. int. Bot. appl. Agric. Trop. 15 : 1091.
- BRUCE, R.R., CHESNERS, J.L., KEISLING, T.C., PALLAS., J.E., SMITTLE, D.A., STANSELL, J.R. AND THOMAS, A.W. 1980. Irrigation of crops in the South-eastern United States : Principles and Practices. USDA-SEA Manual ARM 5-9.
- BREURE, C.J. and ROSENQUIST, E.A. 1976. An oil palm fertilizer experiment in volcanic soils in Papua, New Guinae. pp. 327-341.
- CHAN, K.W. and RANARATNAM, J.A. 1976. Magnesium requirement of oil palms in Malaysia. 45 years if experimental results. pp. 371-388. In International developments in Oil Palm. eds. D.A. Earp and W. Newall. Incorporated Society of Planters. Kuala Lumpur.

- CHAPMAN, C.W. and GRAY, H.M. 1949. Leaf analysis and nutrition of the oil palm. Ann. Bot. 13 : 415-433.
- *COMHAIRE, M. 1968. La fumare du palmier a huile. Centre Nat. d' in form et de doe. der. Prod. de. Phosphates Thomas. Bruxilles, pp. 161.
- CORLEY, R.H.V. 1973. Effects of plant density on growth and yield of oil palm. Expl. Agric. 9 : 169-180.
- CORLEY, R.H.V. and GRAY, B.S. 1976. Growth and morphology. In developments in crop science (1), Oil Palm Research. (editors : Corley, R.H.V.; Hardon, J.J. and Wood, B.J.) pp. 12-19.
- CORLEY, R.H.V., GRAY, B.S. AND Ng S.K. 1971a. Productivity of oil palm (Elaeis guineensis Jacq.) in Malaysia. Expl. Agric. 7 : 129-136.
- CORLEY, R.H.V., HARDON, J.J. and TAN, G.Y. 1971b. Analysis of growth of oil palm (Elaeis guineensis Jacq.) 1. Estimation of growth parameters and application in breeding. Euphytica 20 : 307-315.
- CORLEY, R.H.V. and MOK, C.K. 1972. The effects of nitrogen, phosphorous, potassium and magnesium on growth of oil palm. Expl. Agric. 8:347-353.
- COULTER, J.K. 1958. Mineral nutrition of oil palm in Malaysia. The use of frond analysis as a guide to manurial requirements. Malay. Agric. J. 41 : 131-151.
- *DANIEL, G. and OCHS, R. 1975. Amelioration de la production des jeunes palmier a huile du person par ' emploi d' engrans chlore. Oleagineux. 30 : 295-298.
- *DELL, W. and ARENS, P.L. 1957. Inefficecité du phosphate naturel pour le palmier a huile sure certains sols de Sumatra. Oleagineux. 12:657-683.
- EMMERT, F.H., 1959. Chemical analysis of tissue as a means of determining nutrient requirement of deciduous fruit plant. Proc. Amer. Soc. Hort. Sci. 73 : 521-547.
- *FERWERDA, J.D. 1955. Questions relevant to replanting in oil palm cultivation. M.Sc. Thesis. University of Wageningen, The Netherlands.
- FORDE, St C.M., LEYRITZ, M.J.P and SLY, J.M.A. 1965. The importance of potassium in the nutrition of the

oil palm in Nigeria. Potash Review. Subject 27, 46th suite, June 1966.

- FOSTER, H.L. and CHANG, K.C. 1976. The diagnosis of the nutrient status of oil palms in West Malaysia. pp. 290-312. In International Departments in Oil Palm. eds. D.A. Earp and W. Newall. Incorporated Society of Planters, Kuala Lumpur.
- FOSTER, H.L. and GOH, H.S. 1976. Fertilizer requirements of oil palm in West Malaysia. pp. 234-261. In International Developments in Oil Palm eds. D.A. Earp and W. Newall. Incorporated Society of Planters, Kuala Lumpur.
- GOLDBERG, S.D. and SHMUELI, M. 1970. Drip irrigation a method used under desert conditions of high water and soil salinity. Trans. Amer. Soc. Agri. Eng. 13 : 38-41.
- GREEF, P.F. 1975. Ferti-irrigation of fertilizer materials by means of micro-irrigation systems. Part-I. The deciduous Fruit Grower. 25(8) : 213-217.
- GREEF, P.F. 1975. Ferti-irrigation of fertilizer materials by means of micro-irrigation systems. Part-II. The deciduous Fruit Grower. 25(9) : 240-245.
- GREEN, A.H. 1972. The manuring of oil palm in the field-past results. Oleagineux. 27: 419-423.
- GRUNDER, G. 1960. The role of potassium in the nutrition of oil palm. World Crops. 12: 435-437.
- GUNN, J.S. 1962. The economics of manuring in the oil palm. J. W. Afr. Inst. Oil Palm Res. 3 : 302-307.
- HARDON, J.J., WILLIAMS, C.N. and WATSON, I. 1969. Leaf area and yield in the oil palm in Malaysia. Expl. Agric. 5 : 25-33.
- HARTLEY, C.W.S. 1977. The Oil palm. 2nd .ed. Longman, London. pp. 806.
- HEW, C.K. and NG, S.K. and LIM, K.P. 1973. The rationalisation of manuring of oil palms and its economics in Malaysia. pp. 306-323. In Advances in Oil Palm cultivation. eds. R.L. Wastle and K.A. Earp. Incorporated Society of Planter, Kuala Lumpur.
- HEW, C.K. and POON, Y.C. 1973. The effects of muriate of Potash and bunch ash on uptake of potassium and chlorine in oil palms on coastal soils. pp. 239-

