STANDARDISATION OF SOIL SAMPLING AND FERTILIZER RECOMMENDATION TECHNIQUES FOR COCONUT GARDENS

By

E. F. NIMBA FRANGO

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 654

1998

DECLARATION

I here by declare that this thesis entitled **"Standardisation of soil sampling and fertilizer recommendation techniques for coconut gardens"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other university or society.

Vellanikkara
4-5-98

Nimba

E.F. NIMBA FRANGO

C.S.GOPI
Associate Professor
Department of Soil Science and
Agricultural Chemistry
College of Horticulture

Vellanikkara
4 - 5 -1998

CERTIFICATE

Certified that the thesis entitled "**Standardisation of soil sampling and fertilizer recommendation techniques for coconut gardens**" is a record of the research work done independently by **Ms.E.F. Nimba Frango,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

C.S. Gopi
Chairman, Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms.E.F. Nimba Frango**, a candidate for the degree of **Master of Science in Agriculture**, with major in **Soil Science and Agricultural Chemistry**, agree that the thesis entitled **"Standardisation of soil sampling and fertilizer recommendation techniques for coconut gardens"** may be submitted by Ms.E.F. Nimba Frango, in partial fulfilment of the requirement for the degree.

C.S.Gopi
Associate Professor
Dept. of Soil Science & Agricultural Chemistry
College of Horticulture, Vellanikkara
(Chairman)

Dr.A.I.Jose
Associate Dean
College of Horticulture
Vellanikkara
(Member)

Dr.V.K.G. Unnithan
Associate Professor
Dept. of Agricultural Statistics
College of Horticulture
(Member)

Dr.K.C.Marykutty
Associate Professor
Dept. of Soil Science &
Agricultural Chemistry
College of Horticulture
Vellanikkara
(Member)

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

*I express my deep sense of gratitude to **Sri.C.S. Gopi**, Associate Professor, Department of Soil Science and Agricultural Chemistry, College of Horticulture, Vellanikkara and Chairman of my Advisory Committee for his personal attention, valuable guidance and timely suggestions rendered to me during the course of my research work and preparation of this thesis.*

*Let me place on record my sincere thanks to **Dr.A.I.Jose**, Associate Dean and Former Head of Department of Soil Science and Agricultural Chemistry, College of Horticulture, Vellanikkara for his keen interest and timely suggestions during the course of my research work.*

*I am grateful to **Dr.K.C.Marykutty**, Associate Professor, Department of Soil Science and Agricultural Chemistry and member of my advisory committee for her support, suggestions and good help.*

*My sincere thanks are due to **Dr.V.K.G.Unnithan**, Associate Professor, Department of Agricultural Statistics and member of my advisory committee for the valuable suggestion received during the preparation of thesis.*

*With all regards I acknowledge the kind and generous help provided whole heartedly by **Dr.N.N.Potti**, Professor, Department of Agronomy during the prepartion of the thesis. Without his utmost patience, willingness to understand, valuable suggestions and constructive criticism, this venture would not have been completed successfully. I thank him sincerely.*

*I wish to place on record my indebtedness to **Sri.S.Krishnan**, Assistant Professor, Department of Agricultural Statistics for the valuable help rendered to me during the statistical analysis of the data.*

The good help and cares extended to me from all the staff members of the Department of Soil Science and Agricultural Chemistry is gratefully acknowledged.

I do take this opportunity to thank sincerely the labourers whose assistance and co-operation helped me in the preparation of soil as well as leaf samples for analysis.

No word can truly express my deep sense of gratitude for the help, suggestions and encouragement provided to me by all friends. I thank each and every one of them.

My sincere thanks are due to Sri.Joy, Sri.Jayan, Smt.Mary, Kum.Preeja and Sri.Mohanlal for their prompt service.

The award of ICAR Junior Research Fellowship during the period of my study is gratefully acknowledged.

I am always indebted to my beloved parents, sister, brother and in-laws for their constant encouragement. Their faith and confidence in me made me complete this programme.

At this moment I recall with love and gratitude for the sincere support given to me by my beloved husband. He bore up with me against all the misfortune and was always been a source of inspiration to me. His unfailing patience willingness to understand constant encouragement and sustained interest made me realize this dream. My heartfelt thanks ever remains with him.

Above all I bow my head before God Almighty who blessed me with good health, courage and confidence for the successful completion of the work.

Nimba

E.F. NIMBA FRANGO

In loving memory of
my son

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

INTRODUCTION

In a developing country like India, where the population pressure is continuously increasing, it is being increasingly realised that the land and water resources are limited and the wise use of the same is imperative. Following the introduction of high yielding varieties and hybrids, the emphasis has been on intensification and diversification so as to enhance productivity without caring sustainability which has ultimately resulted in the reduction of soil health by excessive mining of native fertility. It should be noted that different crops or varieties may react differently to varying levels of mineral elements in soil. Therefore, balanced and efficient use of fertilizer is necessary to prevent the removal of soil nutrients by intensive cultivation.

For rational nutrient management, a knowledge of the fertility status and physical properties of soil is essential. It is generally agreed that root development and plant growth are related to the aeration of the soil for which the role of different fractions of soil has to be explored for calibrating a suitable crop specific soil testing programme. One of the most popular methods of determining the soil fertility status practised in our state is soil testing. Infact, soil testing is an essential part of any scheme of agricultural development. Since soil tests and interpretations are based on the samples analysed, care should be taken to see that the soil samples are properly collected and should represent the zone of nutrient absorption.

The soil sampling procedure now practised by the soil testing laboratories is oriented towards giving fertilizer recommendations for rice, by sampling the top 15 cm layer of soil. This method may not be suitable for perennial crops having different rooting pattern and grown under diverse soil and management conditions. The extent and spread of the effective root system determine the soil volume tapped in the feeding zone of the crop plant. Similarly in the traditional method of soil testing the physical properties of the soil are not taken into account.

Therefore, an earnest attempt is made in this study to standardise the soil sampling technique for a perennial crop like coconut, and to work out fertilizer recommendation system considering physical/textural nature of the soil as well as the nutrient level, based on correlation with plant uptake values.

Review of Literature

2. REVIEW OF LITERATURE

India is the third largest coconut producing country in the world and as much as 56 per cent of the area under coconut in India is concentrated in Kerala. While research aimed at improving productivity of this oil seed crop started more than 60 years ago, it is only in the last couple of decades that considerable progress has been made. Apart from superior genetic material and efficient crop management, appropriate nutrient application is important. For this, a knowledge about the rooting pattern, nutrient dynamics in soil with respect to depth and season, its relation to plant uptake and yield is essential. A brief review on these aspects is presented below.

2.1 Root activity pattern of coconut

In a perennial crop like coconut which yields throughout the year, a general knowledge of the root distribution, the location where maximum active roots occur and suitable zone for fertilizer application is of paramount importance.

Studies conducted by Magnaye (1969) in healthy and cadang-cadang affected coconut palms grown on a sandy loam soil showed that most of the primary and secondary roots were within 30 - 90 cm depths.

Kushwah et al. (1973) from their studies on the root distribution of coconut concluded that palms receiving regular cultivation and manuring produced the highest number of roots. They also found that 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 90 cm soil depth.

Results of the experiments on the root activity pattern of fifteen and sixty year old coconut trees (Tall variety) in Philippines in the wet and dry seasons were reported by IAEA in 1975. The zone of the highest root activity was within 1-2 m radial distance from the palm and up to 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 as well as in wet season in Sri Lanka, but activity at lower depths and greater distance was relatively higher in dry season.

The traditional method of studying root distribution is limited in scope because it can only give a picture of total root distributions without distinguishing active, dormant and dead roots. Isotope technique in contrast offer a quick and reliable means of determining the distribution pattern of plant roots.

From a study on the root activity pattern of coconut in Sri Lanka employing ^{32}P, Balakrishnamurthy (1971) suggested that maximum uptake occurred 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.

Studies conducted in Sri Lanka using radiotracer on the efficiency of fertilizer utilization by coconut palms had shown that nutrient uptake was maximum from a lateral distance of 50 cm. A decrease was observed with increase in lateral distance. Activity was very high within a radius of 2 m and within a depth of 10 - 45 cm (IAEA, 1975)

The root activity studies conducted at the Kerala Agricultural University using radiophosphorus on coconut variety West Coast Tall, grown in laterite soil, revealed that the major portion (82.5%) of the active roots reside in an area of 2 m around the palm. The vertical distribution of active roots mainly confined to a depth of 60 cm (84.8%) and the root activity decreased sharply at 90 cm depth. The surface 0 - 20 cm soil is practically devoid of root activity (Anilkumar, 1987)

2.2 Nutrient dynamics in soil

2.2.1 Available N

Nair (1977) in his studies on rice growing soil of Wyanad reported that organic matter content of surface samples ranged from 0.4 to 3.8 per cent while in profile samples, there was a marked trend to decrease with depth.

Bastin (1985) reported that organic carbon content of red soil of Kerala ranged from 0.17 to 0.74 per cent and decreased steadily with depth in the profile.

Sood and Kanwar (1986) studied the distribution of organic carbon in some soil profiles of different agroclimatic zones of Himachal Pradesh and found that organic carbon content decreased with increase in depth.

Studies on organic carbon content of both upland and wetland soils of Edamalayar Command Area revealed a steady decrease in organic carbon with depth (Krishnakumar, 1991).

Ramdas (1970) obtained a high correlation between organic carbon and nitrogen.

