# CHEMISTRY OF COCONUT RHIZOSPHERE

By

**ANILKUMAR, K. S.**

**THESIS**

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Faculty of Agriculture
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# DECLARATION

I hereby declare that this thesis entitled "Chemistry of Coconut Rhizosphere" is a bonafide record of research work dona by me during the course of research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

College of Horticulture,
Vellanikkara,
November 1987.

ANILKUMAR, K.S.

# CERTIFICATE

Certified that this thesis, entitled "Chemistry of Coconut Rhizosphere" is a record of research work done independently by Sri. Anilkumar, K.S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

College of Horticulture,
Vellanikkara,
November 1987.

Dr. P.A. WAHID
Chairman Advisory Committee
Professor (Radiotracer)

Approved by : Chairman

Members 1. Dr. A.I. Jose

2. Prof. V.K.G. Unnithan

3. Dr. P.V. Balachandran

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*Dedicated with grateful memory to*

*the departed soul of my beloved sister,*

*Dr. (Mrs) K. S. Indira Ramakrishnan*

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# Introduction

# INTRODUCTION

Coconut (*Cocos nucifera* Linn.) is grown in India in an area of 1.1 million ha, Kerala state ranks first in area and production of coconut in the country. The crop occupies 6, 62, 657 ha in the state producing 3032 million nuts per annum. The palm is unique as every part of it is useful to man in one way or the other. It is the traditional and the most important crop of Kerala and for the very same reason much attention is being given to maximise its production.

The agrotechniques developed for annual crops cannot be directly applied to perennial crop gardens for several reasons. The most important factor which should be considered while formulating fertilizer management practices is perhaps the probable impact of long-term fertilization on soil characteristics and concomitant alterations in the rhizosphere properties which ultimately determine the nature and magnitude of nutrient availability to the crops. The term rhizosphere is used here in a general sense to include the total volume of soil in which the roots reside and hence influenced by them. The term is preferred because longterm interactions of roots with soil as in perennial crop garden may have a wider influence on soil than just root-soil interface in which sense it is generally used. Fertilizers being the most expensive input, every effort should be made to ensure maximum utilization of the added fertilisers by the palm. These two aspects assume much importance especially because the crop is committed to the land for over 60 years (economic life span) and hence any damage done to the soil through either inadvertant practices, negligence and lack of foresight will be a permanent one which cannot be repaired later.

There has been no concerted effort directed towards understanding the dynamics of soil properties as influenced by regular annual fertilization to the crop and to evaluate the extent to which the fertility of the rhizosphere is affected.

The studies reported in this thesis have the following objectives:

* To evaluate the lateral and vertical spread of active roots of the palm

* To examine the role of active roots in the alteration of the chemical characteristics of rhizosphere

* The changes in chemical characteristics of the soil basins of the palm in relation to long term application of inorganic NPK fertilisers

* To study the nutritional aspects of the palm as influenced by continuous fertilization; and

* To evaluate the relationship of common soil tests with nutrition and yield of the palm

# Review of Literature

## REVIEW OF LITERATURE

Literature relevant to the root activuty pattern of tree crops and mineral nutrition of coconut palm is reviewed in this section.

### 2.1 Root activity pattern of tree crops

The traditional methods of studying root distribution of tree crops are limited in scope because of the labour involved in excavation, tracing and mapping the roots etc. Further, the techniques can only give a picture of total root distribution without distinguising active, dormant and dead roots. Isotope techniques, in contrast, offer a quick and reliable means of determining the distribution pattern of plant roots. Two methods have been adopted viz. plant injection technique (Racz et al., 1967) and soil injection technique (Hall et al., 1953). The former is applicable only in small plants for studying the root distribution pattern while the latter suits any plant for studying the distribution of active roots which are directly responsible for water and nutrient uptake from soil. The soil-injection technique has been extensively used for studying the root activity patterns of tree crops. The method involves soil-injection of a radio-tracer at various depths and radial distance from the plant followed by determination of the plant absorbed radio-activity.

The radio activity recovered in the plant from a particular soil zone depends on the proportion of active roots in that zone. Hence the radio-activity absorbed by the plant gives a measure of the root activity in that soil zone. Generally $^{32}P$, a hard beta emitter is used as the tracer because of its convenient half life (14.3 d) and ease of measurement, even though many others including $^{15}N$ (IAEA, 1975) $^{86}Rb$ (Ellis and Barnes, 1973) and non-radioactive Sr were also used (Fox and Lipps, 1964). In small plants such as cereals, total radio-activity absorbed by the plant can be determined. But this is a difficult proposition in tree crops when the plant can be determined. But this is a difficult preposition in tree crops where the bulk of the plant is too large. In such cases, IAEA (1975) recommended the radioassay of a suitable plant part to evaluate the uptake of the applied label from various root zones.

2.1.1 Fruit trees

Using $^{32}P$-labelled superphosphate, Bojappa and Singh (1973) found that the maximum root activity of mango was upto 2.4 m laterally and 30 cm vertically in the soil. About 77 per cent of root activity was observed upto 60 cm in one trial and it was 85 per cent upto 30 cm depth in another trial. Absorption from the peripheral zone of 3, was 88 per cent in both the experiments.

By selective placement of $^{32}P$ within rooting volume, Atkinson (1974) studied the distribution of root activity in apple trees and concluded that in two year-old trees of cv. Cox/M9 maximum absorption of the radiolabel was from 30 cm depth as against 90 cm depth in twenty five-year-old trees of cv. Fortune/M9.

Experiments carried out to study the root activity pattern of thirty year old orange trees in summer and spring in a fine sandy clay loam of Spain revealed that during summer months the highest root activity was at 2 to 3 m distance from the tree and at 30 cm depth. Early in spring, high root activity was observed near the tree (50 cm distance) and at 60 and 30 cm depths. In mature trees (30 years old), the zone of highest root activity was farther away from the tree than in younger trees of 14 years (IAEA, 1975). Studies conducted in Taiwan with 8 and 12 year old citrus trees had shown that in the former, the highest root activity was at 100 cm lateral distance/10 cm depth in spring season and for the letter in the winter season, the activity was higher near the soil surface within the 100 to 200 cm lateral distance (IAEA, 1975). Working with 'Eureka Round' lemon in the submontane Himalayan region Chandra *et al*. (1979) found maximum absorption of applied $^{32}P$ from a depth of

20 cm. In comparing different radial distances maximum root activity was observed at a radial distance of 60 cm in the post-monsoon period though the treatments (60, 120, 180 cm) did not differ significantly.

2.1.2 Plantation crops

Wet and dry season experiments with fruiting coffee trees in Columbia indicated that in wet season root activity at 30 cm distance/15 cm depth was significantly higher than at any other soil zones tested (IAEA, 1975). In dry season, no indication was obtained of the zones of high and low root activities. Uptake of $^{32}P$ was low in dry season. Experiments conducted in Kenya on the root activity pattern of coffee revealed two zones viz. near the soil surface upto a distance of 82.5 cm from the tree base and in the 45 to 75 cm depth at a distance of 30 cm from the tree. It was also reported that in one-year-old coffee plants growing on Salvador loamy sand nearly all roots were concentrated in the top layer of 30 cm. In two-year-old plants, the lateral spread of the roots was upto 80 cm and for adult trees, it was 130 cm (IAEA, 1975).

Wet and dry season experiments carried out in Cacao garden in Ghana using $^{32}P$-tracer technique revealed that highest root activity was in the upper

2.5 cm soil layer. In both wet and dry season, the effect of distance on root activity was notsignificant, but there was an indication of high root activity near the soil surface at a distance of 90 to 150 cm (IAEA, 1975).

The results of $^{32}P$ tracer studies conducted in Nigeria proved the hypothesis that the feeding roots of oil palm die back because of the effects of dry season draught (Forde, 1972). In Malaysia during the wet season the highest root activity was found at the soil surface at a distance of 3 m from the tree. Amout 70 to 80 per cent of active roots were within 0 to 20 cm depth. In Ivory Coast, highest root activity was observed at 0 to 20 cm depth. Wet season activity was more intense and confined to the surface unlike in dry season where the activity showed a steep decline with depth (IAEA, 1975).

Soong *et al*. (1971) reported the uptake of $^{32}P$ by *Hevea brasiliensis* seedling following $^{32}P$ soil-injection technique and subsequent analysis of leaves and latex. Maximum root activity was found in a lateral distance of 3-6 m from the trees. Jinah *et al*. (1972) examined techniques for the measurement of P uptake by mature trees of *Hevea brasiliensis* from different soils and soil zones. Though leaf and latex assay gave similar results latex assay was more reliable and less tedious. Best time of assay was found to be 4-6 weeks after application. Phosphorus uptake by mature rubber trees from the soil was investigated by Silva *et al*. (1979) using $^{32}P$ soil-injection technique. Radio-activity in the latex, a reliable assay for determining distribution of active roots, was higher when $^{32}P$ application was done at a lateral distance of 0.75 m from the tree and at 15 cm soil depth.

Sankar (1985) made an investigation on the root activity pattern of black pepper vine and allied aspects using phosphorus-32. The results indicated that the active root zone of black pepper vine trailed either on *Erythrina indica* or on teak pole was in a soil column of 30 cm radius around the vine. The active root system of *Erythrina* was found to be more extensive than the vine leading upto 60 cm from the pepper plant.

Root excavation studies in healthy and cadang-cadang affected coconut palms growing on a sandy loam soil showed that most of the primary and secondary roots are within 30 to 90 cm depth (Magnaye, 1969). Root studies in coconut carried out at Veppankulam showed that a great majority of roots were confined to 16 to 60 cm layer of soil (Anon, 1970). Kushwah *et al*. (1973) from their studies on the root distribution of coconut palm opined that palms receiving regular cultivation and manuring produced the highest number of roots. About 74 per cent of the roots produced did not have lateral spread beyond 2 m from the trunk and most of the roots were confined to 120 cm soil depth.

From a study on the root activity pattern of coconut in Sri Lanke employing $^{32}P$, Balakrishnamurthy (1971) suggested that maximum uptake occured from 1 m distance from the palm at a depth of 12 cm. The greatest root activity was observed in the upper 0-30 cm layer of soil close to the palm (within 150 cm) and intensity was more in wet season. Studies conducted in Sri Lanka using radio tracer on the efficiency of fertilizer utilisation by coconut palms had shown that nutrient uptake was maximum from a lateral distance of 50 cm. A decrease was observed with increase in radial distance. Activity was very high within a radius of 2 m within a depth of 10-45 cm (IAEA, 1975).

Results of the experiments on the root activity pattern of 15 and 60 year-old coconut trees (tall var. *Laguna typica*) in the Philippines in wet and dry seasons were reported by IAEA (1975). The zone of highest root activity was at 1 to 2 m radial distance from the palm and upto 15 cm depth. It was also observed that root activity was highest at 0.5 to 1 m distance and 10 to 30 cm depth in dry season (50%) as well as in wet season (60%) in Sri Lanka, but activity at lower depths and greater distances was relatively higher in the dry season.

Ray (1979) reported a study conducted on coconut nutrition using radio isotopes. Methods of soil placement and plant injection techniques for feeding nutrients to coconut have been studied and irrigation practices for efficient uptake and utilisation of nutrients are suggested. The absorption, distribution and translocation pattern of radio active phosphorus and its incorporation into the nuclic acid fraction in healthy and root (wilt) diseased coconut palms have been studied. Carbon assimilation rates (using $^{14}C$) in spherical, semi-spherical and erect canopied coconut palms having different yield characteristics are reviewed and discussed.

## 2.2 Fertilizer application and foliar nutrient levels

Nitrogen fertilization tended to increase leaf K and Ca levels but decreased the Na and Mg levels. Nitrogen and K fertilisation increased foliar Ca and Mg levels but depressed K and Na (Felizardo, 1965). Fremond and Gross (1957) observed increase in Na content of leaves due to K fertilization. Nethsinghe

(1962) reported acceleration of symptoms of Mg deficiency due to NPK fertilisation, whereas Brunin (1968) observed that addition of potash raised the P level in leaf. DeSilva (1974) reported that uptake of Mn was high in palms starved of N. Vernon _et al_., (1978) indicated a significant response in yield to the application of ammonium sulphate and superphosphate though foliar analysis indicated a severe K deficiency. Regular application of 5 kg muriate of potash per palm resulted in a fall of leaf Mg levels from 0.567 to .1887 (Manicot _et al_., 1980). Gopi (1981) found that the palms receiving higher levels of N and K fertilisers had high foliar N and K contents while P fertilizers gave only a marginal increase in foliar P level. Krishnakumar (1983) reported that application of nitrogen, phosphorus and potassic fertilizers resulted in an increase in the content of these nutrients in the 2nd, 10th and 14th leaves. Nair and Wahid (1976) indicated low Ca and K and high Na content in leaf on analysis of unfertilized palms. Devi and Velayutha (1977) after monitoring the nutrient concentration of the 14th leaf of coconut immediately on 2nd and 5th day of fertilizer application indicated a maximum concentration for N and P, and K.

Wahid _et al_. (1975) studied the effect of skipping N, P, K fertilisers for one year after

15 years of regular application. They found a drop in leaf N from 1.9 to 1.5 per cent and K from 1.3 to 0.9 per cent on an acidic soil. Phosphorus levels were not affected. DeSilva (1974) observed a very high concentration of Cu in leaves causing toxicity in palms which are starved of all macronutrients. Devi et al. (1976) studied the trace element status of soil and leaves of three coconut genotypes viz. WCT, TXD and DXT and found accumulation of Mn, Zn and Cu in leaves of fertilized palms.

2.3.1 Plant-induced changes in rhizosphere

Nair and Subbarao (1977) established direct relationship between incidence of phosphate solubilising microbes and available P in coconut and cocoa rhizosphere. Shantaram and Saraswathy (1985) also reported occurence of phosphate solubilizing bacteria in coconut rhizosphere and observed that 26-74 per cent of tricalcium phosphate could be solubilised within 15 days by the P-solubilising fungi in the soil.

Rozycki (1985) observed that bacteria from root zone of pine released into the medium very large amounts of pyruvic, gluconic and uronic acids, in some instances several times higher than the bacterial dry mass.

Merckx <u>et al</u>. (1986a) found that 15 per cent of the total $^{14}C$ fixed by maize could be recovered as a residue in tha soil, while for wheat corresponding figure was two per cent. The rhizosphere $^{14}CO_2$ evolution of wheat accounted for 20 per cent of the fixed $^{14}C$ and was a constant value throughout the growth period. Root-derived products were slowly incorporated by the soil microbial biomass to a maximum of 20 per cent of the residual $^{14}C$ content after 6 weeks of growth. The same authors in a separate study (Merckx <u>et al</u>., 1986b) showed that within four weeks, a micro-environment was created around a plant root characterised by an accumulation of root-derived organic material. A gradual shift was seen from ionic metal to complex high molecular weight form. The extracts from cropped area after six weeks complexed 61, 16 and six per cent of $^{57}Co$, $^{65}Zn$ and $^{54}Mn$ in the case of maise and 31, 15 and one per cent in case of wheat respectively where as it was 64, 1.9 and 0.2 per cent respectively for uncropped area.

2.3.2 Fertiliser application and soil physico-chemical characteristics

Sathirasegaran (1967) after studies using indicator plants reported development of acidity due to application of ammonium sulphate and use of dolomite to correct this and to overcome the Mg deficiency. Devi *et al.* (1975) observed that the pH of coconut soil basins decreased below four as a result of regular application of ammoniacal fertilisers. Consequently the availability of soil Mn increased very much which in turn enhanced the Mn uptake by the palm to almost toxic levels (1000 ppm).

Muliyar and Wahid (1975) found a significant increase in available P content of soil at the end of the year after application of superphosphate. Mahilum (1975) recommended split application of N and K fertilisers in soils of low CEC and high base saturation to avoid $NH_4^+$ and $K^+$ leaching and advised not to split N and K fertilisers in place of high CEC and low base saturation.

Wahid *et al.* (1975) drew attention to the building-up of available P in soil basins receiving annual P application. In view of the lack of response to added P, they suggested skipping of P fertilisers, once a good build-up of available P has been attained following regular P application (Wahid *et al.*, 1977). Work done at the Central Plantation Crops Research Institute, Kasargode has conclusively proved the feasibility of such an approach in coconut gardens (Khan *et al.*, 1983). Higher available P and exchangeable

K values were observed in fertilized plots than in unfertilized plots by Nair and Wahid (1976). Loganathan and Nalliah (1978) reported that P in the soil profile, eight years after concentrated superphosphate treatment, increased the Al-P and to a lesser extent Fe-P and Ca-P.

Eusebio (1970) studying the chemical characteristics of soil of seven-year-old coconut palms showed significant improvement in organic matter, P, K, Ca and S contents of soil. Significant effects were also observed on P and Ca levels by the interaction of management practices and fertilization.

Wahid <u>et al</u>. (1981) observed significant differences in the chemical characteristics of soil basins of 10 coconut varieties/hybrids receiving regular application of NPK fertilizer for over 20 years.