247. In Advances in Oil Palm Cultivation. eds.R.L. Wastle and K.A.Earp. Incorporated Society of Planter, Kuuala Lumopur.
- *INEAC. 1955. Division du palmier a huile. Palmier a huile et plantes vivrieres. Bull. Inf. INEAC. 4: 319.
- JACQUIN N.J., 1763. Selectarum stripium Americanum historia. Vienna. The Genus Elaeis. In Developments in Crop Science (1). Oil Palm Research (1976).
- JACKSON, M.L. 1967. Soil chemical analysis, Prentice Hall of India, New Delhi. pp.495.
- KOO, R.C.J. 1980. Results of Citrus Fertigation studies. Fla. State Hort. Soc., 93 : 33-36.
- KOWAL, J.M.L. and TINKER, P.B.H. 1959. Soil changes under a plantation established from a secondary forest. J. W. Afr. Inst. Oil Palm Res., 2 : 376.
- *LEYRITZ, M.J.P. 1964. WAIFOR twelfth annual report 1963-4. p. 79.
- LO, K.K., CHAN, K.W., GOH, K.H. and HARDON, J.J. 1973. Effect of manuring on yield, vegetative growth and leaf nutrient level of the oil palm. pp. 324-337. In Advances in Oil Palm Cultivation. eds.R.L. Wastle and K.A.Earp. Incorporated Society of Planter, Kuuala Lumopur.
- *MARYNEN, T. 1960. Precis de phytochimie des principales cultures industrielles publis. INEAC Hors serie.
- MOLLEGAARD, H. 1971. Results of fertilizer trial on mixed colloval alluvial soil Ulu Beram estate in West Malaysia. Oleagineux. 26 : 449-453.
- NAIR, M.A. 1981. Nutritional studies on oil palm Elaeis guineensis Jacq. Ph.D.thesis. Kerala Agricultural University, Trichur, India, pp.110.
- NAIR, M.K. and NAMPOOTHIRI, K.U.K. (eds.) 1992. Oil Palm Production Techonology. pp 90.
- NAIR, M.A. and SREEDHARAN, C. 1980. Nutritional Studies on Oil Palm in India The Oil Palm in Agriculture in the Eighties 10 : 201-210.
- NAIR, M.A. and SREEDHARAN, C. 1981. Oil Palm Nutrition. Journal of Plantation Crops. 9 (2) : 66-76.

- NAIR, M.A. and SREEDHARAN, C. 1982. Nutritional requirement of oil palm (Elaeis guineensis Jacq.) J. Plant. Crops. 10 (1) : 45-52.
- NAIR, M.A. and SREEDHARAN, C. 1983. Seasonal Variation in Nutrient Concentration of Foliar Tissue of Oil Palm. J. Plant. Crops. 11(1) : 33-38.
- NG, S.K. 1968. Nutrient content of oil palms in Malaysia II. Nutrients in vegetative tissue. Malay. Agric. J. 46 : 332-391.
- Ng S.K., 1970. Greater productivity of oil palm (Elaeis guineensis L. Jacq.) with efficient fertilizer practices. Proc. 9th Cong. Inst. Potash Trust, Antibes. pp. 357-376.
- NG, S.K. 1976. Review of oil palm nutrition and manuring - scope for greater economy in fertilizer usage. In International Developments in Oil Palm. The incorporated society of planters, Kuala Lumpur, Malaysia. pp. 209-232.
- *Ng S.K., TAN Y.P., CHAN E. and CHEONG S.P., 1974. Nutritional complexes of oil palm planted on peat soil in Malaysia II. Preliminary results of copper sulfate treatments. Oleagineux. 29 : 445-456.
- NG, S.K. AND THAMBOO, S. 1966. Prospects of soil and plant analysis in assessing the fertilizer requirement of oil palm in Malaya. pp. 188-193.. In Proceedings of 2nd Malaysian soil Conf. Ministry of Agriculture, Kuala Lumpur.
- NG, S.K., THAMBOO, S and DE SOUZA, P. 1968. Nutrient content of oil palms in Malaya. 11. Nutrient in vegetative tissues. Malay. agric. J. 46 : 332.
- OCHS, R. 1965. Contribution a l'etude de la fumure potassique du palmier a huile. Research on Mineral Nutrition by the IRHO. In Developments in crop science (1), Oil Palm Research. (eds. Corley R.H.V., Hardon, J.J. and Wood, B.J.). pp. 183-213.
- OCHS, R. and OLIVIN, J. 1976. Research on Mineral Nutrition by the IRHO. In Developments in crop science (1), Oil Palm Research. (eds. Corley R.H.V., Hardon, J.J. and Wood, B.J.). pp. 183-213.
- OLLAGNIER, M. and OCHS, R. 1971. Chlorine a new essential element in oil palm nutrition. Oleagineux. 26 : 1-15.