Reports of Singh and Brar (1973) revealed the higher correlation values of organic carbon percentage with nitrogen uptake and yield compared with the available nitrogen content of soil. They showed that organic carbon content is a better index of available nitrogen.

Ghosh and Hassan (1980) also reported organic carbon as the index of available nitrogen.

Raychoudhury and Anantharaman (1960) found that in Indian rice soils nitrogen decreased with increase in depth in the profile.

Hassan (1977) observed a decrease in total nitrogen with depth and paralleled with organic carbon content.

Gupta *et al.* (1989) studied the profile distribution of various forms of soil nitrogen and arrived at a conclusion that organic carbon was relatively more in surface soil samples and it sharply decreased in 15-30 cm layers in all the plots.

Singh and Ahuja (1990) in a study to find the distribution of nutrients in the Ghaggar river basin found that surface horizons are rich in available nitrogen which decreased with depth.

According to Singh *et al.* (1992) total, organic and fixed ammonia nitrogen decreased with depth in the soil profiles of Haryana.

2.2.2 Available P

Karim and Khan (1956) in a study on the vertical distribution of nutrients in the soils of East Pakistan found that phosphorus increased up to a depth of 17.5 cm and then decreased sharply up to 8.75 cm.

Studies conducted on the vertical distribution of total and available P in some typical soil profiles of Gujarat showed that the top soil was richer than subsoil in total and available P (Patel and Mehta, 1962).

Investigation of Chibba and Sekhon (1985) revealed that available P showed no definite trend with depth.

Sood and Kanwar (1986) studied the distribution of organic and total P in some soil profiles of Himachal Pradesh and found that organic carbon, organic P and total P content decreased with increase in depth. They also reported that the decrease in organic P with soil depth might be due to its association with organic matter.

Singh and Ahuja (1990) reported that maximum accumulation of available P was in the surface layers which decreased with depth.

Dongale (1993) in his studies to find out the distribution of different forms of P in laterite soils of coastal region found that total, organic and reductant soluble P decreased in the solum.

Investigations of Viswanatha and Doddamani (1993) in the soils of Karnataka revealed that saloid P, organic P and total P decreased with depth.

2.2.3 Available K

In the red soils of Coorg, the percentage of total K increased from the surface soil up to parent material except in the second horizon and in the red soils of Madurai the total K content increased with increasing depth from 2.06 to 2.67 per cent (Mosi, 1960).

Raychaudhury and Reddy (1963) studied the fertility status and productivity potential of some red soils of Bangalore and found that K_2O content was high in the surface which increased with depth indicating the accumulation of clay fraction containing potash bearing minerals.

Balaguru (1970) reported an increase in the total K content with increase in depth for red alluvial soils of Tamil Nadu.

Kadrekar (1973) observed that contents of exchangeable, available and water soluble forms of K in acid soils declined with depth of the profile.

Nair (1973) found that the total K_2O content of red soils of Kerala varied from 0.92 to 1.44 per cent for the surface samples and from 0.87 to 1.37 per cent for sub-surface sample.

Ekambaran *et al.* (1975) observed that water soluble and exchangeable K decreased with increase in depth of soil profile.

Investigations of Chibba and Sekhon (1985) revealed that available K was high in the surface soil.

Brar and Sekhon (1987) studied the vertical distribution of K in the five bench mark soil series in North India. The vertical distribution of K in the profile can differ depending upon the relative effect of different factors such as texture, organic carbon content, application of K fertilizers, upward movement of soil K due to capillary rise. Most of the variations in the vertical distribution of K in different profile in the study could however be attributed to texture and organic carbon.

Singh and Ahuja (1990) studied distribution of primary nutrients in Ghaggar river basin and found that K_2O content was high in the surface profiles which decreased with depth.

Study on the distribution of different forms of K in profiles of Entisols by Pal and Mukhopadhyay (1992) brought out that there was no definite pattern of distribution of K in the profile.

2.2.4 pH

Hameed (1975) reported that pH of kole soils decreased with depth.

According to Raguraj (1981) the pH of profiles ranged from 6.0 to 10.1 in red soils and 3.4 to 6.3 in laterite soils of Madurai district. The low pH in laterite soil was attributed to the high organic matter content and also to the leaching of bases. The pH of the surface soil was high compared to the sub-surface layer.

2.2.5 Electrical conductivity

Sampath (1987) reported that electrical conductivity remained low without any change in depth in red and laterite soils of Tamil Nadu.

In laterite soils of Kerala, electrical conductivity was very low and showed little variation within the profile and between soils from different profiles (Deepa, 1995).

Kurup and Aiyer (1973) in their studies in kari, karappadam and kayal soils found that both pH and EC registered maximum values when sampled in October - November and minimum values in March - April.

2.3 Particle size distribution of soil

Parthasarathy (1959) reported that the amount of clay in soil influences many of the physical constants of soil. He also obtained a negative correlation between clay and coarse and fine sand.

According to Queiroz (1963) sand fraction in seven profiles under study decreased with depth. Within the sand fractions, coarse sand decreased and fine sand increased down the profile. The increase of fine particles was attributed to the migration of soil particles with the gravity water.

Nair *et al.* (1966) reported that in cultivated soils of Kerala, true specific gravity, apparent specific gravity and available P and K appeared to be a function of the coarser particles of the soil while water holding capacity, pore space, volume expansion and organic carbon were related to the finer particles of the soil.

Rajagopalan (1969) observed an increase in the coarse sand and clay fractions with depth in a red soil profile at Patchallor in Kerala. Silt and fine sand contents decreased with depth.

Gopalaswamy (1969) observed a decrease in the sand fractions with the depth of soil profile.

Investigations of Sharma *et al.* (1980) revealed that clay content was negatively but significantly correlated with bulk density whereas silt showed no correlation with bulk density.

Ushakumari (1983) reported that soils of Kerala exhibited an appreciable variation in texture ranging from clay to loam. The laterite and red loams were very similar in texture and all types of soils exhibited a downward migration of clay.

Tomar (1987) based on his study in soils of Indo-Gangetic alluvial plains reported that the clay content tended to decrease with depth.

Miura *et al.* (1992) reported that in paddy soils of North-Eastern Thailand clay content gradually decreased with depth.

Singh *et al.* (1993) reported a gradual increase in bulk density (1.35 to 1.4 g cm^{-3}) with depth in low land soils in Kulu valleys of Himachal Pradesh indicating a progressive compaction due to filling of pores by eluvial materials.

2.4 Seasonal variation of nutrients in soil and plants

Heyn *et al.* (1992) studied soil sampling time, depth and drying methods relationships in one year field trial with sugarbeet and winter wheat to improve nitrogen fertilizer recommendation. Spring sampling gave markedly better results in sugarbeet while autumn sampling was mostly acceptable for winter wheat.

Wahid *et al.* (1975) observed no regular pattern of variation in available nitrogen content in soil in different months while a steep fall in exchangeable K with the commencement of monsoon.

Liebhardt and Teel (1977) studied the fluctuation in soil test values for K as influenced by time of sampling. Results revealed that month of sampling, significantly affected K soil test values, which were highest in late May and declined as the growing season progressed, remained low until the relatively higher exchangeable K was re-established in the following spring.

Muliyar and Wahid (1973) observed a decrease in available P content of soil with the onset of rains due to the fixation by newly formed hydrated oxides of iron and aluminium. Subsequent increase in available P resulted due to the release of fixed P when the soil become dry. These results were in conformity with the results obtained by Wahid *et al.* (1975).

Changes of soil P by leaching associated with precipitation were found to be determined by clay content. Leaching of P was found to be nil from soils having a clay content of 23.8 and 18.4 per cent clay but P leaching was there in soils having 8.4 per cent clay (Sharma, 1992).

Wahid *et al.* (1975) reported that a general improvement of leaf N, P and K occurred after the onset of rains.

Generally leaf nitrogen declined with the onset of the monsoon and increased following fertilizer application in September. Leaf K levels increased until December and decreased thereafter whereas Ca and Mg increased after

December. Leaf P increased slightly while S and Fe decreased during rainy season. Ca and Mg levels were little affected by the season. Na fell to its lowest level in September and increased thereafter (Wahid *et al.*, 1981).

Ziller and Prevot (1961) reported that in Dahamey the rain water collected under the coconut palm was richer in K than water falling directly from the sky.

Nye (1961) reported an annual loss of 219.5 kg K, 29.1 kg Ca, 17.9 kg Mg, 3.7 kg P, 9.0 kg NO_3N and 3.4 kg NH_4N per hectare from forest vegetation with annual rainfall of 1,562 mm.

Cecil and Pillai (1973) computed the annual losses of nutrient elements by leaching from a hectare of 170 coconut trees with an annual rainfall of 2,500 mm and the results were as follows: 85.0 kg K, 74.0 kg N, 32.1 kg Na, 25.0 kg Ca, 8.7 kg Mg and 2.9 kg P.

2.5 Mineral nutrition of coconut palm

Coconut palm removes large quantities of nutrients from the soil continuously. This progressive removal of nutrients eventually depletes the soils of its nutrient resources unless replenished through a sustained programme of balanced manuring, coupled with other improved agronomic practices.

Nathanael (1969) outlined the conceptual basis to assess the nutrient requirement of the coconut palm by the equation

$$F = R - S + L$$

where, F is the quantity of fertilizer nutrient, R is the quantity of nutrient recovered by the crop for unrestricted growth, S is the quantity of nutrient supplied by the soil and L is that portion of the fertilizer nutrient not utilised by the crop plant.