## 2.4 Relationships among leaf nutrient levels and yield

As the main requirement of the palm is for K and since it is concentrated in the pericarp and nut water, Selgado (1956) attempted analysis of nut water to examine its utility for deficiency diagnosis. He got a high degree of correlation between yield of copra and K content of nut water and found out that yields were increased by application of K. Ollagnier and Prevot (1959) arrived at optimal fertilisation in a series of soils by analysis of N, P, K, Ca, S and Mo. Bachy (1963) pointed out the importance of K-Ca-Mg equilibrium in the plant and its effect on yields of the oil palm and coconut. Devi and Pandalai (1968) conducted foliar analysis on palms of the same progeny growing on different fertility levels and found that N, Phosphoric acid, potash, lipoid phosphoric acid, Fe and Mn were positively correlated with yield, while Ca and B had little influence on the yield. Ollagnier and Ochs (1971) studied Cl content in coconut palms and concluded that Cl is a major indespensable element in the commercial cultivation of oil and coconut palms and optimum foliar Cl content of 0.5 - 0.6% produced maximum yields. Uexkull (1972) in a study of soils containing high quantities of exchangeable K (300 ppm) found that both young and bearing palms responded to KCl dressing, and the responses were correlated with foliar Cl levels. Ollagnier (1972) suggested that critical level of leaf S lies between 0.20 and 0.23% dry matter. Thomas (1973) reported the relation of leaf N/P, N/K/Ca/Mg ratios, but the level of K has to be interpreted in terms of a nutrient balance between K and Ca. As for single elements, only foliar N and Ca have got positive correlation with yield.

According to Brunin and Coomans (1973), B application to adult palms raised foliar B levels but had no marked effect on yield. Daniel and Manicot (1973) in a study conducted on three year old coconuts in New Hebrides stated that a Cl content of 9th frond of 0.42 - 0.45% is optimum for plant growth.

Thomas and Nandra (1974) after foliar analysis of the nutrient composition of high and low yielding palms of the typical variety showed that yield was correlated with N/P, N/K and Ca/Mg ratios.

Magat *et al*. (1975) reported a positive correlation between copra weight/nut and copra yield/tree and Cl content of leaves, while a negative correlation was found for K levels suggesting that likely limiting nutrients are Cl and K.

Devi and Velayudham (1977) indicated that foliar concentration does not reflect yield differences between genotypes. DeSilva *et al*. (1977) found that S content of the 6th leaf form the most sensitive index to S treatments which in turn enhanced total yield of fruits and weight of copra but decreased weight of kernel/nut. The derived curve for yield vs S concentration in the tissue was C-shaped which was attributed to growth dilution effects. Kanapathy (1977) in a study on dwarf coconut palms showed that there was no yield response to P fertilisation. Ouvrier and Ochs (1979) derived equation for calculating the uptake of N, P, K, Ca, Mg, Na, Cl and S by fertilised coconut trees in relation to copra yields. The uptake of K and Cl were the highest, 193 and 125 kg $ha^{-1}$ respectively for a copra yield of 6700 kg from 138 trees. Nitrogen uptake was 108 kg $ha^{-1}$ and the remainder in the descending order of Na, P, Mg, Ca and S (20-9 kg $ha^{-1}$). The copra accounted for 74, 89, 67 and 24 per cent of the absorbed N, P, Ca and K respectively, the husk accounted for 60 per cent of absorbed K.

Gopi (1981) revealed that the N content of different leaf positions was significantly correlated with yield. The P content of leaf lamina failed to establish significant correlation with yield, irrespective of leaf positions. The coefficients of partial correlation with yield and K per cent of lamina of leaf position 2, 3 and 6 were significant, the highest value of 0.663** being recorded for the 2nd leaf.

According to Krishnakumar (1983) yield of the palms was significantly correlated with the N per cent of leaf lamina. The partial correlation coefficients between yield and the P per cent of the leaf lamina of the three leaf positions were not significant.

The coefficient of partial correlation between yield and K content of 2nd and 10th leaf were significant. The highest r value, 0.432** being recorded by the 10th leaf. On the other hand, the contents of Ca, Mg and Na gave significant correlation with yield only in leaf position 14.

Ziller and Prevot (1963) gave defimition of critical level of an element as the percentage on dry matter basis of that element, below which an application of the appropriate fertilizer had a fair chance in increasing the yield. They gave the critical levels for N, P, K, Ca and Mg in 14th frond as 1.70, 0.10,0.45, 0.50 and 0.40 per cent dry matter respectively. These values were further modified by Fremond _et al_. (1966). The critical levels suggested by them for N, P, K, Ca and Mg are 1.8 to 2.0, 0.12, 0.8 to 1.0, 0.5 and 0.3 respectively. Romney (1966) and Kanapathy (1971) extended the critical levels to dwarf and semi tall palms also with modification. In 1980, Manicot _et al_. confirmed the critical level for K of 14th frond given by Fremond _et al_. (1966) and suggested 1.4 per cent as critical levels for the element in hybrid palms. Manicot _et al_.(1980) suggested critical levels of Fe (50 ppm), Cu (5 to 7 ppm), B (5-10 ppm) and S (0.15 to 0.20 per cent) in 14th frond.

Teffin and Quencez (1980) suggested critical level of Cl as 0.5 to 0.6 per cent. Eschbach and Manicot (1981) revised critical level for Mn (100 ppm) and Zn (15 ppm) in the 14th frond. Gopi and Jose (1983) worked out the critical level of N and K in the 2nd leaf as 3.31 per cent and 2.17 per cent respectively. Krishnakumar (1983) obtained critical level of N and K as 2.9 and 1.8 per cent respectively in 10th frond for maximum yield.

According to Wahid (1984), the critical level concept holds good only in the case of N, K and Cl in coconut as these three nutrients are directly related to yield. For other nutrients, the most practical approach for deficiency diagnosis is through visible symptoms.

## 2.5 Interrelationships among soil test values, leaf nutrients and yield

Nethsinghe (1963) suggested critical soil P level for coconut as 5-9 ppm. Cordova (1965) showed that leaf Ca was highly correlated with soil exchangeable Ca and percentage saturation of the cation exchange capacity. According to him excessive amount of soil exchangeable Ca depressed K uptake and leaf K was more related to percentage K saturation of the CEC than to its total amount in exchangeable form. Regardless of the amount of soil exchangeablo Na, leaf Na tended to be lower in high yielders. With sufficient soil available P and N, highly productive trees tend to prefer soils in which the ratios Ca/Mg, Mg/K, Ca/K and (Ca + Mg)/K varied only narrowly. Jack (1965) observed that soil K decreased from the surface to the sub soil in the high yielding sites, soil K was highly correlated with leaf K and soil and leaf K were highly correlated with number of nuts produced. Devi and Pandalai (1968) reported that foliar nutrient levels reflect to some degree the nutrient status of the soil. Indirakutty and Pandalai (1968) in a study with tall coconut palms growing in four different soil types reported increase in foliar contents of N, $P_2O_5$ and $K_2O$ with increasing yield as against Ca and Mg. The foliar nutrients were in the decreasing order of N, $K_2O$, $P_2O_5$, Cao and Mgo. Nitrogen and $P_2O_5$ were highest in palms grown in red loam, while $K_2O$ was highest in sandy loam. The contents of Mgo and Cao were relatively more in palms growing on littoral sandy soil. The total plant uptake of K was significantly correlated with the corresponding ratios of Ca to K in the soil obtained by ammonium acetate (neutral normal) extraction. The correlations were negative which confirms the preposition that as the ratio of Ca to K in soil increases, the leaf K decreases correspondingly (Nartea, 1969). Querijero (1972) discusses the application of soil and leaf analysis in assessing the nutritional requirements of coconut and other crops. DeSilva *et al.* (1973) on analysis of fronds from bearing and non-bearing palms found that the latter had significantly lower levels of N, P and Mg attributed to an induced lowering of P in fronds caused by a lower uptake of Mg by the tender roots of bearing palms. Thomas (1973) opined that foliar nutrient composition reflected the nutrient status of soil. Wahid *et al.* (1974) in a study of West Coast Tall coconut variety found a negative but insignificant correlation between root CEC and yield. The leaf K + Na content fell with a rise in root CEC, where as Ca + Mg increased. Highly significant correlations were obtained between K/Na and K/(Ca + Mg) and K/Mg ratios in the soil and their corresponding ratios in the leaves. The K content of the leaf and soil was positively correlated with yield with a critical level of 0.8 to 1.0 per cent on a dry weight basis. The leaf K level was affected by the leaf level of Na, Ca and Mg. Ramanathan and Pillai (1974) conducted a study on the permanent experiment plots at Central Plantation Crops Research Institute in Kerala with three permanent plots viz. (1) with regular cultivation (2) with regular cultivation and no manuring (3) with no cultivation and no manuring. Analyses of leaf samples collected during summer and rainy seasons showed that during both the seasons, leaves of palms of first plot contained significantly higher amounts of N and K and average yield of nuts than those of other plots. Available K increased in first plot than other in 0-30 cm and 30-60 cm depth. DeSilva (1976) stated that acidic soil conditions increased the Mn concentration in leaves, but do not consistantly increase the Fe concentration. The distribution of Mn in roots and leaves are also highly related to level of supply. Devi *et al*. (1976) observed an inverse relationship between K and Mg content of leaves. Low soil available K induced low K conentration in leaves. Magat (1975) and Mahilum (1976) reported that soil analysis supplemented by leaf analysis provides a better way of evaluating the nutrient status of growing palms. Mathew and Varkey (1977) in a study on root (wilt) affected areas found that the status of Ca and Mg of soil and leaf was not correlated with incidence of root (wilt) disease. Deb *et al*. (1977) attempted a study on chemical composition of soil and the available nutrient status as a guide for establishing nutrient disorders in coconut palms in major coconut growing acid soils of Kerala. Loganathan and Nallaiah (1978) in a study conducted in Sri Lanka reported that P evaluation in the 14th leaf was significantly correlated with Al-P, Fe-P and $NaHCO_3$-P but not with

Ca-P and organic-P.

Ogiús et al. (1978) proved that leaf Cl levels significantly decreased with increasing S. Correlation analysis between two elements like wise revealed a certain degree of negative interaction which somehow substantiates the apparent antagonism between Cl and S.

# Materials and Methods

# MATERIALS AND METHODS

## 3.1 Root activity pattern of coconut

This study was conducted making use of a standing population of nine-year-old coconut palms (var. West Coast Tall) at the College of Horticulture, Vellanikkara. The location is situated at an altitude of 22.25 m above M.S.L. at latitude 10°32'N and longitude 76°10'E and enjoys typical warm humid tropical climate.

### 3.1.1 Soil

The soil at the experimental location is acidic laterite (oxisol) and gravelly in nature.

### 3.1.2 Method

Phosphorus-32 soil-injection technique was employed for studying the root activity pattern. The trees at the experimental site were spaced at 8 m x 8 m. For application of $^{32}P$, diagonally planted trees were selected. This arrangement gave a minimum distance of 11.3 m between any two treated palms (Fig.1). The selected trees were of more or less uniform growth and vigour in terms of height and number of leaves (Appendix-I).

The experiment was phased over two years (1985 and 1986) during monsoon season between August and

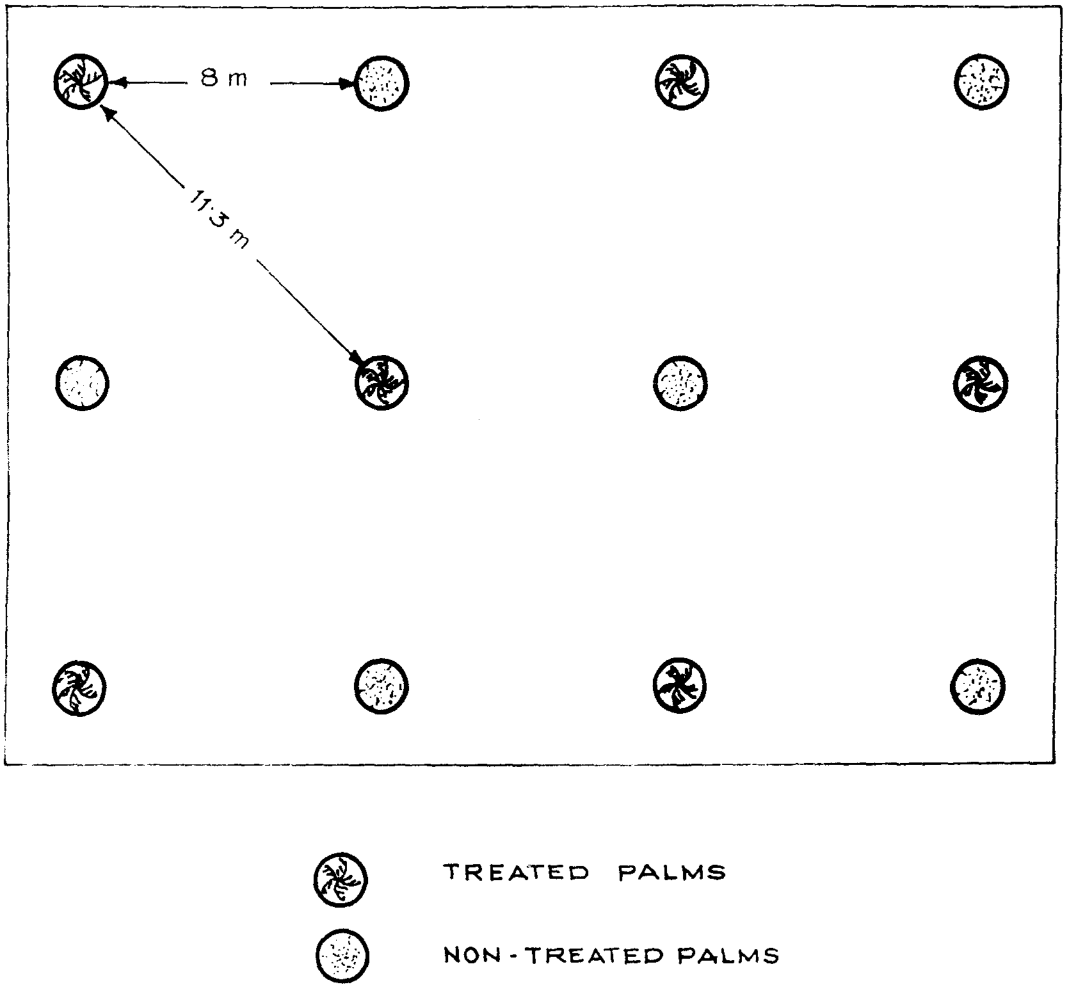


FIG. 1. LAY OUT OF $^{32}P$ EXPERIMENT AT VELLANIKKARA

November. In the first year, the study was confined to 2 m radial distance and in tha second year the study was continued from 2 m to 4 m. There were altogether 15 treatments in the first year experiment being the combinations of five radial distances (30, 60, 100, 150 and 200 cm) and three depths (30, 60 and 90 cm). In the second year experiment, 12 treatments covering the combinations of four lateral distances (200, 250, 300 and 400 cm) and three depths (30, 60 and 90 cm) were included. Both the experiments were conducted in randomised block design with single trees forming the experimental unit (plot size). There were three replications for each treatment.

Equally spaced sixteen holes were dug to the required depth and radial distance around each tree a day in advance of $^{32}P$ application using a soil auger of 5 cm dia. The holes were plugged with PVC tubes of slightly longer length and covered with plastic caps at the open end to prevent filling-up during rains.

In the first year experiment, labelled superphosphate in gelatin capsules with a specific activity of 1.56 mCi.g $P_2O_5^{-1}$ was used as the radioactive source (Fig.2a &b) Each capsule contained 600 mg of superphosphate. At the time of application, the plastic cap of the access tube was removed and one capsule was dropped into it. The total radioactivity

Fig. 2 Placement of encapsulated $^{32}P$ labelled superphosphate in soil

(a) Labelled superphosphate in gelatin capsules

(b) Placement of capsule at required soil depth


(a)

(b)

Fig. 2

applied per tree was 2.4 mCi (88.8 MBq).

In the second year experiment, $^{32}P$ was applied as solution containing a carrier level of 1000 ppm P ($KH_2PO_4$). The application of radioactive solution was done using a field dispenser fabricated and perfected at the Radiotracer Laboratory, College of Horticulture, Vellanikkara (Sankar, 1985). Briefly, the method consisted of applying 4 ml of radioactive solution by the up and down motion of the calibrated plunger of the dispenser into the access tubes (Fig. 3). The radioactivity remaining in the inside of the access tube was then washed down with a jet of about 15 ml distilled water from a wash bottle. The total radioactivity applied per tree was 1.4 mCi (51.8 MBq).

### 3.1.3 Leaf sampling

In the two experiments sixth leaf starting from the first fully opened one was selected for radioassay (Nethsinghe, 1962). Three leaflets were sampled from either side of the middle portion of the frond of each treated palm and pooled to form a sample for each treatment in a replication. In the first year experiment leaf samples were collected at 13,33,50 and 71 days after application. In the second year experiment, the sampling was done on 15th, 33rd, 47th and 63rd day after $^{32}P$ placement. The leaves were

Fig. 3 Soil injection of $^{32}P$ solution using field dispenser

Fig. 3

dried in an oven at 75°C, cut into small pieces after removing the midrib prior to radioassay.

### 3.1.4 Radioassay

For the determination of $^{32}P$ activity in the leaf samples, the method developed by Wahid *et al.* (1985) was followed. The method is based on the determination of $^{32}P$ activity by Cerenkov counting technique. The procedure involved wet digestion of oven-dried and finely cut leaves with 1:1 perchloric-nitric acid mixture and determination of radioactivity in the digest after transfering it quantitatively into a scintillation counting vial. The radioactivity was determined in a micro-processor controlled liquid scintillation system (Rackbeta of L.K.B. Wallac Oy, Finland) adopting channel settings and computer programme recommended for tritium counting by liquid scintillation technique.