- OLLAGNIER, M., OCHS, R. and MARTIN, G. 1970. Manuring of Oil Palms in the World. Fertilite. 36 : 3-63.
- OLSEN, S.R., COLE, C.V., WATANABE, F.S. and DEAN, C.A. 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. US. Dep. Agric. Cir. No. 939, 19.
- PILLAI, R.S.N. and PONNAMMA, K.N. 1992. Botany of Oil Palm. In Oil Palm Production Technology. CPCRI Kasargod Kerala (eds. Nair M.K. and Nampoothiri K.U.K.). pp. 13-20.
- PIPER, C.S. 1957. Soil and Plant Analysis. Hans Publishers. New York.
- PREVOT, P and OLLAGNIER, M. 1954. Peanut and oil palm foliar diagnosis. Interrelations of N, P, K, Ca and Mg. Pl. Physiol. 29 : 26-34.
- PREVOT, P. and OLLAGNIER, M. 1959. Law of minimum and balanced mineral nutrition. pp. 257-277. In Plant Analysis and Fertilizer Problems. American Inst. Biol. Sci., Washington.
- *PREVOT, P. and PEYRE DE MONTBRETON, C., 1958 Etude des gradients en divers elements mineraux selon le rang de la feuille chez le palmier a huile. Oleagineux. 13 : 317-321.
- RAJARATNAM, J.A. 1972. Observation on boron defficient oil palms (Elaeis guineensis). Expl. Agric., 8 : 339-346.
- RAJARATNAM, J.A. 1976. Micronutrients. In Development in crop science (1). Oil Palm Research. (eds. Corley, R.H.V., Hardon, J.J. and Wood, B.J.). pp. 263-270.
- RETHINAM, P. and CHADHA, K.L. 1992. Oil Palm Research in India. Indian Oil Palm Journal. 2(7) : 12-16.
- REES, A.R. and TINKER, P.B.H., 1963. Dry matter production and nutrient content of plantation oil palms in Nigeria. 1. Growth and dry matter production. Pl. Soil. 19 : 19-32.
- ROLSTON, D.E., RAUSCHKOLB, R.S. and HOFFMAN, D.L. 1974. Use of Glycerophosphate for fertilization through Trickle Irrigation System. In Proceedings 2nd International Drip Irrigation Congress. San Diego, pp. 416-421.

- ROSENQUIST, E.A. 1962. Fertiliser Experiments on oil palms in Malaya. Part I. Yield data. J. W. Afr. Inst. Oil Palm Res. 3 : 291-301.
- SHIVASHANKAR, K. and Khan, M.M. (Editors) 1995. Micro - irrigation and Fertigation. University of Agricultural sciences. GKVK. Bangalore. pp 96.
- SINGH, G. 1989. Fertilizer responses in a range of alluvial soils. Proc. 1989 PORIM international palm oil development conference, Kuala Lumpur, Malaysia. pp. 383-394.
- SIVANAPPAN, R.K. 1994. Drip and Sprinkler irrigation in India. Kisan World, 21(2) :11-13.
- SMILDE, K.W. and CHAPAS, L.C. 1963. The determination of nutrient status by leaf sampling of oil palms. J. W. Afr. Inst. Oil Palms Res. 4 : 8-30.
- SNEDECOR, G.W. and COCHRAN, W.G. 1960. Statistical methods. Sixth edition. Oxford IBH publishing Co. Calcutta.
- SOON, C.P. and THYE, K.K. 1976. Growth and yield of inter-cropped oil palms on a coastal clay soil in Malaysia. In International developments in oil palm, ISP. eds. D.A.Earp and W. Newall. Incorporated Society of Planters, Kuala Lumpur.
- SPARNAAIJ, L.D. 1957. Mixed cropping in oil palm cultivation. J. W. Afr. Inst. Oil Palm Res. 2 : 244.
- SPARNAAIJ, L.D. 1960. The analysis of bunch production in the oil palm. J. W. Afr. Inst. Oil Palm Res. 3 : 109-180.
- TAN, K.S. 1973. Fertilizer trials on oil palms in inland soils in Dunlop Estates. pp. 248-279. In Advances in Oil palm Cultivation, eds. R.L. Wastie and D.A. Earp. Incorporated Society of Planters, Kuala Lumpur.
- TAN, K.S. 1976. Efficient fertiliser usage for oil palm in inland soils. pp. 262-288. In International Developments in Oil Palm, eds. D.A.Earp and W. Newall. Incorporated Society of Planters, Kuala Lumpur.
- THOMAS, W. 1953. Present status of diagnosis of mineral requirements of plants by means of leaf analysis. Soil Science. 53. 353-373.