Wahid and Nambiar (1978) developed Nutrient Uptake Index (NUI) that permits comparison of removal of a nutrient by coconut palms at any given stage of growth before bearing. NUI for a given nutrient is arrived at by multiplying the nutrient concentration (per cent) with the number of leaves present at the time of sampling.

A number of workers estimated removal of nutrients by middle aged, bearing palms and have obtained widely varying values. This is probably due to variation in agroclimatic conditions, management practices, varietal differences etc. Eventhough the differences in absolute values between the authors are large, there is a lot of agreement in the pattern of exhaustion. The sequence of importance of the nutrients for coconut palm was K > Cl > N > Ca > Na > Mg > S > P. It is quite evident that the dominant requirement of the palm is K while P is the least, in quantity required.

Pillai and Davis (1963) worked out the quantity of nutrients removed by a single West Coast Tall palm yielding 40 nuts and producing 13 leaves per year. The data was given as follows: N - 321 g, P - 69 g, K - 406 g, Ca - 196 g and Mg - 72 g.

Nathanael (1969) reported that single middle aged palm of tall variety removed 0.59 kg N, 0.26 kg P_2O_5 and 0.85 kg K_2O annually when the yield was about 40 nuts per year. If the mean yield was around 60 nuts, the palm removed 0.72 kg N, 0.33 kg P_2O_5 and 1.08 kg K_2O per year.

Studies conducted by Ouvrier and Ochs (1978) revealed that nutrient removal by the hybrid PB-121 was exhaustive.

Marar and Pandalai (1961) reported that the effects of N and K were equal and additive.

Eden *et al.* (1963) discussed coconut nutrition and requirement in relation to soil conditions existing in Sri Lanka and reported that the only main effect which had shown statistical significance was that of K.

Mathew and Ramadasan (1964) reported that N had a significant effect on all growth characters of young palms in the initial stage; P increased girth at collar and number of fronds produced and the effect was reported to be indirect by enhancing the uptake of K, while the application of K increased girth at collar only.

Mathai *et al.* (1979) found out significant increase in the mean number of leaves produced due to fractional application of NPK.

Loganathan and Balakrishnamurthi (1980) reported that N increased girth, height and leaf production during the pre - bearing period, but P (up to 6½ years) and K (up to 3½ years) had no effect on any vegetative growth parameters in an NPK field experiment in Sri Lanka.

Muliyar and Nelliyat (1971) found that for palms yielding less than 60 nuts annually, the optimum dose of N ranged between 400 and 600 g with a mean of 480 g and that of K ranged between 890 and 1210 g per palm per year.

Nelliyat (1972) suggested that the adult palm dosage should be given to young palm from the third year onwards. He also suggested that once the seedlings are planted in the main field, about one-tenth of the adult palm dosage may be applied after three months, one-third after one year, two-third after 2 years and full dosage thereafter.

2.6 Relationship between soil nutrients, plant nutrients and yield

Generally the suitability of soil test method is judged by obtaining a simple correlation coefficient between the soil test values and yield/nutrient uptake. Many workers have studied such relationships.

2.6.1 Relationship between soil nutrient and plant nutrient

Ollagnier *et al.* (1970) have reported that leaf nitrogen content of oil palm increased from 2.3 to 2.7 per cent by nitrogenous fertilizer application.

Warrier and Piggot (1973) claimed to have found a high concentration of tissue N in fertilized plots of oil palm. In the absence of K fertilizers leaf K content was low and tissue concentration increased when KCl was applied. They also observed low tissue P content when P fertilizers were not applied.

Biswas *et al.* (1987) got positive correlation between organic carbon content of surface soil and foliar nitrogen content of mango trees.

In coconut N fertilization tended to increase leaf K and Ca levels but decreased the Na and Mg levels. N and K fertilization increased foliar Ca and Mg levels but depressed K and Na (Felizardo, 1965).

Wahid *et al.* (1974) in one of their experiment got significant positive correlation between soil and leaf K in coconut. Na correlated negatively with their concentration in leaf, though not significant.

Withholding fertilizer application to coconut for one year lowered foliar N and K levels significantly, but not P levels (Wahid *et al.*, 1975).

Devi and Velayudhan (1977) observed maximum concentration of N,P and K in 14th leaf of coconut immediately on 2nd and 5th day of fertilizer application.

Gopi (1981) found that coconut palms receiving higher levels of N and K fertilizers had high foliar N and K contents, while P fertilizers gave only a marginal increase in foliar P levels.

Krishnakumar (1983) reported that application of N, P and K fertilizers resulted in an increase in the content of these nutrients in the 2nd, 10th and 14th leaves.

Loganathan and Atputharajah (1986) observed that muriate of potash increased leaf K and Cl but decreased leaf Ca and Mg. Ammonium sulphate generally increased leaf N and Ca but decreased leaf K and Cl in coconut.

2.6.2 Relationship between leaf nutrients and yield

Ollagnier *et al.* (1970) reported a yield increase of 5 per cent when leaf N concentration was raised from 2.3 per cent to 2.7 per cent in coconut.

Indirakutty and Pandalai (1968) observed a general increase in foliar nutrient content of N, P_2O_5 and K_2O with increase in yield of coconut palm.

Devi and Pandalai (1968) found that foliar nitrogen, phosphoric acid, potash, iron and manganese were found to be positively correlated to the yield of coconut.

Molleguard (1971) found some correlation between soil P content with yield and levels of this element in leaf tissue of oil palm.

Studying the relationships among root CEC, yield and mono and divalent cations in coconut, Wahid *et al.* (1974) reported a positive correlation of both soil and leaf K contents with yield indicating the role of K in increasing the yield of coconut.

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

Apacible (1974) showed that with application of KCl, the chlorine content of leaf markedly changed and content was also highly correlated with yield. Thus he assumed that, response to KCl was actually due to chlorine and not due to potassium.

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

Kanapathy (1977) in a study on dwarf coconut palm showed that there was no yield response to P fertilization.

Teffin and Quencez (1980) made a detailed study of the importance of Cl for coconut and found that K and Cl having positive correlation with yield.

Gopi and Jose (1983) recommended the second leaf as the best for the simultaneous detection of N and K, since they observed maximum correlation between yield and the content of N and K in this leaf. According to their work, the yield was best correlated with the N content of the 10th leaf followed by the 2nd leaf. In the case of K, maximum correlation was obtained between yield and the K content of second leaf. The P content was not correlated significantly with yield, irrespective of the leaf position.

According to Krishnakumar (1983) yield of the palms was significantly correlated with N per cent of leaf lamina. The partial correlation coefficients between yield and the P per cent of 2nd, 10th and 14th leaves were not significant .

The coefficients of partial correlation between yield and K contents of 2nd and 10th leaves were significant.

Ochs *et al.* (1991) reported that in oil palm for a natural leaf content of 1 per cent or more, K application made no measurable improvement. For contents between 0.9 and 1 per cent the production increase to be expected was low. Below 0.9 per cent, the effectiveness and profitability of K fertilization was demonstrated beyond any doubt.

Jose *et al.* (1991) reported that yield of palm was significantly correlated with N per cent of leaf lamina of 2nd, 10th and 14th leaves and the highest coefficient of partial correlation being registered by 10th leaf.

2.7 Soil testing

Soil testing is a reliable procedure for transferring research findings to farmer's field. Leverington *et al.* (1962) reported that unless K is very deficient, soil analysis is more reliable than leaf analysis for answering potassium requirement of sugarcane.

A comparison of foliar diagnosis with soil analysis for the estimation of P and K requirements of groundnut in Bengal was made by Ollagnier and Giller (1955) in which foliar diagnosis values were better correlated with yield and response to P and K, than soil analysis.

The soil test values are interpreted and fertilizer recommendations are made by different procedures. The most common and widely accepted method is giving fertilizer recommendation based on soil test values alone. The traditional method is oriented towards giving fertilizer recommendation for rice and may not be suitable for perennial crops with different rooting pattern and grown under diverse soil and management conditions.

For better prediction of responses to applied nutrients, it is essential that soil sample to be drawn from the feeding zone of roots.

Turner *et al.* (1978) studied the effect of sampling depth on soil test results and reported that sampling depth significantly affected the levels of P, K, Mg, Ca and pH. Although soil fertility values changed with depth, changes in fertilizer recommendations due to sampling depth were minimal.

Bernard and Stabbert (1988) also emphasised the view of taking sampling depth into consideration while taking soil samples.

According to Amma (1989) soil samples are to be collected in the form of composite samples taken at two depths viz. 0-30 cm and 30-60 cm for fertilizer recommendation for rubber.

Bolland (1992) reported that soil P test values depends on sampling depth.

Though most of the chemical and physical properties are dependent on different size fractions of soil, little importance is being given on this aspect.

Indirakutty and Pandalai (1968) studied the influence of soil types on foliar nutrient composition in coconut and found that foliar nutrient content was more in red loam because of its favourable physical characteristics which allowed uninhibited and extensive development of root system - condition under which the capacity factor could be expected to play a major part in nutrient mobilisation.

According to Salgado (1955) soil analysis measured only the intensity factor while capacity factor took into account not only nutrient status but also the volume of soil available for roots to grow in search of food.

In the present study an attempt is made to develop factors or coefficients to account the contents of gravel, sand and bulk density of soil sample in soil test values of coconut. The results of the study may pave the way to extend this crop specific fertilizer recommendation system to other crops and soil types.

Material and Methods

3. MATERIALS AND METHODS

The soil sampling procedures suitable for perennial crops like coconut have not been systematically evaluated so far. Similarly, contents of gravel and coarse sand are not taken into account in arriving at fertilizer recommendations. This study was, therefore, undertaken to standardize soil sampling technique for coconut and to work out fertilizer recommendation system considering physical/textural nature of the soil as well as the nutrient level, based on correlation with plant uptake values.