The count rates (cpm) were corrected for background and decay. No attempt was made to present the data in dpm as the counting efficiency of the instrument remained virtually constant (32%) during the experiment period.

### 3.1.5 Statistical analysis

As the $^{32}P$ recoveries in the leaf samples showed considerable variability, the data were subjected to logarithmic transformation ($\log_{10}$) prior to analysis of variance.(Panse and Sukhatme, 1967).

### 3.1.6 Percentage root activity

Percentage root activity was computed for each treatment from the following expression:

$$\text{Root activity(\%)} = \frac{\text{Radioactivity recovered in the leaf for the treatment (cpm g}^{-1}\text{)}}{\text{Total radioactivity recovered for all the treatments (cpm g}^{-1}\text{)}} \times 100$$

### 3.1.7 Soil sampling

In order to study the relationship between root activity and soil chemical characteristics, soil samples were collected separately from the basins of three adjacent untreated palms. Using soil auger, soil cores were removed from depths of 20-40, 50-70 and 80-100 cm at radial distances of 30, 60, 150, 200, 250, 300 and 400 cm. These depths correspond to 10 cm above and below of the point of $^{32}P$ placement at the different radial distances. The soil cores were taken from five points corresponding to the depth and radial distance around each tree and pooled to form a sample. The soil samples were air dried and sieved through 2-mm mesh prior to chemical analysis.

## 3.2 Studies on the soil characteristics and coconut nutrition in relation to NPK fertilization

The effects of long term NPK fertilisation on the chemical characteristics of coconut soil basins as well as on foliar nutrient levels were studied making use of palms under an on-going fertilizer trial at the Coconut Research Station, Balaramapuram. This field trial was an NPK factorial experiment testing three levels each of the nutrients. The details of the experiment are as follows:

| | |
|---|---|
| Design | : $3^3$ confounded factorial |
| Total number of treatments | : 27 (N, P and K each at three levels) |
| Number of replications | : 2 |
| Number of blocks | : 6 |
| Total number of plots | : 54 |
| Number of plots per block | : 9 |
| Spacing | : 7.5m X 7.5m |
| Number of experimental palms per plot | : 4 |
| Treatments confounded | : $NPK^2$ in replication 1<br>$NP^2K^2$ in replication 2 |

| | |
|---|---|
| Coconut variety | : West Coast Tall |
| Date of start | : 17.6.1964 |

Levels of nitrogen (g N $palm^{-1}$ $year^{-1}$)

| | |
|---|---|
| $N_0$ | : 0 |
| $N_1$ | : 340 |
| $N_2$ | : 680 |

Levels of phosphorus (g $P_2O_5$ $palm^{-1}$ $year^{-1}$)

| | |
|---|---|
| $P_0$ | : 0 |
| $P_1$ | : 225 |
| $P_2$ | : 450 |

Levels of potassium (g $K_2O$ $palm^{-1}$ $year^{-1}$)

| | |
|---|---|
| $K_0$ | : 0 |
| $K_1$ | : 450 |
| $K_2$ | : 900 |

Nitrogen, phosphorus and potassium were applied through ammonium sulphate (20.5% N) super phosphate (18% $P_2O_5$) and muriate of potash (60% $K_2O$) respectively right from the start of the experiment and no organic matter source was included in the fertiliser schedule. The soil at experimental site was red sandy loam (alfisol). The palms were 22 years old when they were made use of for the present study.

### 3.2.1 Collection of soil samples

Soil samples from the basins of all experimental palms were collected from a distance of 50 cm from the palm and to a depth of 50 cm as followed by Pillai *et al*. (1975). The samples collected from the four palms of each experimental plot were composited to form one sample. Altogether 54 soil samples were taken from the two replications.

Soil samples from different depths viz. 0-25, 25-50, 50-75 and 75-100 cm were also collected from eight selected treatments at a distance of 50 cm from the palm. The samples collected from the basins of the four palms in a plot for a particular depth were then composited to form a single sample. In this way 64 soil samples were collected from the 16 experimental plots in the two replications. The selected eight treatments were the factorial combinations of $N_0$, $N_2$, $P_0$, $P_2$ and $K_0$, $K_2$.

### 3.2.2 Collection of leaf samples

Leaf samples were collected from the 14th frond as suggested by Fremond *et al*. (1966). Four leaflets from either side of the middle portion of the frond of each palm in a plot were collected and pooled for that treatment and replication. In addition, samples were also collected from the sixth frond (young leaf) for comparison. The leaf samples were dried in an oven at 75°C, powdered in a mill with stainless steel blades and stored in polythene bottles.

3.2.3 Analytical methods

3.2.3.1 Soil

Soil samples collected from the experimental plot of root activity studies were analysed for pH, organic carbon, available P, available K and Na, exchangeable Ca and Mg, exchange acidity, cation exchange capacity and extractable Fe, Mn, Zn and Cu. The soil samples collected from NPK trial at Balaramapuram were analysed for all these characteristics excepting cation exchange capacity and exchange acidity. In additon, extractable S and Cl were also determined in these soils. The details of chemical analyses are given in Table 1.

3.2.3.2 Leaf analysis

Leaf samples collected from the NPK trial were analysed for N, P, K, Cl, Ca, Mg, S, Fe, Mn, Zn and Cu. Total N was estimated by $H_2SO_4/H_2O_2$ digestion followed by estimation of N in the digest by the Nessler method developed by Wolf (1982). Chlorine was estimated by titrimetry after digestion (Anon, 1972).

Table 1. Details of the methods followed in soil chemical analysis

| Soil characteristic | Soil-solution ratio | Extraction period (min) | Extractant used | Method of estimation | Instrument used | Reference |
|---|---|---|---|---|---|---|
| pH ($H_2O$) | 1 : 2.5 | - | - | Direct reading | pH meter | Jackson (1958) |
| Organic carbon | - | - | - | Walkeley-Black | Titrimetric | Jackson (1958) |
| Available P | 1 : 10 | 5 | Bray - I | Molybdenum blue | Spectrophotometer | Jackson (1958) |
| Available K | 1 : 10 | 30 | N Ammonium acetate (pH 7) | Direct reading after dilution | Flame photometer | Jackson (1958) |
| Available Na | 1 : 10 | 30 | " | Direct reading after dilution | Flame photometer | Jackson (1958) |
| Available Ca | 1 : 10 | 30 | " | Direct reading using $SrCl_2$ as releasing agent. | Atomic absorption spectrophotometer | Jackson (1958) |
| Available Mg | 1 : 10 | 30 | " | " | " | Jackson (1958) |
| Exchange acidity | 1 : 20 | 15 | $BaCl_2$-Triethanol amine | Titrimetric | - | Mehlich (1953) |
| Cation exchange capacity | - | - | - | Summation of exchangeable K, Na, Ca, Mg and H | - | Black (1965) |
| Available S | 1 : 10 | 30 | $KH_2PO_4$ with 500 ppm P | Turbidimetric | Spectrophotometer | Fox *et al*. (1964) and Jones *et al*. (1972) |
| Available Cl | 1 : 5 | 5 | Water | Mohr's titration | - | Jackson (1958) |
| Extractable Fe, Mn, Zn and Cu | 1 : 10 | 15 | Double acid HCl 0.05 N + $H_2SO_4$ 0.025 N | Direct reading | Atomic absorption spectrophotometer | Page (1982) |

Determination of other nutrient elements in the leaf samples was done after digestion with 1:1 $HNO_3$ - $HClO_4$ diacid mixture (Johnson and Ulrich, 1959). Phosphorus in the digest was estimated spectrophotometrically by the vanadomolybdate yellow colour method (Jackson, 1958).

Potassium was estimated using flame photometer while estimations of Ca and Mg, Fe, Mn, Zn and Cu were done in an atomic absorption spectrophotometer. For the atomic absorption spectrophotometric determination of Ca and Mg $SrCl_2$ was used as the releasing agent. Total S in the digest was estimated turbidimetrically (Jackson, 1958).

3.2.4 Statistical analysis

Analysis of variance and simple correlation analysis were used to bring out the treatment effects and the nature of relationships among variables respectively. The statistical analyses were done at the Computer Centre, Kerala Agricultural University, Vellanikkara.

# Results and Discussion

# RESULTS AND DISCUSSION

## 4.1 Pattern of $^{32}P$ absorption by coconut palm

The studies on the absorption of soil-applied $^{32}P$ were conducted in the monsoon seasons of 1985 and 1986. In the first year the application of $^{32}P$ was done in the form of encapsulated superphosphate, while in the second year $^{32}P$ was applied in solution form. The experiment conducted in the first year covered radial distances upto 200 cm from the palm, whereas in the second year, the pattern of root activity from 2 to 4 m distance from the palm was studied. In both cases, the maximum depth tried was 90 cm.

### 4.1.1 Pattern of $^{32}P$ absorption from an area of 2 m radius around the palm

The data on the recovery of radioactivity in the palm leaves at 13, 33, 50 and 71d after $^{32}P$ placement are furnished in Tables 2 to 5 respectively. It was observed that the absorption of the radiolabel was more or less uniform from the various radial distances namely 30, 60, 100, 150 and 200 cm from the palm at all sampling intervals. However, significant differences were observed with respect to depth of placement at 13, 33 and 71 d after application. There was a gradual decrease in the absorption of $^{32}P$ with increasing depth.

Table 2. Absorption of applied $^{32}P$ by coconut palm (cpm $g^{-1}$ leaf) from an area of upto 2 m radius and 90 cm depth 13days after placement (log transformed values)

| Depth (cm) | Lateral distance (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 30 | 60 | 100 | 150 | 200 | Mean |
| 30 | 1.737 (54.551) | 1.628 (42.486) | 2.080 (120.176) | 1.594 (39.221) | 1.550 (35.489) | 1.719 (52.412) |
| 60 | 1.745 (55.652) | 1.650 (44.664) | 1.793 (62.122) | 1.415 (26.031) | 1.307 (20.274) | 1.580 (38.061) |
| 90 | 0.847 (7.026) | 0.916 (8.244) | 0.465 ( 2.915) | 0.595 (3.934) | 0.955 (9.021) | 0.755 (5.695) |
| Mean | 1.442 (27.640) | 1.398 (25.010) | 1.445 (27.918) | 1.202 (15.949) | 1.272 (18.715) | |

SEM : 0.403

CD (0.05) for comparison of

Lateral distance : Not significant

Depth : 0.521

Lateral distance x depth : Not significant

Parenthesis denote retransformed values

Table 3. Absorption of applied $^{32}P$ by coconut palm (cpm $g^{-1}$ leaf) from an area of upto 2 m radius and 90 cm depth 33 days after placement (log transformed values)

| Depth (cm) | Lateral distance (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 30 | 60 | 100 | 150 | 200 | Mean |
| 30 | 2.844 (698.248) | 2.966 (923.817) | 2.666 (463.434) | 2.583 (383.257) | 2.297 (198.163) | 2.670 (468.091) |
| 60 | 2.857 (719.509) | 2.649 (445.226) | 2.523 (333.198) | 2.579 (379.444) | 2.188 (154.301) | 2.557 (360.942) |
| 90 | 2.041 (109.835) | 1.924 (83.851) | 2.093 (123.835) | 1.772 (59.093) | 2.171 (148.252) | 1.997 (99.385) |
| Mean | 2.579 (379.444) | 2.514 (326.601) | 2.427 (267.410) | 2.310 (204.147) | 2.219 (165.486) | |

SEM : 0.324

CD (0.05) for comparison of

Lateral distance : Not significant

Depth : 0.420

Lateral distance x depth : Not significant

Parenthesis denote retransformed values

Table 4. Absorption of applied $^{32}P$ by coconut palm (cpm $g^{-1}$ leaf) from an area of upto 2 m radius and 90 cm depth 50 days after placement (log transformed values)

| Depth (cm) | Lateral distance (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 30 | 60 | 100 | 150 | 200 | Mean |
| 30 | 2.983 (961.510) | 3.165 (1463.248) | 2.922 (835.922) | 2.696 (497.029) | 2.718 (522.507) | 2.896 (787.252) |
| 60 | 3.187 (1538.254) | 2.966 (923.817) | 2.714 (517.309) | 2.874 (748.866) | 2.549 (353.797) | 2.857 (719.509) |
| 90 | 2.818 (657.495) | 2.540 (346.793) | 2.327 (212.477) | 2.306 (202.117) | 2.597 (354.926) | 2.518 (329.883) |
| Mean | 2.996 (990.786) | 2.892 (779.421) | 2.653 (449.741) | 2.623 (419.342) | 2.623 (419.342) | |

SEM : 0.256

CD (0.05) for comparison of

Lateral distance : Not significant

Depth : Not significant

Lateral distance x depth : Not significant

Parenthesis denote retransformed values

Table 5. Absorption of applied $^{32}P$ by coconut palm (cpm $g^{-1}$ leaf) from an area of upto 2 m radius and 90 cm depth 71 days after placement (log transformed values)

| Depth (cm) | Lateral distance (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 30 | 60 | 100 | 150 | 200 | Mean |
| 30 | 3.148 (1405.886) | 3.209 (1617.104) | 3.022 (1052.039) | 2.900 (795.163) | 2.696 (497.029) | 2.996 (990.786) |
| 60 | 3.148 (1405.886) | 2.996 (990.786) | 3.070 (1174.340) | 3.035 (1084.072) | 2.792 (619.307) | 3.009 (1020.954) |
| 90 | 2.518 (329.883) | 2.549 (353.797) | 2.692 (492.085) | 2.388 (244.399) | 2.662 (458.824) | 2.562 (364.569) |
| Mean | 2.940 (870.030) | 2.918 (827.607) | 2.927 (844.322) | 2.775 (595.029) | 2.718 (522.507) | |

SEM : 0.201

CD (0.05) for comparison of

Lateral distance : Not significant

Depth : 0.261

Lateral distance x depth : Not significant

Parenthesis denote retransformed values

The decrease was most conspicuous and significant at 90 cm depth. This trend was observed irrespective of the interval of sampling. The lateral distance x depth interaction was not significant at any sampling interval.

The absorption of $^{32}P$ as a function of time is shown in Fig. 4. The overall absorption increased from 32 cpm on 13th day to 792 cpm $g^{-1}$ leaf at the end of the experiment (71st day after placement).

4.1.2 Pattern of $^{32}P$ absorption from an area of 2 to 4 m radius around the palm

In this experiment, a comparison of the absorption of $^{32}P$ from 200, 250, 300 and 400 cm radial distances was made keeping the depths of placement similar to that in the previous experiment. The data on the radioactivity recovered in the leaves after 15, 33, 47 and 63 days of application are presented in Tables 6 to 9. It was observed that the absorption of $^{32}P$ was not influenced by lateral distance from the tree and depth of placement during the first 33 days. However, significant differences in the absorption of the applied label from different radial distances and depths were observed at later intervals of sampling, namely 47 and 63 days after $^{32}P$ application. The data indicated a gradual decrease in $^{32}P$ absorption with

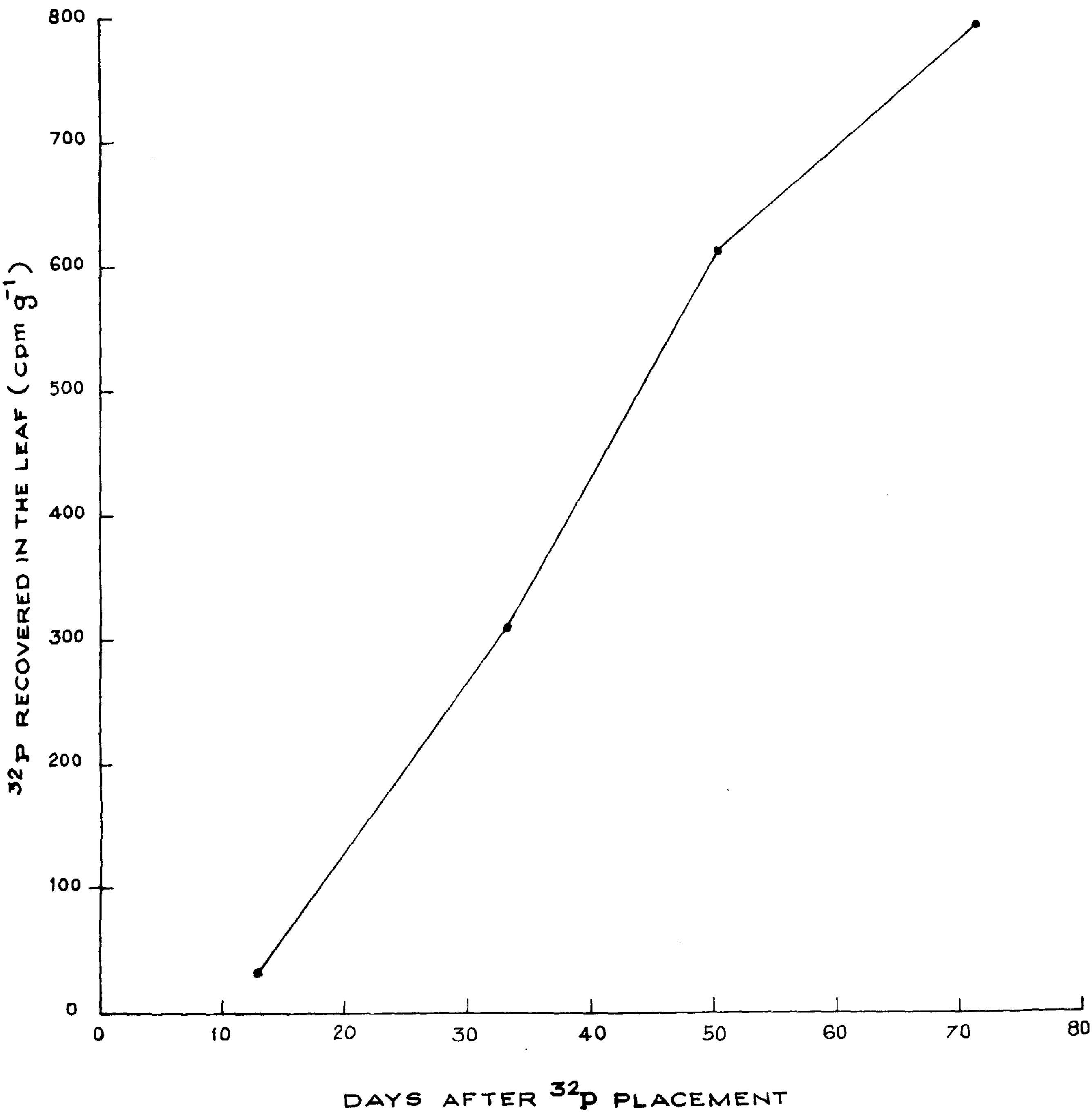


FIG. 4. ABSORPTION OF APPLIED $^{32}$P BY COCONUT PALM FROM AN AREA OF UPTO 2 m RADIUS AND A DEPTH UP TO 90 cm AS A FUNCTION OF TIME