- *TINKER, P.B. 1976. Transport of water to plant roots in soil. Phil. Trans. R. Soc. Lond., B., 273 : 445-461.
- TINKER, P.B. and SMILDE, K.W. 1963. Cation relationship and Magnesium deficiency in the oil palm. J. W. Afr. Inst. Oil Palm Res. 4 : 82-100.
- ULRICH, A. 1952. Physiological bases for assessing the nutritional requirements of plants. Ann. Rev. of Plant Physiol. 3 : 207-228.
- UMAR AKBAR, F.H., TAMPUBOLON, D., ANURYDDUB and OLLAGNIER, M. 1976. Fertiliser experimentation on oil palm in North Sumatra. pp. 342-360. In International Developments in Oil Palm, eds. D.A. Earp and W. Newall. Incorporated Society of Planters, Kuala Lumpur.
- VAN DER VOSSEN, H.A.M. 1970. Nutrient status and fertilizer responses of oil palms on different soils in forest zone of Ghana. Ghana J. Agric. Sci. 3 : 109-129.
- *VAN DER VOSSEN, H.A.M. 1974. Towards more efficient selection for oil yield in the oil palm (Elaeis guineensis, L. Jacqin). In The Oil Palm ed. Hartley, C.W.S. 2nd edn. Longman. London. pp. 806.
- VARGHESE, P.T and CECIL, R.S. 1992. Management. Oil Palm Production Technology. CPCRI. Kasaragod Kerala. (editors : Nair M.K. and Nampoothiri K.U.K.).
- *VANDERWEYEN, R. 1952. Nations de culture Elaeis au Congo Bekge, Brussels.
- VON UEX KILL, H.R. 1971. Response of coconuts to (potassium) chloride in Philippines. Oleagineux 27 : 13-19.
- WAHID, P.A., KANNAN, K., KAMALAM, N.V. and VENUGOPAL, V.K. 1981. Genotypic and Seasonal Variation in the Mineral Nutrition of Coconut Palm. J. plant. crops. 9(2) : 105-111.
- WARRIAR, S.M. and PIGGOTT, C.J. 1973. Rehabilitation of oil palms by corrective manuring based on leaf analysis. In Advances in oil palm cultivation, p. 289.

- WATANABE, F.S. and OLSEN, S.R. 1965. Test of an ascarbic acid method for determining phosphorous in water and NaHCO_3 extracts from soil. Soil Sci. Soc. Am. Proc. 29 : 677-678.
- WERKHOVEN, J. 1965. The manuring of the oil palm. Varlags gesellschaft fur Ackerbau GmbH. 55 pp. Honover.
- WOOD ,B.J., PIGGOT, C.J., PHANG SEW and NESBIT, D.P., 1973. Areal application in oil palms. In:R.L. Waste and D.A Earp (editor), Advances in oil palm cultivation. In corporated society of planters, Kuala Lumpur, pp. 167-182.
- ZAKARAH, A.R., HAW, J. and SHARIFUDDIN, H.A.M. 1985. Accimi-lation and migration of phosphate applied as rock phosphate in the oil palm plantations. Pertanika. 8 : 317-321.

* Originals not seen.

ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ
ವಿಶ್ವವಿದ್ಯಾನಿಲಯ ಗ್ರಂಥಾಲಯ
ಗಾ.ಕೃ. ೨.ಲಿ, ಬೆಂಗಳೂರು-65

- 7 MAY 1996

ಅನುಚ್ಛದ್ಧಿ ಸಂ. **Th. 4080**
ವ ಸಂ .