The present study was conducted making use of two standing population of coconut gardens grown under good and average management practices, which are separated by a distance of about one kilometre. Details of the experiment are furnished below.

3.1 Experimental site

Coconut gardens were located at Mulamkunnathukavu (Thrissur Dt). Seventy five West Coast Tall palms were identified in each garden which were in the age group of 15-20 years. Among these, twenty healthy palms were selected for the study.

The area enjoyed a typical humid tropical climate. The soil at the experimental location was deep, well drained, acidic laterite (Oxisol) and gravelly in nature.

3.2 Collection and processing of soil samples

Soil samples were collected from the base of the selected palms in three seasons.

3.2.1 Seasons of sampling (S)

(1) Before the onset of S.W. monsoon (in May) (S_1)

(2) After the cessation of S.W. monsoon (in October) (S_2)

(3) After the cessation of N.E. monsoon (in January) (S_3)

3.2.2 Category of palms

(1) Good management - situation A

In this plot 25 kg farm yard manure, 25 kg green leaves, 1 kg urea, 0.5 kg super phosphate and 1kg muriate of potash were applied/palm/year in open circular basins. During summer months irrigation was also given at 4 days interval.

(2) Average management - situation B

Here 6 -8 kg wood ash and 25 - 30 kg green leaves were only applied.

3.2.3 Types of sampling

Basin of 1.8 m radius was formed around each palm for the application of manures and fertilisers. Soil samples were taken from different radial distances and depths from the base of the palm.

3.2.3.1 Radial distances (L)

(1) Inside the basin within a radius of 120-180 cm from the bole of the palm (L_1)

(2) Basin cum outside within a distance of 150-210 cm from the bole of the palm (L_2)

(3) Outside the basin within a distance of 180-240 cm from the bole of the palm (L_3)

3.2.3.2 Depths (D)

(1) 0-15 cm (D_1)

(2) 0-30 cm (D_2)

(3) 0-45 cm (D_3)

3.2.3.3 Distance-depth combinations

(1) L_1D_1	(4) L_2D_1	(7) L_3D_1
(2) L_1D_2	(5) L_2D_2	(8) L_3D_2
(3) L_1D_3	(6) L_2D_3	(9) L_3D_3

Soil samples were taken using soil tube and were designated as radial rhizosphere columns (RRC). For each distance-depth combination RRC's were collected from four different directions (north, east, south and west) around each palm and the four RRC's were mixed to make a composite sample. Thus the total number of composite samples collected were:

20 palms x 2 categories x 3 seasons x 9 distance-
depth combinations = 1080

Samples were air dried and sieved through 2 mm mesh prior to chemical analysis.

3.3 Collection and processing of leaf samples

Leaf samples were collected from the 10 th frond of the selected palms as suggested by Gopi (1981). From each palm, six leaflets (three from each side of the rachis) were taken without cutting the leaf. Only the middle 10 cm long portion of the leaflet was used for analysis. Marginal threads and midribs were removed, cleaned, dried, cut into small pieces, ground and made into composite samples.

3.4 Biometric observation

Data on yield and yield attributes were collected at the time of each sampling. In each palm, the bunch having nuts of fist size was tagged and the number of nuts present in each bunch starting from the tagged bunch up to the last bunch having fully matured nuts was counted and recorded as total expressed yield.

For recording the leaf production, the fully opened youngest leaf was tagged and treated as No.1 and counted all the leaves in the increasing order of age and recorded as total leaf production.

From the second sampling onwards, in addition to total number of nuts, bunches and leaves, the nuts, bunches and leaves produced up to the sampling time were separately counted and recorded as seasonal expressed production.

3.5 Analytical procedure

3.5.1 Soil analysis

Soil samples were analysed to assess pH, EC, organic carbon, available P and available K. pH and EC were determined at a soil water ratio of 1:2.5. Organic carbon content was estimated by Walkley and Black's rapid titration method as described by Jackson (1958). The available P was extracted using Bray No.1 extractant and the content was determined colorimetrically by ascorbic acid blue colour method (Watanabe and Olsen, 1965). The available K content was assessed flame photometrically after extracting with neutral normal ammonium acetate (Jackson, 1958). Soil size fractions were also separated by washing through sieves of different mesh size and they are designated as follows (Brady, 1984)

(1) Fraction 1 (F1) - >2mm

(2) Fraction 2 (F2) - 1-2 mm

(3) Fraction 3 (F3) - 0.5-1 mm

(4) Fraction 4 (F4) - 0.2-0.5 mm

(5) Fraction 5 (F5) - <0.2 mm

Bulk density was also determined by dividing the total mass (m) of RRC's with corresponding volume (v) and expressed as g cm^{-3} .

3.5.2 Plant analysis

The total nitrogen was determined by the microkjeldahl digestion distillation method. For the determination of total P and K the samples were digested in a mixture of nitric acid, sulphuric acid and perchloric acid as suggested by Jackson (1958) The P content was determined colorimetrically by vanadomolybdate yellow colour method in nitric acid medium and K content by flame photometry (Jackson, 1958).

3.5.3 Statistical analysis

Comparison of physio-chemical properties of two plots was done using `t' test (Panse and Sukhatme, 1985). Correlation studies were also conducted to study the nature of relationship among different variables. Correlation coefficients were worked out between soil parameters, leaf nutrient content and yield and yield attributes.

Results

4. RESULTS

Results of the present investigations are presented below.

4.1 Variation of physico-chemical properties of soil

4.1.1 Effect of depth, radial distance and season

4.1.1.1 Total weight of RRC's

Data presented in Tables 1a and 1b show that in situation A and B the total weight of soil column increases as the depth and radial distance from the bole increases. Though the volume remains constant, situation B recorded higher values for a particular RRC compared with situation A. In both cases maximum weight was noticed at L_3D_3 (690 g-A; 990 g-B) and minimum at L_1D_1 (246 g-A; 354 g-B).

4.1.1.2 Particle size distribution

Distribution of fraction-1 in the field soil as well as different size separates in 2 mm sieved sample was studied and the data are presented in Tables 2a, 2b and Fig.1a, 1b for situations A and B respectively. It was observed that fraction-1 decreases as the depth increases and increases as the distance from the palm increases. In both situation minimum value was obtained at L_1D_3 and maximum value at L_3D_1 for situation A and L_1D_1 for situation B. The pattern of distribution of fraction-5 was just reverse, which is evident from the tables.

4.1.1.3 Bulk density

Bulk density of different RRCs are presented in Tables 1a and 1b. Results indicated that bulk density was maximum for RRCs taken from outside the basin

Table 1a. Quantitative characterisation of soil physical properties in situation A

RRC	Total weight (g)	Particle size distribution, g					Bulk density g cm^{-3}
		F1	F2	F3	F4	F5	
L_1D_1	246	7	6	36	17	180	1.26
L_1D_2	430	12	9	46	23	340	1.02
L_1D_3	677	16	18	103	48	492	1.23
L_2D_1	258	8	8	36	19	187	1.35
L_2D_2	453	13	12	52	29	347	1.02
L_2D_3	678	18	24	94	52	490	1.24
L_3D_1	273	10	9	36	21	197	1.45
L_3D_2	463	14	21	74	45	309	1.30
L_3D_3	690	19	37	120	72	442	1.36
Mean	463	13	16	66	36	331	1.25

Table 1b. Quantitative characterisation of soil physical properties in situation B

RRC	Total weight (g)	Particle size distribution, g					Bulk density g cm^{-3}
		F1	F2	F3	F4	F5	
L_1D_1	354	96	19	45	17	177	1.80
L_1D_2	558	142	24	62	23	307	1.24
L_1D_3	977	204	55	132	48	538	1.60
L_2D_1	359	96	20	46	18	179	1.90
L_2D_2	568	148	27	73	27	293	1.40
L_2D_3	984	254	56	132	49	493	1.67
L_3D_1	364	96	22	52	19	175	1.96
L_3D_2	577	150	31	84	31	281	1.60
L_3D_3	990	259	56	133	49	493	1.70
Mean	636	160	34	84	31	326	1.65

L - Radial position from the bole

D - Depth from surface (cm)

F - Soil size fraction

Table 2a. Distribution of soil particles in situation A

RRC	Particle size distribution, %				
	F1	F2	F3	F4	F5
L_1D_1	2.8	2.4	14.6	6.9	73.3
L_1D_2	2.8	2.1	10.7	5.3	79.1
L_1D_3	2.4	2.6	15.2	7.1	72.7
L_2D_1	3.1	3.1	13.9	7.4	72.5
L_2D_2	2.8	2.6	11.5	6.4	76.7
L_2D_3	2.6	3.5	13.9	7.7	72.3
L_3D_1	3.7	3.3	13.2	7.7	72.1
L_3D_2	3.0	4.5	16.0	9.7	66.8
L_3D_3	2.7	5.4	17.4	10.4	64.1
Mean	2.9	3.2	14.0	7.6	72.2