Table 6. Absorption of applied $^{32}P$ by coconut palm (cpm $g^{-1}$ leaf) from an area of 2 to 4 m radius and upto 90 cm depth 15 days after application (log transformed values)

| Depth (cm) | Lateral distance (cm) | | | | |
|---|---|---|---|---|---|
| | 200 | 250 | 300 | 400 | Mean |
| 30 | 1.776 (59.687) | 1.732 (54.008) | 1.767 (58.505) | 1.185 (15.324) | 1.615 (41.231) |
| 60 | 1.984 (96.448) | 2.032 (107.660) | 1.620 (41.645) | 1.411 (25.772) | 1.763 (57.923) |
| 90 | 1.563 (36.570) | 1.780 (60.286) | 1.385 (24.272) | 1.759 (38.830) | 1.580 (38.062) |
| Mean | 1.776 (59.687) | 1.850 (70.744) | 1.589 (38.830) | 1.395 (24.762) | |

SEM : 0.247

CD (0.05) for comparison of

Lateral distance : Not significant

Depth : Not significant

Lateral distance x depth : Not significant

Parentheses denote retransformed values

Table 7. Absorption of applied $^{32}P$ by coconut palm (cpm $g^{-1}$ leaf) from an area of 2 to 4 m radius and upto 90 cm depth 33 days after application (log transformed values)

| Depth (cm) | Lateral distance (cm) | | | | |
|---|---|---|---|---|---|
| | 200 | 250 | 300 | 400 | Mean |
| 30 | 2.392 (246.855) | 2.154 (142.440) | 2.184 (152.766) | 2.054 (113.179) | 2.197 (157.417) |
| 60 | 2.353 (225.613) | 2.158 (143.871) | 2.058 (114.316) | 2.197 (157.417) | 2.193 (155.851) |
| 90 | 2.227 (168.829) | 1.837 ( 68.654) | 1.845 ( 70.041) | 1.845 ( 70.041) | 1.941 ( 87.272) |
| Mean | 2.323 (210.363) | 2.049 (112.053) | 2.032 (107.660) | 2.032 (107.660) | |

SEM : 0.166

CD (0.05) for comparison of

Lateral distance : Not significant

Depth : Not Significant

Lateral distance x depth : Not significant

Parenthesis denote retransformed values

Table 8. Absorption of applied $^{32}P$ by coconut palm (cpm $g^{-1}$ leaf) from an area of 2 to 4 m radius and upto 90 cm depth 47 days after application (log transformed values)

| Depth (cm) | Lateral distance (cm) | | | | |
|---|---|---|---|---|---|
| | 200 | 250 | 300 | 400 | Mean |
| 30 | 2.384 (241.968 | 2.388 (244.399) | 2.271 (186.580) | 1.997 (99.385) | 2.262 (182.887) |
| 60 | 2.401 (251.840) | 2.154 (142.440) | 2.058 (114.316) | 1.641 (43.780) | 2.062 (115.465) |
| 90 | 2.180 (151.246) | 1.772 (59.093) | 1.789 (61.504) | 1.672 (46.954) | 1.854 (71.455) |
| Mean | 2.323 (210.363) | 2.106 (127.606) | 2.041 (109.835) | 1.772 (59.093) | |

SEM : 0.205

CD (0.05) for comparison of

Lateral distance : 0.346

Depth : 0.300

Lateral distance x depth : Not significant

Parenthesis denote retransformed values

Table 9. Absorption of applied $^{32}P$ by coconut palm (cpm $g^{-1}$ leaf) from an area of 2 to 4 m radius and upto 90 cm depth 63 days after application (log transformed values)

| Depth (cm) | Lateral distance (cm) | | | | |
|---|---|---|---|---|---|
| | 200 | 250 | 300 | 400 | Mean |
| 30 | 2.423 (264.750) | 2.392 (246.855) | 2.332 (214.612) | 2.132 (135.495) | 2.319 (208.271) |
| 60 | 2.358 (227.880) | 2.284 (192.261) | 2.106 (127.606) | 1.967 (92.667) | 2.180 (151.246) |
| 90 | 2.310 (204.147) | 1.858 (72.173) | 1.667 (46.487) | 1.863 (72.898) | 1.924 (83.851) |
| Mean | 2.366 (232.482) | 2.180 (151.246) | 2.036 (108.742) | 1.989 (97.417) | |

SEM : 0.166

CD (0.05) for comparison of

Lateral distance : 0.281

Depth : 0.243

Lateral distance x depth : Not significant

Parenthesis denote retransformed values

increasing lateral distance from the tree. Despite this, the difference between 200 and 400 cm was only found statistically significant. Among the three depths of placement, the absorption from 90 cm was the least here again. The lateral distance x depth interaction was also not found to be significant. The overall mean absorption of $^{32}P$ from 200 to 400 cm radial distance is shown in Fig. 5 as a function of time. There was a sharp increase in the absorbed radioactivity from 45.7 cpm $g^{-1}$ at 15 d to 133.5 cpm $g^{-1}$ at 33 d after application beyond which the increase was only marginal.

### 4.1.3 Distribution of active roots in different soil zones

From the two experiments conducted on the absorption of $^{32}P$ by coconut palm, it was observed that the mean values for the depths of placement at a lateral distance of 200 cm were similar. In the first experiment the mean values obtained for 30, 60 and 90 cm depths at 2 m lateral distance were 206.7, 161.8 and 124.8 cpm $g^{-1}$ respectively. The mean values obtained for the same treatments in the second year experiment were 175.3, 187.9 and 117.5 cpm $g^{-1}$ respectively. In view of the similarities in the observed values for the three depths at 2 m radial distance in these two experiments, the mean values obtained for other

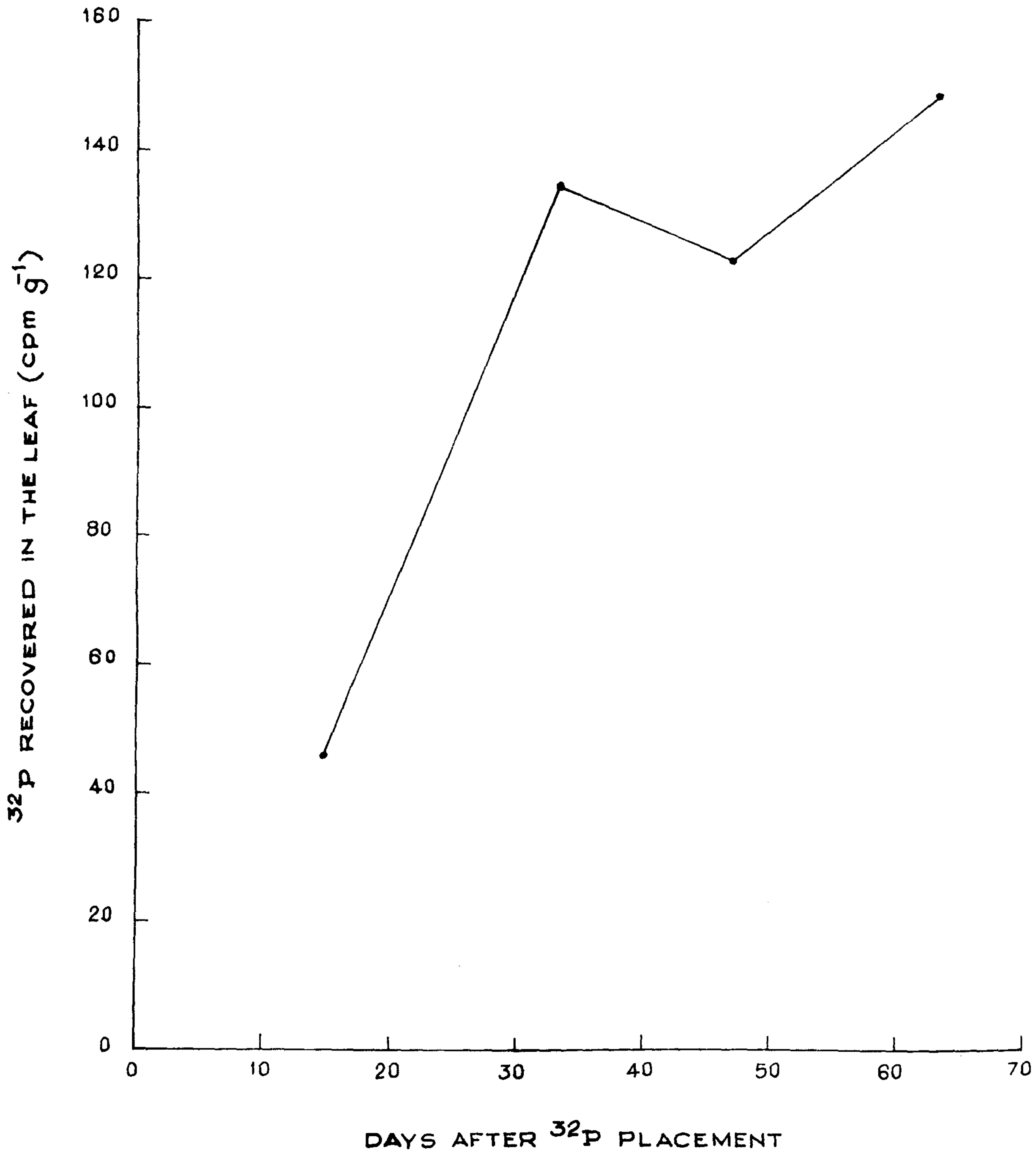


FIG. 5. ABSORPTION OF APPLIED $^{32}P$ COCONUT PALM FROM AN AREA OF 2 TO 4 m RADIUS AND A DEPTH UPTO 90 cm AS A FUNCTION OF TIME

treatments in these experiments may also be considered intercomparable. Based on the reasoning that the absorption of applied $^{32}P$ from different soil zones reflects the relative density of active roots in them, the percentage root activity of the palm in each soil zone upto a radial distance of 4 m was computed. For this purpose, the mean cpm values of the data presented in Tables 2 to 9 were made use of. However, for the three depths at 2 m radius from the palm, the mean values obtained in the two experiments were averaged. These computed values are given in Table 10. From these data, percentage root activity at different depths and lateral distances were worked out (Table 11). The data indicated that a major portion of the root activity was within an area of 2 m radius around the palm. The vertical distribution of active roots was mainly confined to a depth of 60 cm and the root activity decreased sharply at 90 cm depth. The overall pattern (Fig. 6 and 7) indicates a gradual decrease of root activity from near the palm to farther away from it. On the other hand, the decrease in root activity with depth is less marked upto 60 cm. As the experiments were conducted in the rainy season, the data relating to absorption of $^{32}P$ from different depths and lateral distances may be considered to reflect the active root density in these soil zones and are not affected by

Table 10. Absorption of applied $^{32}P$ from various soil zones from the two experiments (mean cpm $g^{-1}$ leaf)

| Depth (cm) | Lateral distance (cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 | 60 | 100 | 150 | 200* | 250 | 300 | 400 |
| 30 | 476.4 | 552.1 | 470.4 | 277.5 | 190.9 | 146.7 | 137.6 | 69.5 |
| 60 | 542.3 | 367.5 | 335.0 | 299.1 | 174.9 | 143.5 | 91.3 | 63.7 |
| 90 | 113.8 | 96.0 | 78.4 | 68.2 | 121.2 | 64.8 | 46.9 | 60.9 |

* Mean values obtained in each experiment was averaged

Table 11. Relative root activity of coconut palm at different lateral distances and depth (%)

| Depth (cm) | Lateral distance (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 | 60 | 100 | 150 | 200 | 250 | 300 | 400 | Mean |
| 30 | 9.5 | 11.1 | 9.4 | 5.6 | 3.8 | 2.9 | 2.8 | 1.4 | 46.5 |
| 60 | 10.9 | 7.4 | 6.7 | 6.0 | 3.5 | 2.9 | 1.8 | 1.3 | 40.5 |
| 90 | 2.3 | 1.9 | 1.6 | 1.4 | 2.4 | 1.3 | 0.9 | 1.2 | 13.0 |
| Mean | 22.7 | 20.4 | 17.7 | 13.0 | 9.7 | 7.1 | 5.5 | 3.9 | |