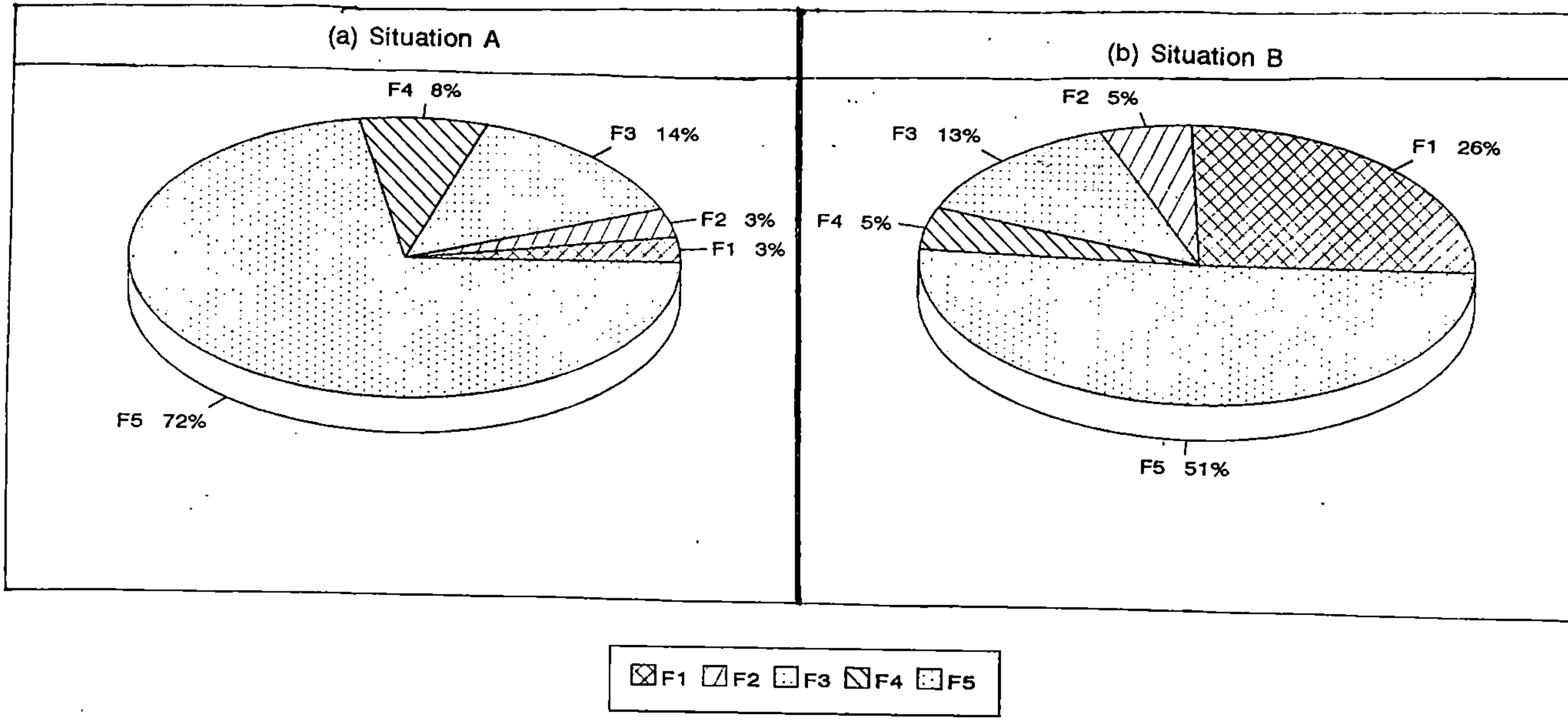
Table 2b. Distribution of soil particles in situation B

RRC	Particle size distribution, %				
	F1	F2	F3	F4	F5
L_1D_1	27.1	5.4	12.7	4.8	50.0
L_1D_2	25.4	4.3	11.1	4.1	55.1
L_1D_3	20.9	5.6	13.5	4.9	55.1
L_2D_1	26.7	5.6	12.8	5.0	49.9
L_2D_2	26.1	4.8	12.8	4.8	51.5
L_2D_3	25.8	5.7	13.4	5.0	50.1
L_3D_1	26.4	6.0	14.3	5.2	48.1
L_3D_2	26.0	5.4	14.5	5.4	48.7
L_3D_3	26.2	5.6	13.4	4.9	49.9
Mean	25.6	5.4	13.2	4.9	50.9

L - Radial position from the bole

D - Depth from surface (cm)

F - Soil size fraction



F - Soil size fraction

Fig.1. Distribution pattern of soil particles in coconut rhizosphere

(L_3) and minimum at L_1. Considering the depth wise variation, highest value was observed in 0-15 cm layer of soil (D_1) and lowest at D_2. Results obtained in situation A is in conformity with that in situation B.

4.1.1.4 Percentage of roots

Data on root fraction distribution in both the situations presented in Table 3 showed that pattern of distribution was similar in both the situations though, the magnitude of occurrence varied between the situations. In both cases root biomass tended to increase with progressive increase in the length of soil column, but decreased with greater radial distances.

In situation A, values of percentage distribution of root fraction in 0-15 cm, 0-30 cm, 0-45 cm at L_1 and L_3 were 0.16, 0.26, 0.29 and 0.07, 0.13, 0.16 respectively.

In situation B the percentage content of roots in fixed soil volumes were low. Thus the data showed that situation A manifested higher percentage of roots than situation B.

4.1.1.5 Soil reaction

Data pertaining to the effect of depth, radial distance and season on pH of situation A and B are presented in Table 4 and Fig.2. It was observed that pH decreased with increase in depth and radial distance. In situation A highest value was recorded at L_1D_1 and L_1D_2 (6.1) and minimum value at L_3D_3 (5.7) in the first

Table 3. Root distribution pattern of coconut palm

RRC	Root fraction (%)			
	Situation A		Situation B	
	Mean	Range	Mean	Range
L_1D_1	0.16	0.02 - 0.46	0.08	0.00 - 0.20
L_1D_2	0.26	0.03 - 0.46	0.18	0.01 - 0.50
L_1D_3	0.29	0.01 - 0.42	0.26	0.03 - 0.66
L_2D_1	0.12	0.02 - 0.41	0.09	0.01 - 0.26
L_2D_2	0.20	0.02 - 0.43	0.15	0.03 - 0.42
L_2D_3	0.21	0.01 - 0.39	0.21	0.01 - 0.53
L_3D_1	0.07	0.01 - 0.38	0.08	0.01 - 0.30
L_3D_2	0.13	0.01 - 0.36	0.11	0.07 - 0.29
L_3D_3	0.16	0.01 - 0.29	0.14	0.00 - 0.49
Mean	0.18	0.01 - 0.46	0.14	0.00 - 0.66

Table 4. Pattern of pH in coconut rhizosphere

RRC	Situation A			Situation B		
	S_1	S_2	S_3	S_1	S_2	S_3
L_1D_1	6.1	5.8	5.8	6.6	6.4	5.9
L_1D_2	6.1	5.9	5.8	6.4	6.3	5.9
L_1D_3	6.0	5.8	5.7	6.5	6.3	5.9
L_2D_1	6.0	5.8	5.8	6.2	6.0	5.9
L_2D_2	5.8	5.7	5.7	6.3	6.0	5.7
L_2D_3	5.9	5.6	5.7	6.1	5.9	5.6
L_3D_1	5.8	5.6	5.7	6.0	6.0	5.8
L_3D_2	5.8	5.6	5.7	5.9	5.9	5.7
L_3D_3	5.7	5.5	5.7	5.9	5.9	5.7
Mean	5.9	5.7	5.7	6.2	6.1	5.8

L - Radial position from the bole

D - Depth from surface (cm)

S - Season

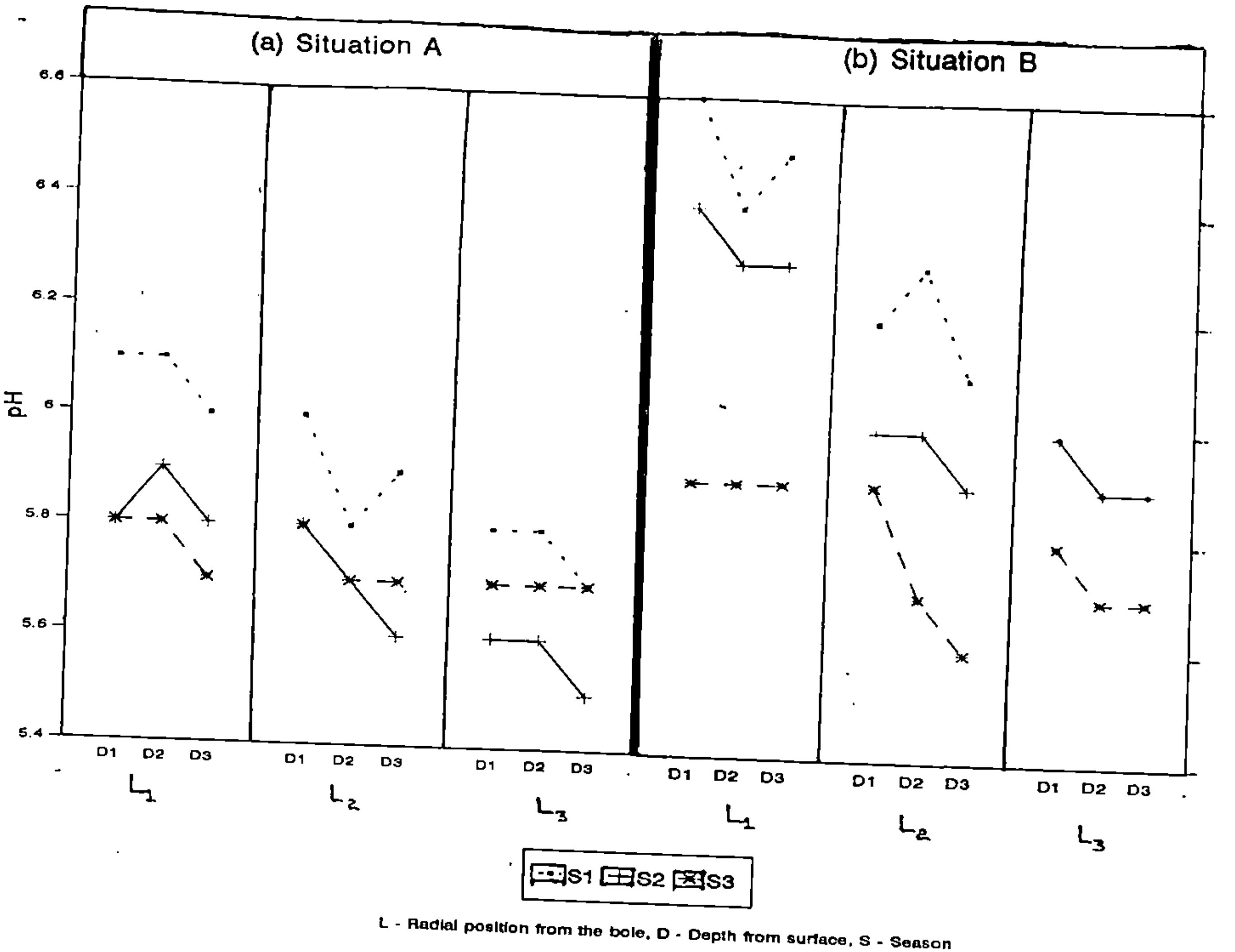


Fig.2. Distribution pattern of pH in coconut rhizosphere

season. In the second season highest value was at L_1D_2 (5.9) and lowest at L_3D_3 (5.5). But in the following season pH is almost stabilised for all locations.

In situation B, pH variation followed the same pattern as that in situation A, though corresponding value for each location was higher compared with situation A. In all the seasons L_1D_1 recorded the highest and L_3D_3, the lowest pH.

4.1.1.6 Electrical conductivity (dS m^{-1})

Data showed that EC decreased with depth and distance from the palm in both situations (Table 5 and Fig.3). In both situations EC followed same pattern of variation. Maximum value was recorded at L_1D_1 in the second season (0.218-A; 0.187-B) and minimum value at L_3D_3 in the first season and the values were 0.077 and 0.083 for situation A and B respectively. Compared with situation B, situation A recorded higher values for EC.

4.1.1.7 Organic carbon (per cent)

In both situations organic carbon decreased with depth and radial distance (Table 6 and Fig.4). In all the seasons maximum organic carbon content was noticed at L_1D_1.

In situation A, highest value obtained was 0.63 at L_1D_1 and lowest value at L_3D_3 (0.48) in the first season. In second and third seasons also the highest values were recorded at L_1D_1 with a mean value of 0.66 and 0.63 respectively and lowest value at L_3D_3 (0.50 and 0.49). Comparing the seasons, highest value was recorded in the second season (0.66).

Table 5. Pattern of EC in coconut rhizosphere (dS m^{-1})

RRC	Situation A			Situation B		
	S_1	S_2	S_3	S_1	S_2	S_3
L_1D_1	0.129	0.218	0.164	0.177	0.187	0.176
L_1D_2	0.123	0.177	0.162	0.141	0.173	0.143
L_1D_3	0.118	0.109	0.097	0.118	0.135	0.121
L_2D_1	0.118	0.168	0.154	0.149	0.153	0.131
L_2D_2	0.117	0.163	0.146	0.134	0.147	0.128
L_2D_3	0.091	0.152	0.129	0.116	0.138	0.111
L_3D_1	0.100	0.164	0.146	0.137	0.118	0.111
L_3D_2	0.085	0.118	0.139	0.093	0.110	0.106
L_3D_3	0.077	0.109	0.117	0.083	0.096	0.091
Mean	0.106	0.153	0.139	0.128	0.140	0.124

Table 6. Pattern of organic carbon in coconut rhizosphere (per cent)

RRC	Situation A			Situation B		
	S_1	S_2	S_3	S_1	S_2	S_3
L_1D_1	0.63	0.66	0.63	0.55	0.58	0.55
L_1D_2	0.60	0.61	0.60	0.54	0.51	0.53
L_1D_3	0.55	0.56	0.48	0.44	0.41	0.48
L_2D_1	0.56	0.64	0.58	0.51	0.52	0.49
L_2D_2	0.54	0.63	0.55	0.47	0.49	0.48
L_2D_3	0.52	0.55	0.53	0.43	0.43	0.47
L_3D_1	0.52	0.58	0.58	0.52	0.50	0.48
L_3D_2	0.53	0.57	0.55	0.44	0.48	0.47
L_3D_3	0.48	0.50	0.49	0.42	0.43	0.43
Mean	0.55	0.59	0.55	0.48	0.48	0.49

L - Radial position from the bole

D - Depth from surface (cm)