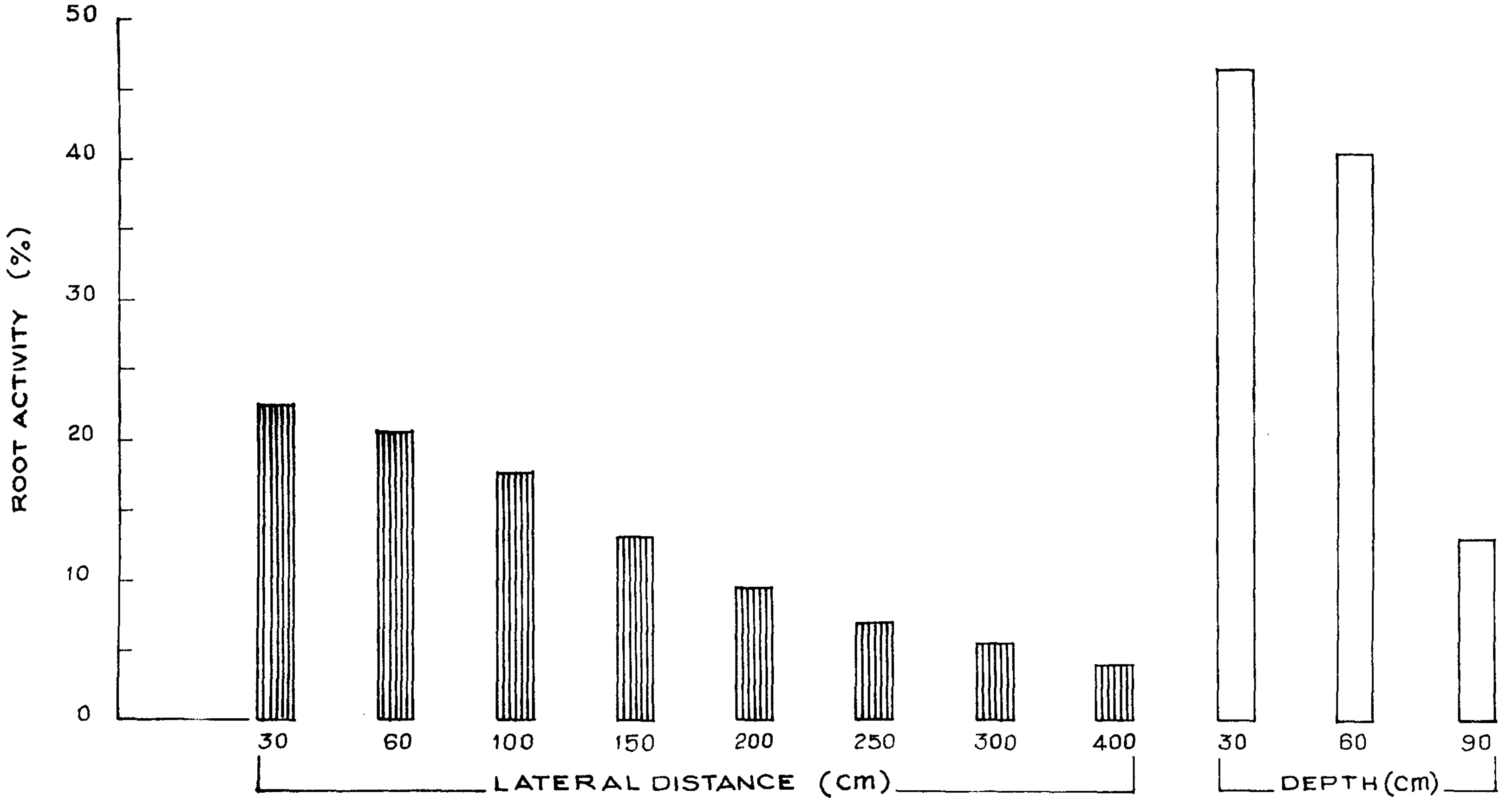


FIG. 6. COCONUT ROOT ACTIVITY IN RELATION TO DISTANCE FROM THE PALM AND SOIL DEPTH

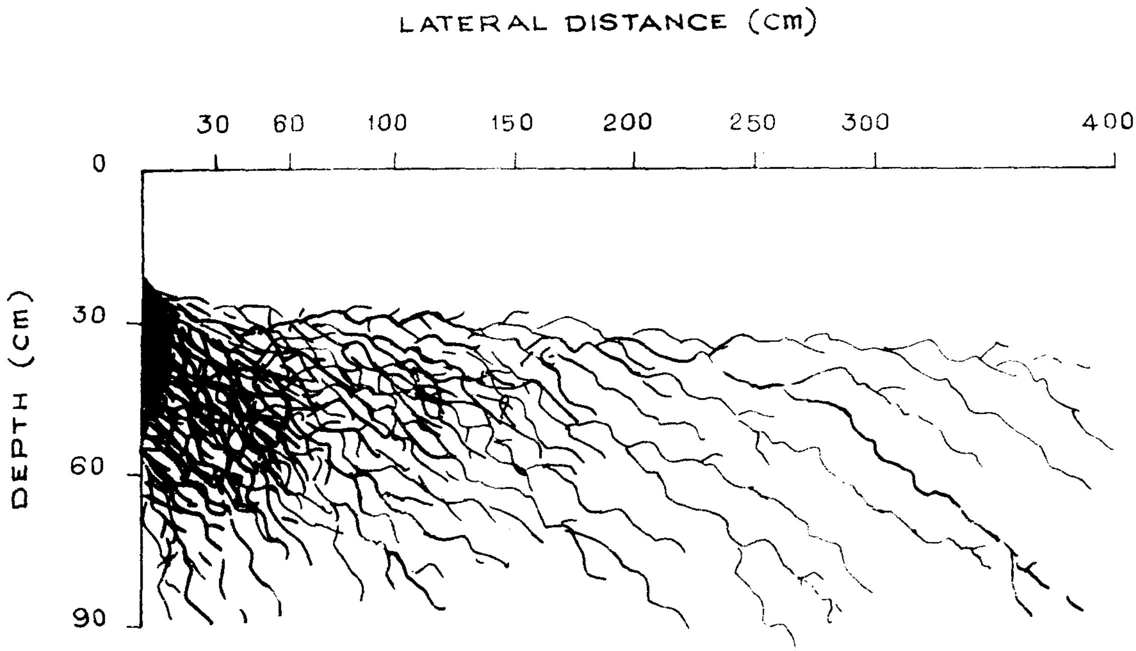


FIG. 7. DIAGRAMATIC REPRESENTATION OF ACTIVE ROOT SYSTEM OF COCONUT PALM

limiting moisture supply or moisture gradients along the rhizosphere profile. Therefore, it may be concluded that nearly 85 per cent of the active roots reside within 2 m radius around the palm. Almost same percentage of active roots may be found within 60 cm soil layer.

The current recommended practice of fertilizer application is in a circular soil basin of radius 1.8 m and 25 cm depth around the palm (KAU, 1986). The results of the present study does not contradict this view. For maximum utilization of applied fertilizer, a circle of radius 2 m may be recommended. Excavation studies (Kushwah et al., 1973) as well as visual observation during opening of the basins for fertiliser application had clearly indicated that 0-25 cm surface layer is devoid of any root. Perhaps, the regular disturbance caused during annual opening of the soil basins for fertilizer application might have caused the roots to shy away from the surface layer. The results reported by Balakrishnamurthy (1971) from Sri Lanka strengthens this reasoning. He observed that most of the root activity was confined to within the upper 0-30 cm soil layer. The general practice of fertilizer application in coconut gardens is to apply the fertilizers in a circle around the palm (Manicot et al., 1980; Thampan, 1982). The method of application of fertilizers to adult trees as practised in India thus suffers from the drawback that unless the nutrients are leached down, the utilisation of the added inputs by the palm would be seriously affected. Among the applied nutrients, P uptake by the palm may be worst affected because of the limited mobility of this element in oxisols. In the light of these results, it is suggested that spreading of fertilisers on the soil surface within 2 m radius around the palm rather than basin application is more appropriate in coconut gardens as it would encourage proliferation of roots in the upper soil layer and thus bring the roots in close contact with the applied nutrients.

The study of root activity was conducted in two phases as otherwise the experiment would have been virtually impractical owing to the large requirement of land space, palms and radioactivity. It was observed that the application of $^{32}P$ in capsules was more hazardous than its application in the form of solution using field dispenser as evidenced from the relatively higher exposure dose received during the use of capsules (80 mrem) compared to zero dose received during the use of field dispenser.

### 4.1.4 Soil physicochemical characteristics as influenced by soil depth and lateral distance from the palm

The changes in soil physico-chemical characteristics in relation to depth and lateral distances from the palm were studied by analysing soil samples corresponding to the lateral distances and depths considered in the root activity experiment. It may be noted, however, that the soil samples from 20-40 cm, 50-70 cm and 80-100 cm depths were collected to correspond the depths of $^{32}P$ placement at 30, 60 and 90 cm respectively. The data pertaining to the soil characteristics are presented in Table 12. Significant variations were observed at different lateral distances from the palm in the concentrations of available P, exchangeable K, Ca, available Mn, Zn and Cu and also in base saturation. Generally speaking, there was more accumulation of these nutrients near the palm up to about 150-200 cm radius then beyond it. This is expected because the fertilizer application was restricted to an area of radius 1.8 m around the palm. Thus, P, K and Ca which are supplied through superphosphate and muriate of potash could get accumulated in the fertilized area. On the other hand, soil pH, organic carbon, exchangeable Mg, available Fe, exchange acidity and CEC were found to be more or less same irrespective of the distance from the palm.

Table 12. Physico-chemical characteristics of Vellanikkara soil as influenced by lateral distance from the palm and depth

| Treatment | pH | Organic carbon (%) | Bray-IP (ppm) | Exch. K (me/ 100g) | Exch. Na (me/ 100g) | Exch. Ca (me/ 100g) | Exch. Mg (me/ 100g) | Avail. Fe (ppm) | Avail. Mn (ppm) | Avail. Zn (ppm) | Avail. Cu (ppm) | PBS | Exch. acidity (me/100g) | CEC (me/ 100g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lateral distance (cm) | | | | | | | | | | | | | | |
| 30 | 5.32 | 1.00 | 6.75 | 0.53 | 0.25 | 2.03 | 0.65 | 28.80 | 99.68 | 29.52 | 10.64 | 26.31 | 10.22 | 13.90 |
| 60 | 5.78 | 0.82 | 3.43 | 0.78 | 0.28 | 4.16 | 0.38 | 28.01 | 88.99 | 30.91 | 6.35 | 34.93 | 9.88 | 15.46 |
| 100 | 5.71 | 0.95 | 2.57 | 0.53 | 0.25 | 2.43 | 0.64 | 27.93 | 86.36 | 27.46 | 7.39 | 28.90 | 10.14 | 13.99 |
| 150 | 5.48 | 0.97 | 2.65 | 0.24 | 0.22 | 2.08 | 0.82 | 28.40 | 83.40 | 23.63 | 11.07 | 28.79 | 10.23 | 13.59 |
| 200 | 5.39 | 0.97 | 1.56 | 0.21 | 0.21 | 1.79 | 0.69 | 28.08 | 78.56 | 28.46 | 12.68 | 23.23 | 9.86 | 12.75 |
| 250 | 5.52 | 0.84 | 0.70 | 0.15 | 0.21 | 2.06 | 0.61 | 28.89 | 46.60 | 11.56 | 6.42 | 21.12 | 12.08 | 15.17 |
| 300 | 5.44 | 0.87 | 0.65 | 0.12 | 0.20 | 1.82 | 0.5[illegible] | 28.50 | 46.21 | 7.88 | 7.13 | 19.15 | 12.49 | 15.21 |
| 400 | 5.39 | 0.79 | 0.76 | 0.11 | 0.18 | 1.82 | 0.5[illegible] | 27.00 | 46.22 | 13.72 | 7.49 | 16.79 | 13.87 | 16.53 |
| CD(0.05) | NS | NS | 1.79 | 0.12 | 0.04 | 1.16 | NS | NS | 11.54 | 10.66 | 4.14 | 9.34 | NS | NS |
| Depth (cm) | | | | | | | | | | | | | | |
| 20-40 | 5.41 | 1.10 | 3.84 | 0.33 | 0.22 | 2.28 | 0.61 | 23.70 | 78.08 | 26.98 | 10.09 | 22.91 | 11.67 | 15.11 |
| 50-70 | 5.46 | 0.85 | 1.61 | 0.31 | 0.22 | 2.09 | 0.62 | 29.97 | 75.52 | 27.41 | 8.43 | 24.94 | 10.79 | 14.06 |
| 80-100 | 5.64 | 0.75 | 1.77 | 0.37 | 0.23 | 2.44 | 0.61 | 30.94 | 63.32 | 10.54 | 7.42 | 26.86 | 10.84 | 14.56 |
| CD(0.05) | NS | 0.11 | 1.10 | NS | NS | NS | NS | 4.02 | 7.07 | 6.43 | NS | NS | NS | NS |
| SEM(±) | 0.20 | 0.11 | 1.09 | 0.08 | 0.02 | 0.71 | 0.15 | 3.99 | 7.02 | 6.49 | 2.52 | 5.68 | 2.07 | 2.23 |

PBS : Per cent base saturation

The effect of depth was marked on the organic matter content, available P, available Fe, available Mn and available Zn in the soil where as the other characteristics of the soil were not found to be influenced by this parameter. In the case of organic matter and available P, a significant decrease was observed beyond 50 cm depth. In the case of Mn and Zn the availability remained constant up to 70 cm depth beyond which there was a decrease. On the other hand, a significant increase in available Fe content was observed in the deeper soil layers.

4.1.5 Effect of active root density on soil characteristics

Simple correlations were woked out between per cent root activity and physicochemical characteristics of the soil at various lateral distances and depths (Table 13). Positive correlations were observed between root activity and organic carbon, available P, available K, available Mn and Zn, while negative correlation was observed between root activity and exchange acidity.

The increase in organic carbon content with an increase in root activity may be due to the organic matter incorporation into soil during degeneration of roots while the increased availability of nutrients

Table 13. Correlations(r) between coconut root activity and soil physico-chemical characteristics

| Soil characteristics | 'r' value |
|---|---|
| pH | -0.126 |
| Organic carbon | +0.539* |
| Bray IP | +0.575** |
| Exchangeable K | +0.510* |
| Exchangeable Ca | +0.296 |
| Exchangeable Mg | -0.009 |
| Exchange acidity | -0.413* |
| Cation exchange capacity | -0.389 |
| Per cent base saturation | +0.370 |
| Available Fe | -0.400 |
| Available Mn | +0.767** |
| Available Zn | +0.503* |
| Available Cu | +0.298 |

* Significant at 5% level

** Significant at 1% level

df:22

such as P, Mn and Zn may be as a result of increased activity of P-solubilizing microflora and the release of root exudates with chelating properties.

Nair and Subbarao (1977) reported the presence of phosphate-solubilising microbes in coconut rhizosphere. A direct relationship was found between the population of phosphate solubilizers and available P content of the soil. Shantaram and Saraswathy (1985) also confirmed the occurence of phosphate solubilising bacteria in the rhizosphere of coconut. Recently, Merckx et al. (1986a, 1986b) in a series of experiments demonstrated the chelating properties of root-derived materials. They found increased complexation of $^{65}Zn$ $^{54}Mn$ and $^{57}Co$ by root derived organic materials in the rhizospheres of maize and wheat as compared to uncropped area. Even though these studies were confined to soil-root interface (commonly called rhizosphere), it is possible that in long-term situation such as in a perennial crop garden the sphere of influence of root may be widened to include larger volume of soil. The results of the present study points to such a possibility. Perhaps, the increased concentrations of extractable Zn and Mn in soil with increasing root activity may be due to the release of these nutrients following chelation.

Correlation between root activity and pH, exchangeable Ca, exchangeable Mg, CEC, base saturation, available Fe, and Cu were not significant.

## 4.2 Effect of N P K fertilizers on soil physico chemical characteristics

Chemical analyses of 0-50 cm layer of the coconut soil basins indicated that regular annual application of NPK fertilizers namely ammonium sulphate, super phosphate and muriate of potash influenced the soil characteristics at varying degrees (Table 14).

With increasing rate of applied N, soil pH decreased markedly from 4.88 in $N_0$ plots to 4.38 in $N_2$ plots. A similar trend was also seen in the case of available Mn. On the other hand, available S status increased with N fertilizers. These effects were noticed not only in the 0-50 cm layer but also in various depths from 0-100 cm (Fig. 8). These data indicated considerable influence of long-term application of ammonium sulphate on the charateristics of soil basins. The lowering of soil pH following the application of ammonical fertilizers is a well-known phenomenon due to the release of $H^+$ ions during nitrification of $NH_4^+$ ions (Tisdale and Nelson, 1985). The $H^+$ ions so released could have been responsible for the depletion of Mn from the soil horizons. Increased availability of Mn in a similar

Table 14. Effect of NPK fertilizer application on chemical characteristics of Balaramapuram soil

| Treatment | pH | Organic carbon (%) | Bray IP (ppm) | Exch. K (ppm) | Exch. Ca (me/100g) | Exch. Mg (me/100g) | Avail. S (ppm) | Avail. Fe (ppm) | Avail. Mn (ppm) | Avail. Zn (ppm) | Avail Cu. (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_0$ | 4.88 | 0.46 | 76.89 | 94.08 | 1.55 | 0.79 | 75.00 | 23.81 | 40.38 | 3.01 | 0.80 |
| $N_1$ | 4.52 | 0.50 | 72.41 | 66.47 | 1.65 | 0.71 | 155.56 | 31.26 | 31.26 | 2.75 | 0.79 |
| $N_2$ | 4.38 | 0.50 | 67.93 | 83.75 | 1.29 | 0.52 | 186.11 | 22.63 | 25.87 | 2.47 | 0.87 |
| $P_0$ | 4.55 | 0.49 | 5.65 | 85.82 | 1.35 | 0.81 | 133.89 | 27.67 | 29.43 | 2.78 | 0.87 |
| $P_1$ | 4.52 | 0.46 | 65.14 | 77.76 | 1.45 | 0.63 | 143.89 | 22.31 | 33.73 | 2.59 | 0.79 |
| $P_2$ | 4.70 | 0.48 | 146.45 | 62.38 | 1.67 | 0.57 | 138.89 | 24.38 | 34.34 | 2.86 | 0.80 |
| $K_0$ | 4.50 | 0.43 | 87.25 | 45.01 | 1.63 | 0.69 | 162.22 | 24.19 | 31.02 | 2.81 | 0.82 |
| $K_1$ | 4.57 | 0.50 | 57.62 | 90.10 | 1.55 | 0.59 | 143.89 | 26.81 | 32.60 | 2.78 | 0.80 |
| $K_2$ | 4.71 | 0.52 | 72.38 | 90.85 | 1.30 | 0.74 | 110.56 | 23.37 | 33.88 | 2.66 | 0.83 |
| CD (0.05) | 0.20 | 0.06 | 31.84 | 15.47 | NS | NS | 60.08 | NS | 9.94 | NS | NS |
| SEM(+) | 0.10 | 0.03 | 15.35 | 7.46 | 0.33 | 0.23 | 28.97 | 3.45 | 4.79 | 0.22 | 0.06 |