S - Season

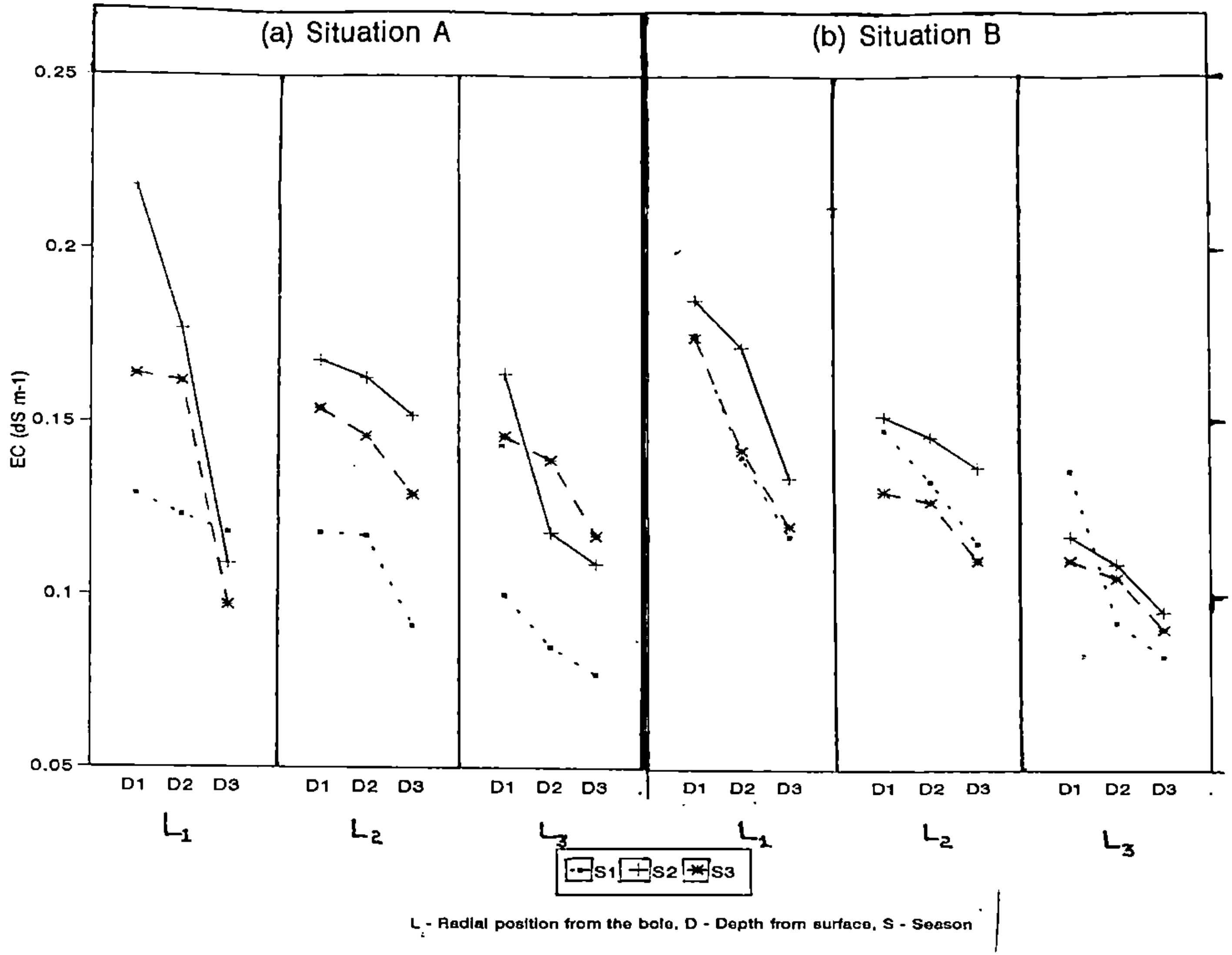


Fig.3. Distribution pattern of EC in coconut rhizosphere

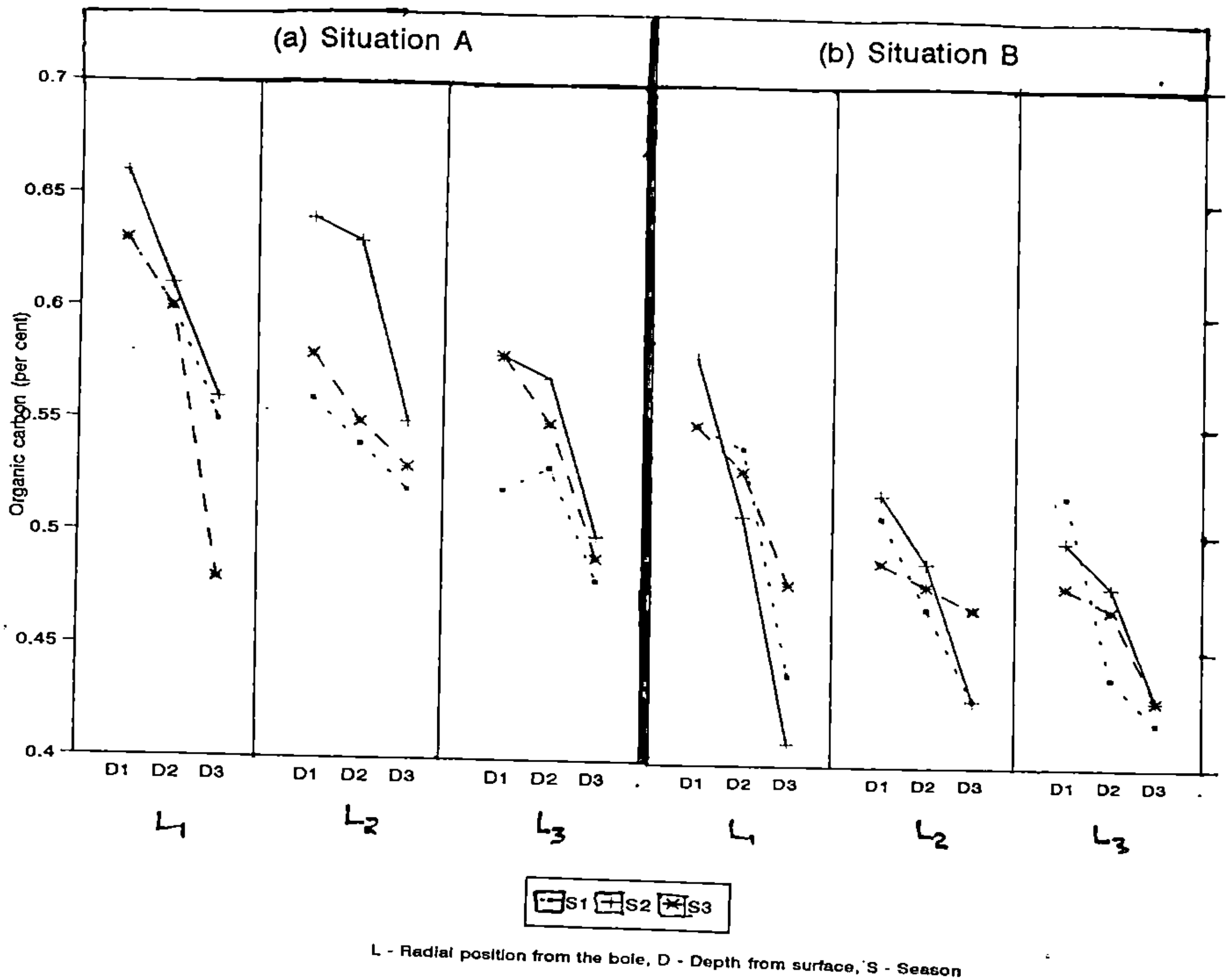


Fig.4. Distribution pattern of organic carbon in coconut rhizosphere

In situation B also maximum organic carbon content was noticed at L_1D_1 and the values were 0.55, 0.58 and 0.55 for first, second and third seasons respectively. The minimum value recorded for L_3D_3 was almost the same for all the seasons.

4.1.1.8 Available P (ppm)

In situations A and B, available P decreased with increase in depth and radial distance from the bole (Table 7 and Fig.5).

In situation A, maximum available P content was noticed at L_1D_1 (24.5 ppm) and minimum at L_3D_3 (6.3 ppm) in the first season. Similarly in the following seasons also highest values were at L_1D_1 and lowest values at L_3D_3.

In situation B also pattern of distribution of available P followed same trend as in situation A - maximum at L_1D_1 (28.7, 37.8 and 30.9 ppm for first, second and third season respectively) and minimum at L_3D_3 (4.1, 5.9 and 5.4 ppm).

In both situations maximum available P content was recorded in the second season.

4.1.1.9 Available K

Data on distribution of available K in soil columns presented in Table 8 and Fig. 6 revealed that available K content varied with radial and vertical distances from the bole. In situation A during first season highest value was recorded at L_1D_1 (153 ppm) and as the depth increased, K content decreased to 135

Table 7. Pattern of available P in coconut rhizosphere (ppm)

RRC	Situation A			Situation B		
	S_1	S_2	S_3	S_1	S_2	S_3
L_1D_1	24.5	22.5	18.8	28.7	37.8	30.9
L_1D_2	18.8	18.9	17.2	17.0	29.4	23.0
L_1D_3	10.4	16.8	11.1	14.3	10.2	11.8
L_2D_1	13.7	18.8	16.3	15.1	22.3	17.6
L_2D_2	12.8	15.6	13.6	14.3	20.9	12.3
L_2D_3	8.9	10.9	13.3	9.3	14.2	8.2
L_3D_1	10.6	14.4	11.0	12.4	14.0	12.2
L_3D_2	7.7	10.1	8.5	9.3	13.4	10.0
L_3D_3	6.3	9.4	8.4	4.1	5.9	5.4
Mean	12.6	15.3	13.1	13.8	18.7	14.6

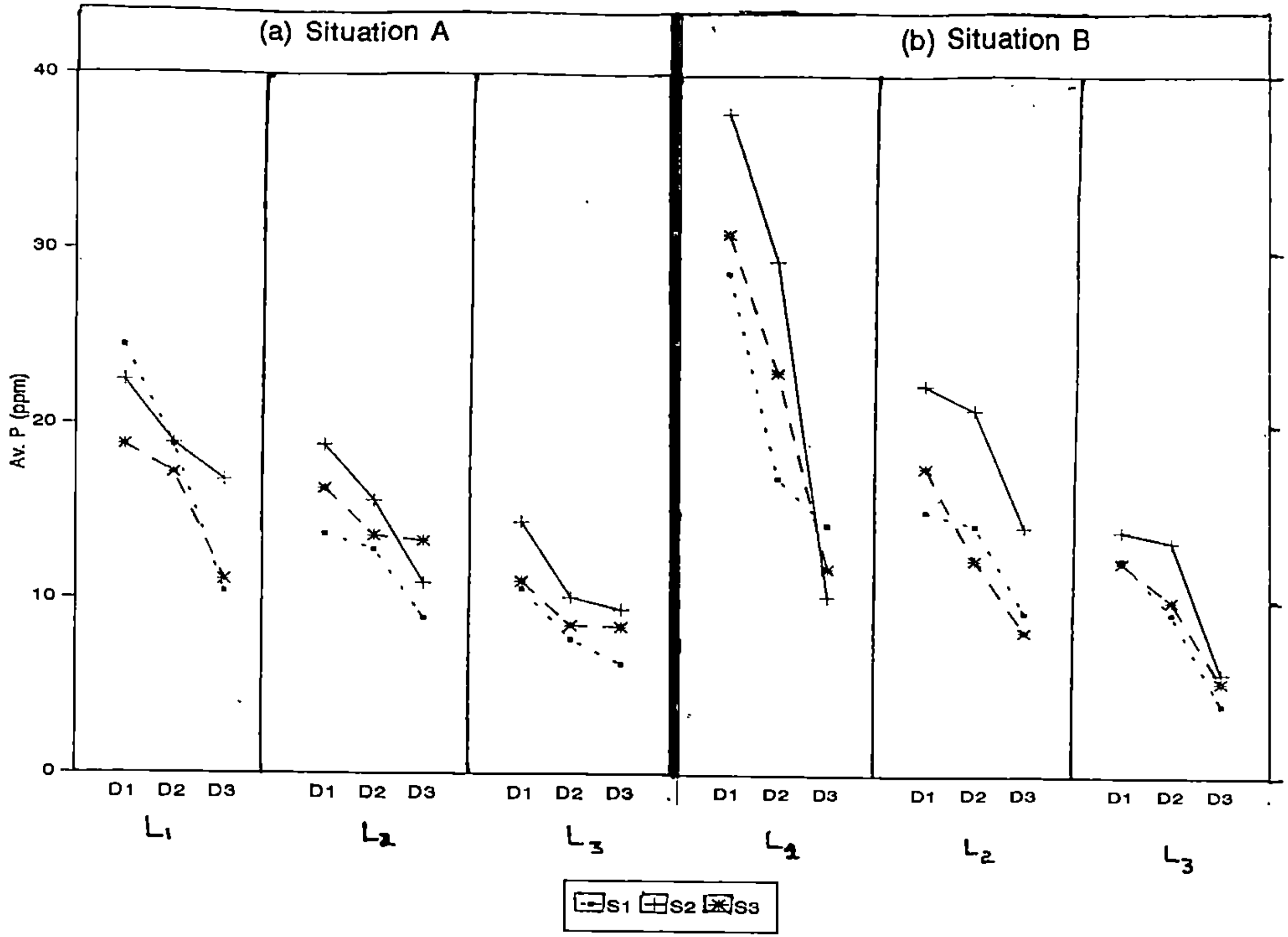
Table 8. Pattern of available K in coconut rhizosphere (ppm)

RRC	Situation A			Situation B		
	S_1	S_2	S_3	S_1	S_2	S_3
L_1D_1	153	149	129	94	102	89
L_1D_2	150	184	152	91	88	87
L_1D_3	135	181	148	76	89	76
L_2D_1	133	163	123	89	93	84
L_2D_2	126	149	119	72	67	77
L_2D_3	101	132	112	52	59	46
L_3D_1	108	116	104	68	59	64
L_3D_2	99	113	97	60	57	56
L_3D_3	87	101	96	43	49	51
Mean	121	143	120	72	74	70