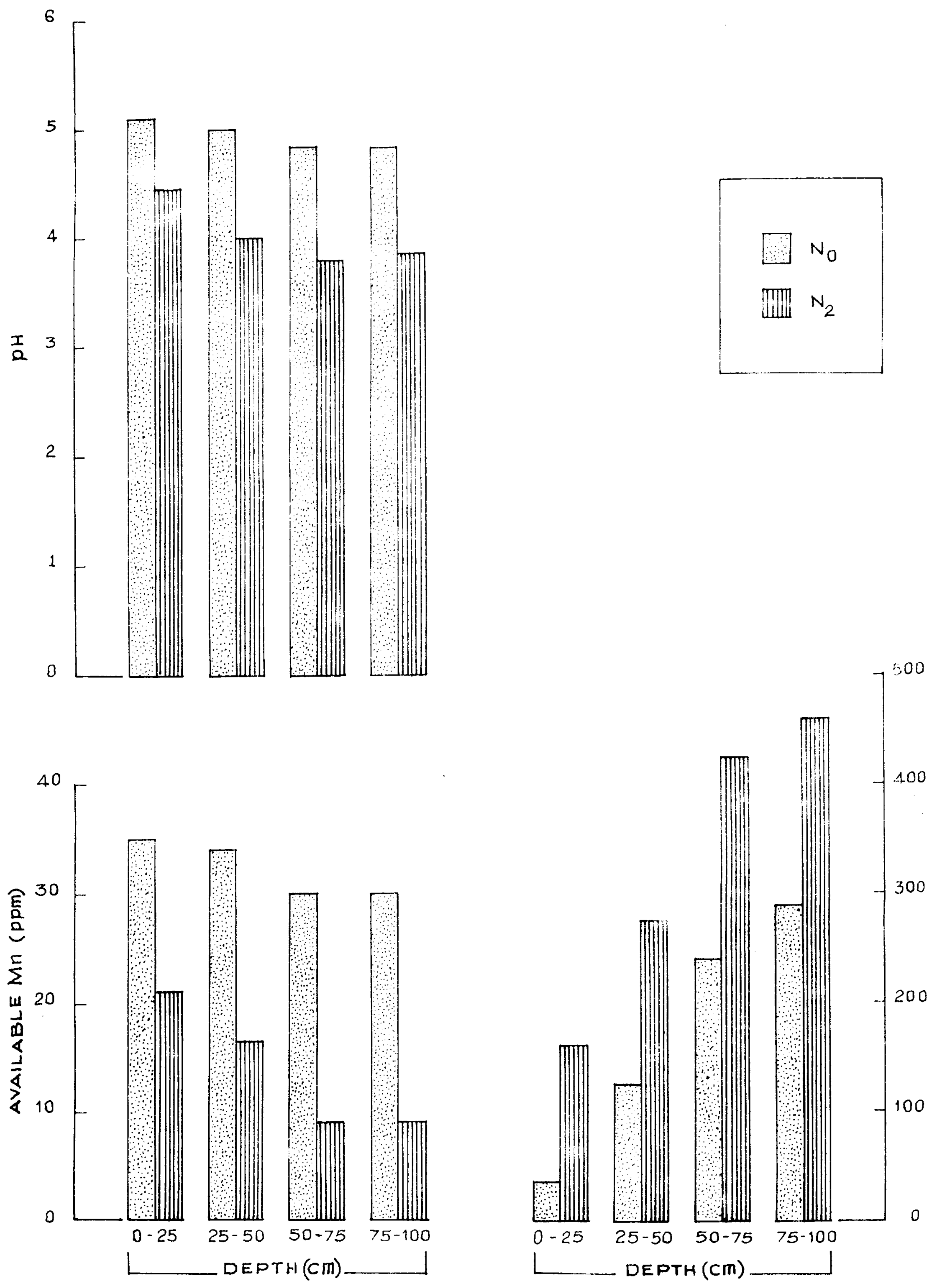


FIG. 8. EFFECT OF N FERTILIZATION ON pH AND AVAILABILITY OF S AND Mn IN SOIL

type of soil due to regular application of ammoniacal fertilizers was reported by Devi et al. (1975). These authors attributed this effect to the decreasing pH of the soil. It may be noted that the results obtained by them were for coconut garden receiving fertilisation for eight continuous years, where the results obtained in the present study were in respect of coconut garden receiving regular fertilization since 22 years. If a comparison is made between these results, it will be evident that in the initial stages there was an increased availability of Mn in the soil due to N fertilizer application but prolonged application of the fertilizer had led to the erosion of Mn fertility in coconut soil basins. In the light of these observations, it is suggested that unless ameliorative measures such as liming are resorted to, the soil Mn status will be badly affected in the long run. Further studies are essential to find out means of maintaining or restoring the pH of soil basins on a long-term basis.

On the contrary, S status of the soil throughout the profile up to 100 cm depth has been considerably improved. This enrichment of S in the soil is obviously due to the $SO_4^{2-}$ content of the fertilizer. On an average, ammonium sulphate contains 21 per cent

N and 24 per cent S. Large amount of sesquixosides present in this alfisol could also have helped in the retention of $SO_4^{2-}$.

Application of super phosphate increased the available P content of the soil from 5.65 ppm in $P_0$ plots to 146.45 ppm in $P_2$ plots (Table 14). Depth-wise analysis of the soil revealed P accumulation even up to a depth of 75-100 cm (Fig.9). Soil build-up of P following annual application of phosphatic fertilizers has been reported by several workers (Wahid et al., 1975; Wahid et al., 1977 and Khan et al., 1983). In acid soils containing large amount of sesquioxides, the mobility of P is limited due to fixation. The results of the present study however, revealed that long continued application of super phosphate could enhance the movement of P into deeper layers, consequent to heavy build-up in the surface layers. In this respect the behaviour of P is more or less same as that of S in the soil. Heavy rainfall, received during the time of fertilizer application could also be responsible for leaching of phosphate to lower layers from P-saturated upper layers. It was also observed that the application of super phosphate significantly reduced the exchangeable K content of the soil. This effect could be perhaps due to the influence of Ca present in the fertilizer

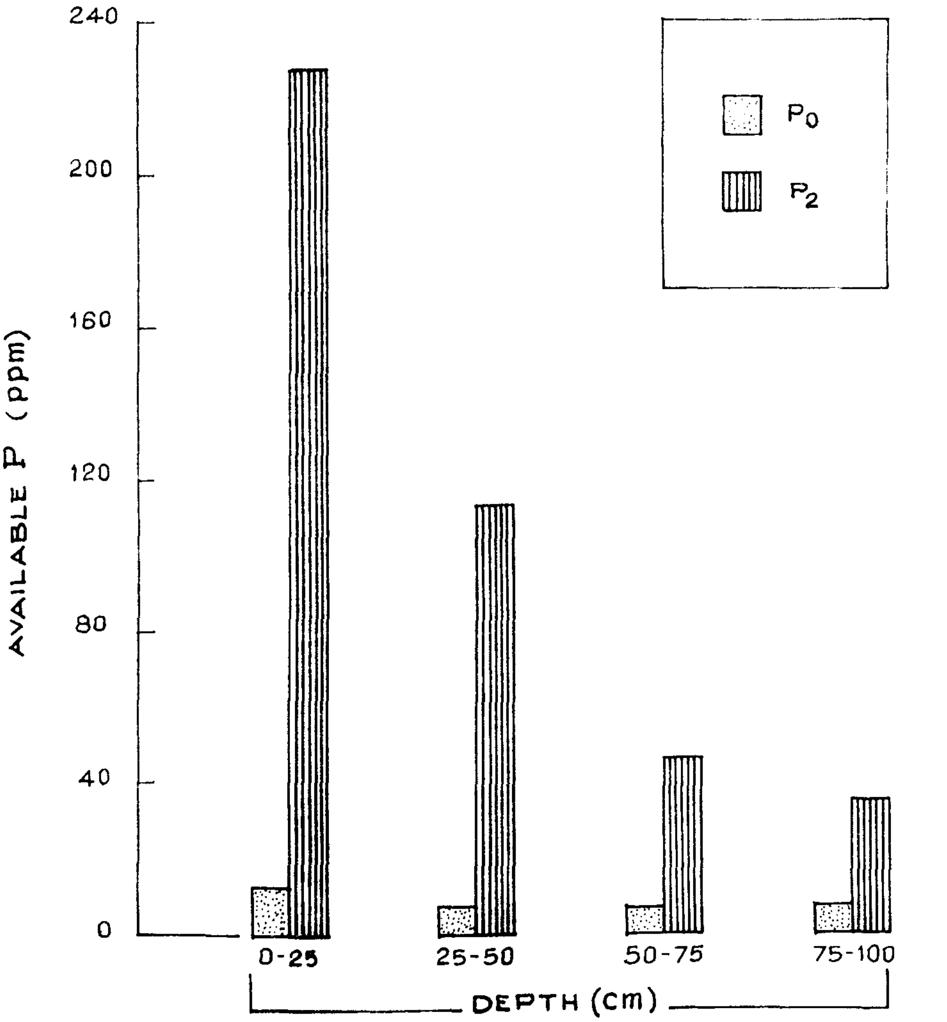


FIG. 9. VERTICAL DISTRIBUTION OF SOIL AVAILABLE P AS INFLUENCED BY P FERTILIZATION

material on replacing K from the exchange sites in the soil. Such a possibility is evident from the tendency of exchangeable Ca to increase with increasing rates of super phosphate (Table 14).

Application of muriate of potash increased the available K and organic carbon content of the soil (Table 14). The effect on soil exchangeable K was however N-dependent as revealed from the significant N x K interaction (Table 15). It was found that higher rates of ammonium sulphate application led to a reduction in exchangeable K. This effect could be due to the removal of $K^+$ ions from the exchange sites by $H^+$ ions generated in the nitrification process. However, in general, there was a build-up of exchangeable K in muriate of potash receiving plots. The accumulation of K was noticed in lower layers up to 75-100 cm in these plots (Fig. 10). Another important observation was the significant improvement in the organic carbon content of the soil due to K fertilizers. This effect was also seen at all soil depths studied (Fig. 10). In this context, it may be pointed out that the yield and growth of the palms under this experiment were influenced only by muriate of potash application (KAU, 1987). From these observations it may be reasonably expected that K application would have promoted more root growth which

Table 15. Effect of N x K fertiliser interaction on Exch. K (ppm) of Balaramapuram Coconut soil

| | $K_0$ | $K_1$ | $K_2$ | Mean |
|---|---|---|---|---|
| $N_0$ | 41.34 | 125.84 | 115.05 | 94.08 |
| $N_1$ | 54.95 | 75.33 | 69.16 | 66.47 |
| $N_2$ | 38.74 | 69.16 | 88.34 | 63.75 |
| Mean | 45.01 | 90.10 | 90.85 | |

SEM(±) : 22.38

CD (0.05) for comparison of

Main effect (K) : 15.47

Interaction (NK) : 10.94

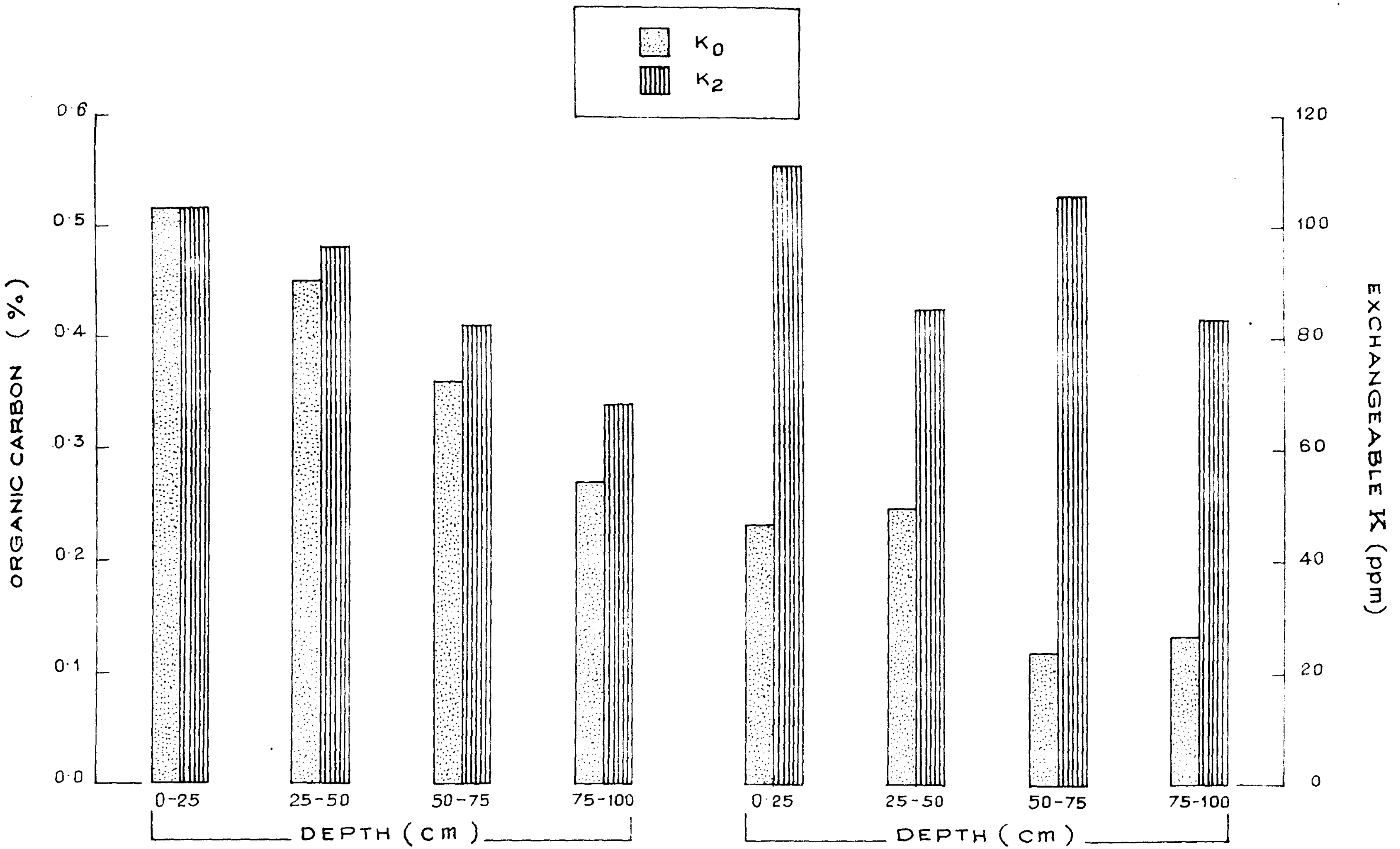


FIG. 10. EFFECT OF K FERTILIZATION ON ORGANIC CARBON AND AVAILABLE K STATUS OF SOIL

in turn, would have increased the organic carbon content of the soil. Evidence for such an effect was obtained from the positive correlation between root activity and organic carbon content (Table 13).

The effect of long-term NPK fertilizer application on the availability of Fe, Zn and Cu as well as Ca and Mg, were not found to be significant. Even though Cl content of the soil was also estimated, the data are not presented because the concentration in the soil was negligible irrespective of the treatments.

The data on the distribution of nutrients at different soil depths are given in Table 16. Of these, available P, K, Mn, S and soil characteristics such as pH and organic carbon were found to be influenced by one or more of the fertilizer material applied to the palms. This aspect has been covered in the foregoing discussion. Hence the data presented in Table 16 are made use of for understanding the distribution of other nutrients with soil depth. Generally speaking exchangeable Mg decreased with depth, so also is the case with available Cu. On the other hand available Fe increased from 20.2 ppm in 0-25 cm soil layer to 35.4 ppm in the lower most soil layer (75-100 cm).

Table 16. Chemical characteristics of soil as influenced by depth in NPK experiment

| Treatment | pH | Organic carbon (%) | Bray IP (ppm) | Exch. K (me/100g) | Exch. Ca (me/100g) | Exch. Mg (me/100g) | Avail. S (ppm) | Avail. Fe (ppm) | Avail. Mn (ppm) | Avail. Zn (ppm) | Avail. Cu (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | | | | | | | | | | | |
| 0-25 cm | 4.80 | 0.52 | 115.8 | 0.20 | 2.59 | 1.08 | 96.9 | 20.2 | 28.1 | 2.17 | 0.94 |
| 25-50 cm | 4.45 | 0.46 | 59.9 | 0.17 | 2.61 | 1.25 | 198.8 | 25.3 | 25.3 | 2.43 | 1.02 |
| 50-75 cm | 4.32 | 0.38 | 26.8 | 0.17 | 2.00 | 0.71 | 332.5 | 30.1 | 19.5 | 2.45 | 0.91 |
| 75-100 cm | 4.34 | 0.30 | 20.7 | 0.14 | 1.87 | 0.69 | 373.1 | 35.4 | 17.0 | 2.13 | 0.82 |
| CD (0.05) | 0.19 | 0.05 | 55.31 | NS | NS | 0.48 | 53.01 | 4.15 | 4.76 | NS | 0.14 |
| SEM(±) | 0.18 | 0.05 | 54.26 | 0.05 | 0.86 | 0.47 | 51.99 | 4.07 | 4.67 | NS | 0.13 |

## 4.3 Relationships of soil test values with foliar nutrient levels and yield

Simple correlations between available nutrient concentrations in soil (0-50 cm depth) and the level of corresponding nutrients in the 6th and 14th leaves were not significant and hence data are not presented. A similar correlation analysis was also carried out between the available nutrient concentrations in 0-25, 25-50, 50-75 and 75-100 cm depths and foliar nutrient levels. Among the nutrients studied namely, P, K, Ca, Mg, S, Fe, Mn, Zn, and Cu significant correlations were obtained only for K. Available K content of 0-25 cm soil depth (ammonium acetate extract) was positively correlated with K content of 6th leaf (0.657**) and 14th leaf (0.694**). The correlation coefficients were 0.804** and 0.715** respectively for 6th and 14th leaves when 50-75 cm soil core was considered. Available K content of 75-100 cm depth also yielded positive correlations of 0.611** and 0.731** with the K levels of 6th and 14th leaves respectively. The correlations between available K content of 25-50 cm soil depth and foliar K levels were, however, not significant.

Correlations were also worked out between soil available nutrient concentrations in different depths and yield of nuts. The results are presented in Table 17. The correlations between soil test values

Table 17. Correlation (r) between soil test values and coconut yield

| Soil characteristics | Soil sampling depth (cm) | | | | |
|---|---|---|---|---|---|
| | 0-50 | 0-25 | 25-50 | 50-75 | 75-100 |
| Organic carbon | 0.316* | 0.085 | 0.555* | 0.286 | 0.845** |
| Bray IP | -0.100 | -0.113 | -0.051 | -0.230 | -0.162 |
| Exch. K | 0.093 | 0.506* | 0.218 | 0.520* | 0.717** |
| Exch. Ca | -0.068 | -0.385 | 0.166 | -0.184 | 0.067 |
| Exch. Mg | 0.033 | -0.376 | -0.128 | 0.006 | 0.106 |
| Available S | -0.057 | 0.122 | 0.122 | 0.135 | 0.269 |
| Available Fe | -0.112 | 0.173 | 0.502* | 0.129 | 0.004 |
| Available Mn | 0.087 | -0.096 | -0.122 | -0.222 | -0.166 |
| Available Zn | -0.207 | 0.306 | -0.024 | 0.501* | 0.151 |
| Available Cu | -0.031 | 0.246 | 0.547* | 0.128 | 0.241 |
| | df:52 | df:14 | df:14 | df:14 | df:14 |

* Significant at 5% level

** Significant at 1% level

for 0-50 cm soil depth with yield were not significant. In the case of 0-25 cm depth exchangeable K was positively correlated with yield while available Fe and available Cu in the 25-50 cm depth gave positive correlations with yield. Exchangeable K and available Zn content of the 50-75 cm soil depth were also positively correlated with yield whereas in the case of 75-100 cm soil depth, only exchangeable K showed significant correlation with yield. A positive correlation was also obtained between yield and organic carbon content of 0-50, 25-50 and 75-100 cm soil depths. These results indicate that ammonium acetate extractant is suitable for evaluating the available K status of this soil. The data also suggest that taking 0-50 cm soil core for available K test in coconut garden may not give reliable information on the soil K availability to the palm. Instead soil samples from 0-25 cm depth or from deeper layers below 50 cm would be more suitable for the purpose. It is surprising to note that eventhough 0-25 cm layer do not support active roots, good correlation was obtained between the K content of this layer and foliar K level and yield. Perhaps, it may be because the K concentration of this soil layer might be influencing the concentration of K in the deeper layers. Available Fe and Cu content in the 25-50 cm depth and Zn in the 50-75 cm depth were also correlated with yield. These were considered as chance correlations as the trend was not as consistent as that obtained for K. The results also indicated a positive role of organic matter status almost throughout the profile in increasing the yield. It may be noted that the palms were not receiving any organic matter treatments since planting. Therefore, the changes in organic matter content along the soil profile could be due to the changes in the rate of regeneration and degeneration of the roots over a long period. The positive correlation between soil organic carbon content and yield of the palm thus suggests that higher yielders produce more roots and thus add to the organic matter content of the soil. The relationship between organic matter contents and root activity in various soil zones also strengthens this view (Table 13). Working on the nutritional aspects of uniformly managed coconut palms but ranging in yield from less than five nuts to more than 125 nuts per year, Wahid et al., (1974) observed that there was accumulation of bases especially K and Ca in the basins of high-yielding palms. Probably the organic matter content and hence the exchange capacity of the soil might have been improved due to increased root activity. The present finding also corroborates these results.

## 4.4 Effect of fertiliser application on foliar nutrient levels and yield

The data pertaining to the effect of regular application of NPK fertilisers on nutrient composition of the 6th frond are given in Table 18. The K levels in the foliage was influenced by the levels of added P and K. Application of super phosphate decreased the levels of foliar K content from 2.03 at $P_0$ level to 1.76 per cent at $P_1$ level. Further decrease at $P_2$ level was not observed. On the contrary, application of increasing levels of muriate of potash increased the K content of the leaf steadily from 0.95 ($K_0$) to 2.62 per cent ($K_2$). A reverse trend was observed on Mg levels of the frond as influenced by muriate of potash application. The Mg content decreased from 0.345 to 0.237 per cent with increasing level of potassium. Application of ammonium sulphate increased the Mn content of the leaf while potassic fertilisation decreased it. Eventhough the main effects of N, P and K fertilization were not significant, there was a significant NxP interaction on the N levels of the 6th frond. The highest concentration of N in the leaf was recorded for $N_1P_1$ treatment (Table 19).

The data pertaining to the nutrient composition of 14th leaf as influenced by NPK fertilizer application are given in Table 20. There was a marginal but

Table 18. Nutrient composition of 6th frond as influenced by fertiliser application

| Treatment | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (%) | Cl (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_0$ | 1.01 | 0.125 | 1.98 | 0.216 | 0.280 | 0.098 | 0.699 | 158.3 | 302.1 | 20.32 | 5.77 |
| $N_1$ | 1.10 | 0.132 | 1.95 | 0.251 | 0.258 | 0.098 | 0.809 | 167.0 | 302.0 | 17.51 | 5.47 |
| $N_2$ | 1.04 | 0.125 | 1.66 | 0.264 | 0.305 | 0.096 | 0.734 | 128.7 | 368.6 | 21.06 | 5.93 |
| $P_0$ | 1.04 | 0.121 | 2.03 | 0.232 | 0.253 | 0.103 | 0.747 | 177.0 | 321.1 | 23.63 | 6.13 |
| $P_1$ | 1.04 | 0.127 | 1.76 | 0.243 | 0.302 | 0.056 | 0.769 | 153.8 | 341.8 | 19.79 | 5.18 |
| $P_2$ | 1.08 | 0.133 | 1.81 | 0.255 | 0.290 | 0.092 | 0.727 | 123.2 | 309.7 | 15.46 | 5.86 |
| $K_0$ | 1.07 | 0.121 | 0.95 | 0.267 | 0.345 | 0.101 | 0.692 | 149.6 | 354.1 | 21.99 | 5.88 |
| $K_1$ | 1.05 | 0.133 | 2.03 | 0.228 | 0.265 | 0.095 | 0.786 | 143.7 | 313.2 | 20.73 | 5.88 |
| $K_2$ | 1.04 | 0.127 | 2.62 | 0.235 | 0.237 | 0.096 | 0.764 | 160.7 | 305.4 | 16.16 | 5.40 |
| CD(0.05) | NS | NS | 0.36 | NS | 0.07 | NS | NS | NS | 50.59 | NS | NS |
| SEM(±) | 0.04 | 0.01 | 0.17 | 0.03 | 0.03 | 0.01 | 0.051 | 26.45 | 24.39 | 4.54 | 0.66 |

Table 19. Effect of N x P fertilizer interaction on N content of 6th leaf (%)

| | $P_0$ | $P_1$ | $P_2$ | Mean |
|---|---|---|---|---|
| $N_0$ | 1.020 | 0.907 | 1.115 | 1.014 |
| $N_1$ | 1.115 | 1.157 | 1.032 | 1.101 |
| $N_2$ | 0.990 | 1.042 | 1.098 | 1.043 |
| Mean | 1.042 | 1.035 | 1.081 | |

SEM(±) : 0.030

CD (0.05) for comparison of

Main effect : Not significant

Interaction (N x P) : 0.060

Table 20. Effect of fertilizer application on nutrient composition of 14th leaf

| Treatment | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (%) | Cl (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_0$ | 0.906 | 0.114 | 1.478 | 0.276 | 0.328 | 0.103 | 0.609 | 142.7 | 467.8 | 21.82 | 3.93 |
| $N_1$ | 1.074 | 0.116 | 1.388 | 0.260 | 0.352 | 0.106 | 0.702 | 141.7 | 439.8 | 21.22 | 4.33 |
| $N_2$ | 1.029 | 0.116 | 1.193 | 0.344 | 0.340 | 0.104 | 0.732 | 146.8 | 537.5 | 19.25 | 5.81 |
| $P_0$ | 1.039 | 0.112 | 1.312 | 0.264 | 0.330 | 0.105 | 0.657 | 147.5 | 505.0 | 19.09 | 4.47 |
| $P_1$ | 1.009 | 0.118 | 1.330 | 0.281 | 0.339 | 0.101 | 0.715 | 135.4 | 459.7 | 23.76 | 3.88 |
| $P_2$ | 0.962 | 0.115 | 1.420 | 0.334 | 0.348 | 0.107 | 0.671 | 148.3 | 480.5 | 19.44 | 5.72 |
| $K_0$ | 0.988 | 0.112 | 0.540 | 0.306 | 0.399 | 0.103 | 0.657 | 136.2 | 491.5 | 21.53 | 5.02 |
| $K_1$ | 0.993 | 0.119 | 1.370 | 0.304 | 0.322 | 0.104 | 0.687 | 151.5 | 466.2 | 21.75 | 4.43 |
| $K_2$ | 1.028 | 0.114 | 2.146 | 0.269 | 0.299 | 0.106 | 0.700 | 143.5 | 487.5 | 19.02 | 4.63 |
| CD(0.05) | 0.090 | NS | 0.310 | 0.070 | 0.060 | NS | NS | NS | NS | NS | NS |
| SEM(±) | 0.040 | 0.010 | 0.150 | 0.030 | 0.030 | 0.010 | 0.050 | 14.79 | 39.49 | 4.90 | 0.78 |

significant increase in foliar N level following nitrogen fertilization at $N_1$ level. The N levels in the frond were also influenced by the interaction of applied NK fertilizers (Table 21). The highest N content in the leaf (1.125%) was observed for $N_2K_1$ combination. The levels of K in the leaf steadily increased from 0.54 to 2.15 per cent at the highest level of potassic fertilization (Table 20). The data also indicated a significant increase in Ca concentration of the leaf at $N_2$ level where as Mg content decreased with increasing level of potassic fertilizer. The levels of other nutrients in the frond were not influenced by NPK fertilization.

In coconut, foliar analysis for diagnostic purpose is conducted with samples taken from 14th leaf (Fremond *et al*., 1966). In the present study, 6th frond is also included to represent young stage as younger leaves were found to accumulate more NPK than older leaves (Krishnakumar, 1983). The effect on NPK fertilisation on the nutrient levels of both 6th and 14th leaves were more less same excepting that N levels in the 14th frond was influenced by NxK interaction, where as that of 6th frond was influenced by NxP interaction. This discrepancy, however, cannot be explained with the data generated from the experiment.

Table 21. Effect of N x K fertilizer interaction on N level of 14th leaf (%)

| | $K_0$ | $K_1$ | $K_2$ | Mean |
|---|---|---|---|---|
| $N_0$ | 0.922 | 0.792 | 1.005 | 0.906 |
| $N_1$ | 1.058 | 1.063 | 1.100 | 1.074 |
| $N_2$ | 0.985 | 1.125 | 0.980 | 1.029 |
| Mean | 0.988 | 0.993 | 1.028 | |

SEM($\pm$) : 0.030

CD (0.05 for comparison of

Main effects (N) : 0.090

Interaction (N x K) : 0.060

Eventhough the rate of N application at $N_2$ level was 680 g per palm per year, the absorption of N as revealed by foliar analysis (Tables 18 and 20) was well below the critical level of 1.82 to 2.00 per cent (Fremond *et al.*, 1966). The sandy nature of the soil coupled with high rainfall would have favoured heavy leaching of the applied N resulting in its low recovery in the plant.

The depressing effect of K applied on foliar Mg levels was reported by several workers, (Wahid *et al.*, 1974; Coomans, 1977; and Manicot *et al.*, 1980). The effect of N fertilization to increase Mn content of 6th leaf and a reverse trend in the case of K fertilization may be due to the effect of ammoniacal fertilizer on soil reaction. The absence of such an effect on Mn level of 14th leaf may be explained by the relative immobility of this nutrient in plant system. It is possible that younger leaves may be better suited for studying such effects. It is noteworthy that eventhough the application of ammonium sulphate had led to heavy build-up of soil available S (Table 14 and Fig. 8), the plant has not taken up more sulphate as evidenced from the lack of difference in foliar S level among the N treatments. The effect of K application to increase the K levels in the leaf was also reported by earlier workers (Manicot *et al.*, 1980). The yield of these palms was influenced by NxK interaction, the highest yield being at $N_2K_2$ level of fertiliser application (Table 22). It is surprising to note that even beyond the critical level of 0.8 to 1 per cent K in the 14th frond (Fremond *et al.*, 1966), the palm had responded to K application. The foliar level of K at $K_2$ level of fertilizer application was 2.146 per cent (Table 21). Uexkull (1972) working on K nutrition of coconut in the Philippines noticed that even when the K supply in the soil was adequate, the palms responded to muriate of potash application. This led to the discovery of the importance of Cl nutrition. Muriate of potash is also used as a Cl carrier to coconuts growing especially in the inland areas away from the sea coast (Ollagnier and Ochs, 1971). The importance of Cl nutrition was also confirmed later by other workers (Magat *et al.*, 1975). The results of the present study, however, do not indicate the influence of Cl on yield. This conclusion is based on the lack of improvement in the foliar Cl level following the application of muriate of potash (Tables 18 and 20).

It was further observed that K level in both 6th and 14th leaves were positively correlated with yield of nuts per palm. The 'r' values were 0.500** and 0.544** respectively. None of the other foliar

Table 22. Effect of N x K fertilizer interation on coconut yield (nuts/palm/year)

| | $K_0$ | $K_1$ | $K_2$ | Mean |
|---|---|---|---|---|
| $N_0$ | 6.313 | 19.958 | 23.052 | 16.469 |
| $N_1$ | 2.948 | 36.335 | 42.177 | 27.152 |
| $N_2$ | 3.730 | 48.590 | 60.910 | 37.743 |
| Mean | 4.330 | 34.961 | 42.073 | |

SEM(±) : 2.380

CD (0.05) for comparison of

Main effects : 6.99

Interaction (N x K) : 4.94

nutrients was found to have positive correlation with yield. From the results it may be concluded that K was responsible for the higher yield and that the critical level of 0.8 to 1.0 per cent K in the 14th leaf established by Fremond *et al*., 1966 does not hold good for coconut growing in this region.

The results obtained in this study clearly demonstrate the impact of prolonged application of NPK fertilizers on the chemical characteristics of red sandy loam soil under coconut. Eventhough generalisation of these finding to apply to other soils may not be quite valid, the results do point to the importance of considering soil factors while interpreting the results of long-term fertilization trials in perennial crop gardens. Generally, the effects of fertilizer application on growth and yield of plant are interpreted in terms of the major nutrients(s) contained in the material rather than in terms of the fertilizer material used. Eventhough, the effects manifested are the results of several interactions between the fertilizer material and soil components, plant uptake of other nutrient elements present in the material etc., these factors are generally not taken into account while interpreting the data generated. Perhaps, the often-reported discrepancies in the response of plantation crops to fertilizer application may be due to the difference in the type of fertilizer material used, soil type etc. In view of these, the conclusions drawn from long-term fertilizer trials in perennial crop gardens are more valid and meaningful if based on the fertilizer material used rather than on a specific nutrient(s) contained in them.

# Summary

SUMMARY

An investigation on the chemistry of soil basins of coconut palm (*Cocos nucifera* Linn.) was conducted during 1985-'86 at the College of Horticulture, Vellanikkara. The main objectives of the experiment were to evaluate the lateral and vertical spread of active roots of the palm, to examine the role of active roots in the alteration of the chemical characteristics of the soil basins, to investigate the changes in chemical characteristics of the soil basins in relation to long-term application of inorganic NPK fertilisers, to study the nutritional aspects of the palm as influenced by continuous fertilisation and to evaluate the relationship of common soil test values with nutrition and yield of the palm.

The coconut var. West Coast Tall was invariably used for the study. For root activity studies radio. phosphorus was employed as the tracer and radio-assay of plant samples was done based on Cerenkov counting technique. For the chemical analysis of soil and leaf samples spectrophotometric, flame photometric and atomic absorption spectrophotometric methods were adopted.

The salient findings from these studies are summarised below:

The studies on root activity pattern of coconut revealed that major portion of the active roots reside in an area of 2 m radius around the palm. The vertical distribution of active roots was mainly confined to a depth of 60 cm and the root activity decreased sharply at 90 cm depth. The surface 0-20 cm soil is practically devoid of root activity.

Of the two methods of radiophosphorus application tried in the experiments, soil injection of $^{32}P$ using a field dispenser is less hasarduous than placement of labelled superphosphate in gelatin capsules.

The concentrations of available P, exchangeable K, Ca, extractable Mn, Zn and Cu and per cent base saturation decreased significantly with increasing lateral distance from the palm. Soil pH, organic carbon, exchangeable Mg, available Fe, exchange acidity and CEC were found to be more or less same irrespective of the lateral distance from the palm.

In the case of organic matter and available P, a significant decrease was observed beyond 50 cm depth.

The availability of Mn and Zn remained fairly constant upto 70 cm depth beyond which it decreased. On the other hand, there was a significant increase in available Fe content with increasing soil depth.

Root activity was positively correlated with organic carbon, available P, available K, available Mn and Zn and negatively correlated with exchange acidity. Correlations between root activity and pH, exchangeable Ca, Mg, CEC, per cent base saturation, available Fe and Cu were not significant.

Studies conducted with palms under an existing 22-year-old NPK fertiliser experiment at Coconut Research Station, Balaramapuram revealed that continuous application of ammonium sulphate decreased soil pH markedly from 4.88 in $N_0$ plots to 4.38 in $N_2$ plots. A decrease in available Mn was also observed as a consequence of nitrogen fertilization. However, a reverse trend was observed in the case of available S status of the soil basin.

Long-term application of superphosphate improved available P status of soil from 5.65 ppm in $P_0$ plots to 146.45 ppm in $P_2$ plots. The results of the present study indicated that regular and continuous application of superphosphate could enhance the movement of P into deeper layers consequent on its heavy build-up in the surface layers. Application of superphosphate significantly reduced exchangeable K content of soil, supposed to be due to the replacement of K in exchange sites by Ca of the fertilizer material.

Continuous application of muriate of potash increased the available K content as well as organic carbon content of soil. The effect of exchangeable K in soil is found to be N-dependent as revealed from the significant N x P interaction.

The effect of long term NPK fertilization on the availability of Fe, Zn and Cu as well as Ca and Mg were not found to be significant. Exchangeable Mg and Cu decreased with depth and Fe increased from 20.2 ppm in 0-25 cm soil layer to 35.4 ppm in 75-100 cm soil layer.

Among the soil nutrients, only K was found to be correlated with foliar level. Available K content of 0-25, 50-75 and 75-100 cm soil layers was positively correlated with K levels of 6th and 14th leaves.

The correlations between nutrient concentrations in 0-50 cm layer soil and yield were not significant. However, significant positive correlations were obtained between available K content of 0-25 and

50-75 cm soil layer and yield. Available K gave positive correlation with yield at 75-100 cm soil layer also. Positive correlation was also obtained between organic carbon contents of 0-50, 25-50 and 75-100 cm deep soil layers and yield.

Application of superphosphate decreased the 6th leaf K content from 2.03 at $P_0$ level to 1.76 per cent at $P_1$ level. Application of KCl increased K content steadily from 0.95 at $K_0$ level to 2.62 per cent at $K_2$ level.

The Mg content of the leaves decreased with increasing level of K application confirming antagonism between these two nutrient elements. Foliar Mn levels also decreased with increasing level of K fertilization.

Nitrogen fertilization increased Mn content of the 6th frond. Highest concentration of N in 6th leaf was recorded for $N_1P_1K_0$ treatment.

A steady increase in K content in 14th frond from 0.54 to 2.15 per cent was observed following K fertilization. It was also observed that critical level of K (0.8 - 1.0%) in the 14th frond suggested by Fremond et al. (1966) does not hold good for palms grown in thisarea as response to KCl fertiliser was obtained even beyond this foliar level. Potassium levels in both 6th and 14th fronds showed significant positive correlations with yield whereas correlations with Cl levels were not significant. These results suggest that the field response was due to K contained in the fertilizer and not due to Cl.

The results obtained from the studies help to formulate the following recommendations:

i) For maximum utilisation of applied fertilizer in coconut gardens, application should be done in a circle of radius 2 m around the palm. Evidences suggest that spreading the fertilisers over the area rather than application in basins would be more beneficial to the crop by way of encouraging the roots to explore nutrient-rich surface soil layers

ii) Long-term application of ammoniacal fertilizers induce acidification of soil and help develop sub-soil acidity. This, in turn, leads to erosion of Mn fertility. Further studies on long-term liming is needed to find out ways and means of maintaining and/or restoring the soil pH.

iii) It is suggested that application of phosphatic fertilizers could be skipped for a few years in regularly P-fertilized gardens as considerable build-up of available of P occurs due to this and P application was not found to increase coconut yields.

## ABBREVIATIONS USED

| | |
|---|---|
| °C | : Degree Celsius |
| CD | : Critical difference |
| CEC | : Cation exchange capacity |
| cm | : Centimeter |
| cpm | : Counts per minute |
| cv. | : Cultivar |
| d | : Days |
| df | : Degree of freedom |
| dia. | : Diameter |
| dpm | : Disintegrations per minute |
| g | : Gram |
| ha | : Hectare |
| IAEA | : International Atomic Energy Agency, Vienna |
| KAU | : Kerala Agricultural University |
| Kg | : Kilogram |
| m | : Meter |
| MBq | : Mega bequerel |
| mCi | : Millicurie |
| meq | : Milli equivalents |
| min | : Minutes |
| m rem | : Milli rem |
| MSL | : Mean sea level |
| N | : Normal |
| NS | : Not significant |
| PBS | : Per cent base saturation |
| ppm | : Parts per million |
| r | : Simple correlation coefficient |
| RBD | : Randomised black design |
| SEM | : Standard error of mean |
| Var. | : Variety |
| Viz. | : Namely |
| vs. | : Versus |

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* Originals not seen

# Appendices

## Appendix - I

Data on the growth characteristics of the coconut palms selected for root activity studies

| Growth parameter | Replication | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Height (m) | 3.5<br>(10.0) | 3.0<br>(23.3) | 3.2<br>(18.8) |
| Number of leaves | 24.8<br>(14.5) | 20.9<br>(30.6) | 21.6<br>(25.9) |

Note: Parenthesis denote coefficient of variation in percentage

## Appendix - II

Analysis of variance of log transformed leaf cpm $g^{-1}$ values for the experiment on root activity of coconut (upto 2 m lateral distance)

| Source | Degrees of freedom | Mean sum of squares | | | |
|---|---|---|---|---|---|
| | | 13 | 33 | 50 | 71 |
| Block | 2 | 0.301 | 1.116 | 1.830 | 2.201 |
| Lateral distance | 4 | 0.573 | 1.028 | 1.443 | 0.497 |
| Depth | 2 | 25.551** | 10.327** | 3.464 | 5.105** |
| Interaction | 8 | 0.801 | 0.674 | 0.406 | 0.344 |
| Error | 28 | 2.579 | 1.673 | 1.041 | 0.646 |

** Significant at 1% level

## Appendix - III

Analysis of variance of log transformed leaf cpm $g^{-1}$ values for the root activity of coconut (from 2 to 4 m lateral distance)

| Source | Degrees of freedom | Mean sum of squares | | | |
|---|---|---|---|---|---|
| | | Sampling intervals (days) | | | |
| | | 15 | 33 | 47 | 63 |
| Block | 2 | 5.161 | 1.662 | 1.144 | 1.104 |
| Lateral distance | 3 | 1.964 | 0.979 | 2.458* | 1.371* |
| Depth | 2 | 0.603 | 1.334 | 2.651* | 2.552* |
| Interaction | 6 | 0.587 | 0.080 | 0.232 | 0.292 |
| Error | 22 | 0.975 | 0.438 | 0.666 | 0.438 |

* Significant at 5% level

## Appendix - IV

Analysis of variance for testing significance of soil depth and distance from the palm on soil physico chemical characteristics

| Source | Degree of freedom | Mean sum of squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | pH | Organic carbon | Bray-IP | Exch.K | Exch.Ca | Exch.Mg |
| Block | 2 | 3.66 | 4.54 | 3.26 | 0.01 | 1.19 | 5.34 |
| Lateral distance | 7 | 2.02 | 1.62 | 10.35** | 33.06** | 3.73** | 2.16 |
| Depth | 2 | 2.88 | 21.74** | 10.41** | 1.38 | 0.47 | 0.11 |
| Interaction | 14 | 0.57 | 0.86 | 5.05** | 0.78 | 1.04 | 1.34 |
| Error | 46 | | | | | | |

| Source | Degree of freedom | Mean sum of squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Av. Fe | Av. Mn | Av. Zn | Av. Cu | PBS | Exch. acidity | CEC |
| Block | 2 | 0.41 | 6.43 | 0.20 | 0.20 | 1.66 | 2.45 | 1.39 |
| Lateral distance | 7 | 0.07 | 28.83** | 5.96** | 2.80* | 3.31** | 1.61 | 0.90 |
| Depth | 2 | 7.77** | 10.08** | 17.57** | 2.29 | 0.97 | 0.46 | 0.44 |
| Interaction | 14 | 2.01* | 0.83 | 1.96* | 1.20* | 0.61 | 0.26 | 0.22 |
| Error | 46 | | | | | | | |

* Significant at 5% level
** Significant at 1% level

PBS Per cent base saturation
CEC Cation exchange capacity

## Appendix - V

Analysis of variance for testing significance of fertilization on chemical characteristics of coconut soil of NPK field trial

| Source | Degree of freedom | Mean sum of squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | pH | Organic carbon | Bray IP | Exch. K | Exch.Ca | Exch.Mg |
| Block | 5 | 3.83 | 2.09 | 0.53 | 1.95 | 2.17 | 3.97 |
| Treatments | | | | | | | |
| N | 2 | 15.33** | 3.56* | 0.17 | 9.49** | 0.64 | 0.82 |
| P | 2 | 2.15 | 0.16 | 42.41** | 5.09* | 0.52 | 0.66 |
| K | 2 | 2.62 | 7.16** | 1.86 | 24.77** | 0.59 | 0.24 |
| NP | 4 | 0.35 | 0.52 | 0.62 | 1.60 | 0.82 | 1.70 |
| NK | 4 | 0.87 | 0.29 | 0.80 | 4.68** | 0.89 | 0.87 |
| PK | 4 | 0.09 | 1.37 | 0.78 | 1.88 | 0.33 | 0.76 |
| Error | 22 | | | | | | |

| Source | Degree of freedom | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | Avail.S | Avail.Fe | Avail.Mn | Avail.Zn | Avail.Cu |
| Block | | 2.92 | 2.96 | 0.82 | 0.97 | 3.30 |
| Treatments | | | | | | |
| N | 2 | 8.21** | 1.30 | 4.68* | 2.94 | 1.15 |
| P | 2 | 0.06 | 1.23 | 0.62 | 0.79 | 1.30 |
| K | 2 | 1.71 | 0.54 | 0.18 | 0.38 | 0.15 |
| NP | 4 | 0.36 | 0.22 | 0.18 | 0.25 | 1.61 |
| NK | 4 | 0.35 | 0.34 | 0.20 | 1.31 | 0.50 |
| PK | 4 | 0.69 | 1.05 | 0.59 | 0.34 | 0.39 |
| Error | 22 | | | | | |

* Significant at 5% level

** Significant at 1% level

## Appendix - VI

Analysis of variance showing significance of effect of depth on soil chemical characteristics (NPK field trial)

| Source | Degree of freedom | Mean sum of squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | pH | Organic carbon | Bray IP | Exch.K | Exch.Ca | Exch.Mg |
| Block | 1 | 5.41 | 3.48 | 0.12 | 3.96 | 3.59 | 1.16 |
| Treatment | 7 | 29.41** | 2.08 | 4.19** | 13.28** | 2.21 | 3.31* |
| Depth | 3 | 11.65** | 28.23 | 5.15** | 2.17 | 1.63 | 2.90 |
| Interaction | 21 | 0.30 | 0.59 | 1.15 | 1.42 | 0.49 | 1.90* |
| Error | 31 | | | | | | |

| Source | Degree of freedom | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | Avail.S | Avail.Fe | Avail.Mn | Avail.Zn | Avail.Cu |
| Block | 1 | 3.63 | 4.96 | 39.12 | 1.38 | 0.09 |
| Treatment | 7 | 11.78** | 1.35 | 20.68** | 1.60 | 1.37 |
| Depth | 3 | 47.39** | 20.59** | 9.62 | 0.74 | 3.10 |
| Interaction | 21 | 0.30 | 1.36 | 0.36 | 0.68 | 1.20 |
| Error | 31 | | | | | |

* Significant at 5% level

** Significant at 1% level

Appendix - VII

Analysis of variance for testing significance of effect of NPK treatment on nutrient levels of sixth leaf (NPK field experiment)

| Source | Degree of freedom | Mean sum of squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | N | P | K | Cl | Ca | Mg |
| Block | 5 | 8.04 | 0.62 | 2.38 | 1.17 | 1.38 | 0.53 |
| Treatments | | | | | | | |
| N | 2 | 2.09 | 0.70 | 2.04 | 2.42 | 1.18 | 1.09 |
| P | 2 | 0.67 | 1.60 | 1.38 | 0.35 | 0.24 | 1.28 |
| K | 2 | 0.20 | 1.36 | 47.50** | 1.88 | 0.79 | 6.30** |
| NP | 4 | 2.85* | 0.91 | 0.99 | 0.13 | 1.62 | 0.41 |
| PK | 4 | 1.19 | 0.54 | 1.02 | 0.55 | 0.32 | 0.77 |
| NK | 4 | 0.17 | 1.78 | 1.15 | 0.31 | 0.49 | 0.13 |
| Error | 22 | | | | | | |

| Source | Degree of freedom | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | S | Fe | Mn | Zn | Cu |
| Block | 5 | 0.29 | 1.19 | 0.46 | 0.94 | 4.33 |
| Treatments | | | | | | |
| N | 2 | 0.02 | 1.15 | 4.96* | 0.34 | 0.26 |
| P | 2 | 0.59 | 2.08 | 0.89 | 1.62 | 1.11 |
| K | 2 | 0.22 | 0.21 | 2.30 | 0.91 | 0.36 |
| NP | 4 | 0.06 | 1.43 | 0.44 | 0.61 | 2.15 |
| PK | 4 | 0.86 | 1.00 | 0.30 | 0.74 | 0.28 |
| NK | 4 | 0.24 | 0.58 | 0.71 | 0.38 | 0.95 |
| Error | 22 | | | | | |

* Significant at 5% level
** Significant at 1% level

## Appendix - VIII

Analysis of variance for testing significance of effect of NPK treatment on nutrient levels of 14th leaf (NPK field experiment)

| Source | Degree of freedom | Mean sum of squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | N | P | K | Cl | Ca | Mg |
| Block | 5 | 4.38 | 1.62 | 3.09 | 0.48 | 0.36 | 1.06 |
| Treatments | | | | | | | |
| N | 2 | 8.46** | 0.02 | 1.92 | 3.30 | 4.01* | 0.30 |
| P | 2 | 1.69 | 0.33 | 0.28 | 0.75 | 2.63 | 0.12 |
| K | 2 | 0.54 | 0.43 | 57.80** | 0.40 | 0.87 | 6.06** |
| NP | 4 | 2.47 | 0.60 | 1.87 | 0.72 | 0.66 | 0.44 |
| PK | 4 | 3.29* | 1.45 | 2.34 | 0.15 | 1.00 | 0.55 |
| NK | 4 | 1.45 | 0.60 | 0.26 | 0.38 | 0.56 | 1.60 |
| Error | 22 | | | | | | |

| Source | Degree of freedom | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | S | Fe | Mn | Zn | Cu |
| Block | 5 | 0.80 | 2.04 | 1.90 | 0.38 | 1.17 |
| Treatments | | | | | | |
| N | 2 | 0.03 | 0.07 | 3.25 | 0.15 | 3.20 |
| P | 2 | 0.20 | 0.48 | 0.66 | 0.56 | 2.88 |
| K | 2 | 0.05 | 0.54 | 0.24 | 0.19 | 0.29 |
| NP | 4 | 0.14 | 0.31 | 0.46 | 0.87 | 1.39 |
| PK | 4 | 0.83 | 0.28 | 0.52 | 0.57 | 0.20 |
| NK | 4 | 0.08 | 0.16 | 0.95 | 0.62 | 0.42 |
| Error | 22 | | | | | |

* Significant at 5% level
** Significant at 1% level

## Appendix - IX

Analysis of variance for testing significance of effect of fertiliser application on average yield per palm per year (NPK field experiment)

| Source | Degrees of freedom | Mean sum of squares |
|---|---|---|
| Block | 5 | 139.73 |
| Treatment | | |
| N | 2 | 2036.67** |
| P | 2 | 194.76 |
| K | 2 | 7240.02** |
| NP | 4 | 227.46 |
| NK | 4 | 680.22** |
| PK | 4 | 157.63 |
| Error | 22 | 102.27 |

** Significant at 1% level

# CHEMISTRY OF COCONUT RHIZOSPHERE

By

**ANILKUMAR, K. S.**

**ABSTRACT OF A THESIS**

submitted in partial fulfilment of
the requirement for the degree

**Master of Science in Agriculture**

Faculty of Agriculture
Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry
COLLEGE OF HORTICULTURE
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ABSTRACT

An investigation on the root activity pattern of coconut palm (*Cocos nucifera* Linn.) and the influence of long term application of NPK fertilisers was conducted at the College of Horticulture, Vellanikkara. The coconut variety West Coast Tall was invariably used for the study.

It was found that major portion of the active roots of coconut were within an area of 2 m radius around the palm. The vertical distribution of active roots was mainly confined to a depth of 30-60 cm and the root activity decreased sharply at 90 cm depth. The surface 25 cm soil layer is practically devoid of roots. Based on these results it is suggested that the fertilizers may be applied to an area of 2 m radius around the palm for their maximum utilization.

Root activity was positively correlated with organic carbon, available P, available K, available Mn and Zn and negatively correlated with exchange acidity.

Studies on the effect of long term NPK fertilization on soil chemical characteristics revealed that regular application of ammonium sulphate reduced the

soil pH markedly (from 4.88 in $N_0$ plots to 4.38 in $N_2$ plots). A decrease in available Mn and an increase in available S also observed with continuous N fertilization.

Continuous P fertilization, improved available P status of soil from 5.65 ppm in $P_0$ plots to 146.45 ppm in $P_2$ plots. Heavy build up of available P also noticed in lower layers with continuous P fertilization. Application of superphosphate reduced K status of soil probably due to replacement by Ca in exchange sites.

Continuous application of muriate of potash increased the available K content as well as organic carbon content of soil. The effect on exchangeable K in soil is found to be N-dependent as revealed from the significant N x K interaction.

Significant positive correlations were observed between soil available K in the 0-25, 50-75 and 75-100 cm depths and the levels of K in 6th and 14th fronds. Available K in the 0-25, 50-75 and 75-100 cm soil layers is positively correlated with yield. Organic carbon at 0-50, 25-50 and 75-100 cm soils depths also showed positive correlation with yield

Among the micronutrients studied Fe and Cu (25-50 cm soil layer) and Zn (50-75 cm soil layer) showed positive correlations with yield.

Foliar Mg and Mn levels decreased with increasing rates of K fertilization, while N fertilisation increased foliar Mn content. Nitrogen fertilisation also increased foliar N and Ca contents.

Potassium levels in 6th and 14th fronds showed significant positive correlations with yield ('r' values 0.500** and 0.544** respectively). The critical K level found by Fremond *et al.* (1966) (0.8 to 1.0%) need a revision as significant yield increase was observed even at foliar K levels of 2.15 to 2.62 ppm in 14th and 6th leaf respectively of the experimental palms.