L - Radial position from the bole

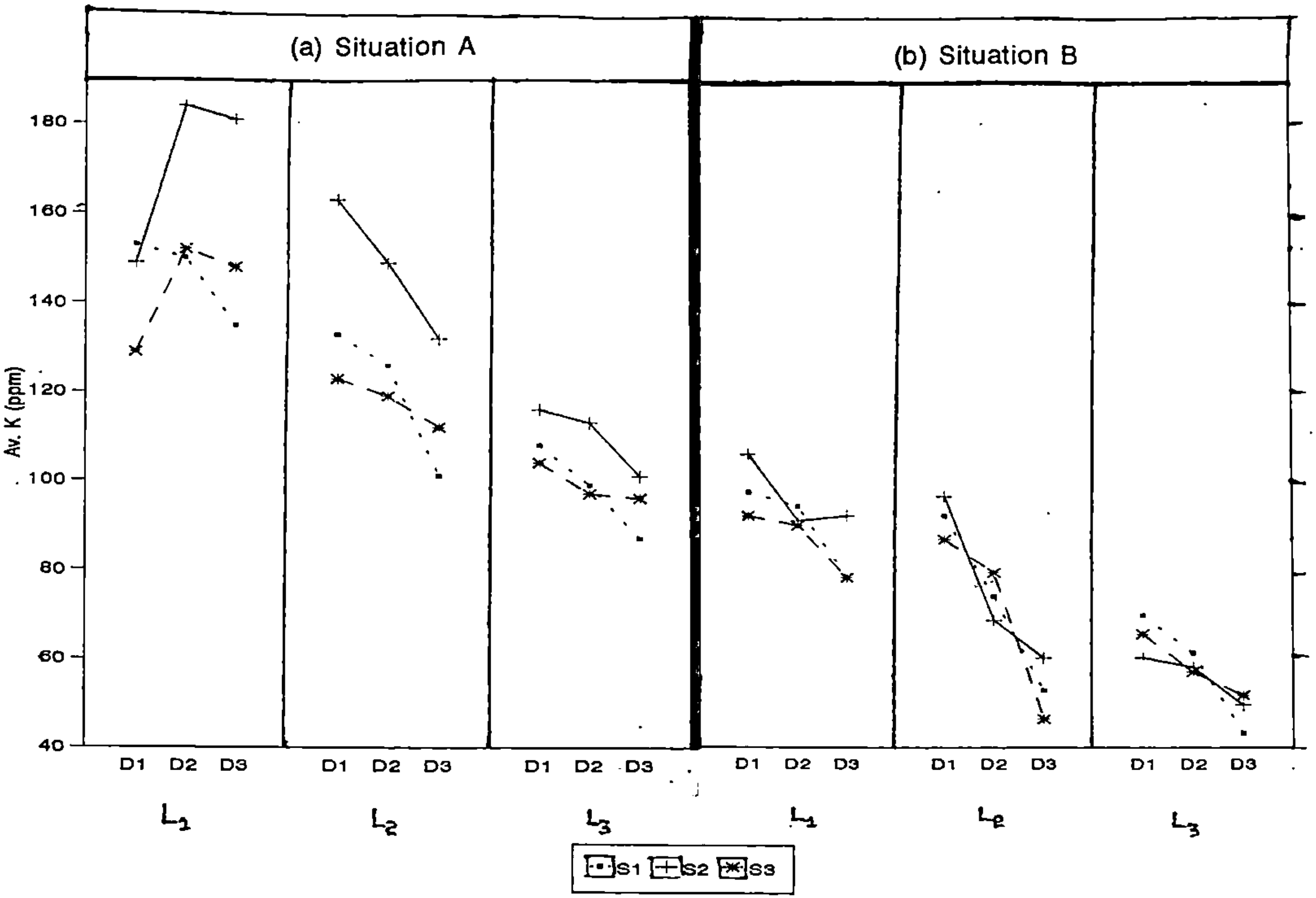
D - Depth from surface (cm)

S - Season



L - Radial position from the bole, D - Depth from surface, S - Season

Fig.5. Distribution pattern of available P in coconut rhizosphere



L - Radial position from the bole, D - Depth from surface, S - Season

Fig.6. Distribution pattern of available K in coconut rhizosphere

ppm (L_1D_3). But in the next two seasons maximum available K content was in 0-30 cm column (L_1D_2) of soil. In all the seasons minimum value was at L_3D_3.

In situation B maximum available K content was at L_1D_1 and decreased with increase in depth and radial distance. Like other nutrients, highest value was recorded in the second season.

4.1.2 Two factor interaction studies

4.1.2.1 Depth x radial distance (D x L)

Combined effect of depth of sampling and distance from the bole on soil chemical properties presented in Table 9 showed that in both situations maximum values were recorded at L_1D_1 and values decreased as the depth and distance from the bole increased.

4.1.2.2 Depth x season (D x S)

It was noticed that maximum values for the chemical properties studied were recorded at S_2 and minimum at S_1 for all depths (Table 10). Situation A manifested wider fluctuations of all the characteristics. Increasing the depth of soil samples for analysis tended to minimise variation.

Variations in organic carbon, pH, EC and available K were little due to depth and season in situation B.

4.1.2.3 Radial distance x season (L x S)

Combined effect of radial distances and season on chemical properties presented in Table 11 showed that pH, EC, organic carbon, available P and K

Table 9. Effect of radial distance and depth on soil chemical properties

Situation	RRC	pH			EC (dS m^{-1})			O.C (%)			Av.P (ppm)			Av.K (ppm)		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	L_1	5.9	5.9	5.8	0.170	0.154	0.108	0.64	0.60	0.53	21.9	18.3	12.8	144	162	155
	L_2	5.9	5.7	5.7	0.147	0.142	0.124	0.59	0.57	0.53	16.3	14.0	11.0	140	131	115
	L_3	5.7	5.7	5.6	0.137	0.114	0.101	0.56	0.55	0.49	12.0	8.8	8.0	109	103	95
B	L_1	6.3	6.2	6.2	0.180	0.152	0.125	0.56	0.53	0.44	32.5	23.1	12.1	95	89	80
	L_2	6.0	6.0	5.9	0.144	0.136	0.122	0.51	0.48	0.44	18.3	15.8	10.6	89	72	52
	L_3	5.9	5.8	5.8	0.122	0.103	0.090	0.50	0.46	0.43	12.9	10.9	5.1	64	58	48

L - Radial position from the bole

D - Depth from surface (cm)

Table 10. Effect of soil depth and season on soil chemical properties

Situation	RRC	pH			EC (dS m^{-1})			O.C (%)			Av.P (ppm)			Av.K (ppm)		
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
A	D_1	6.0	5.7	5.8	0.116	0.183	0.155	0.57	0.63	0.60	16.3	18.6	15.4	131	143	119
	D_2	5.9	5.7	5.7	0.108	0.153	0.149	0.56	0.60	0.57	13.1	14.9	13.1	125	149	123
	D_3	5.9	5.6	5.7	0.095	0.123	0.114	0.52	0.54	0.50	8.5	12.4	10.9	108	138	119
B	D_1	6.3	6.2	5.9	0.154	0.153	0.139	0.53	0.53	0.51	18.7	24.7	20.2	84	85	79
	D_2	6.2	6.1	5.8	0.123	0.143	0.126	0.48	0.49	0.49	13.5	21.2	15.1	74	71	73
	D_3	6.2	6.0	5.7	0.106	0.123	0.108	0.43	0.42	0.46	9.2	10.1	8.5	57	66	58

S - Season

D - Depth from surface (cm)

Table 11. Effect of radial distance and season on soil chemical properties

Situation	RRC	pH			EC (dS m^{-1})			O.C (%)			Av.P (ppm)			Av.K (ppm)		
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
A	L_1	6.1	5.8	5.8	0.123	0.168	0.141	0.59	0.61	0.57	17.9	19.4	15.7	146	171	143
	L_2	5.9	5.7	5.7	0.109	0.161	0.143	0.54	0.61	0.55	11.8	15.1	14.4	120	148	118
	L_3	5.8	5.6	5.7	0.087	0.130	0.134	0.51	0.55	0.54	8.2	11.3	9.3	98	110	99
B	L_1	6.5	6.3	5.9	0.145	0.165	0.147	0.51	0.50	0.52	20.0	25.8	21.9	87	93	84
	L_2	6.2	6.0	5.7	0.133	0.146	0.123	0.47	0.48	0.48	12.9	19.1	12.7	71	73	69
	L_3	5.9	5.9	5.7	0.104	0.108	0.103	0.46	0.47	0.46	8.6	11.1	9.2	57	55	57

L - Radial position from the bole

S - Season

showed minimum variation outside the basin between seasons in both the situations. Variations were widest in S_2 in situation B than in situation A.

4.1.3 Main effects

4.1.3.1 Depth (D)

Effect of vertical distance on physico-chemical characteristics of soil in good and average management conditions are presented in Table 12.

A gradual and steady decline in all the characteristics studied shall be observed in both situations. The conspicuous difference between the situations had been found to be a lower pH, a higher organic carbon and available K content in respect of chemical properties and a significant improvement in fraction 4 and 5 in the good managed situation. Mean increases in the organic carbon and available K were 16.7 per cent and 77.8 per cent and fraction 4 and 5 were 55.1 per cent and 41.7 per cent respectively. The data also showed that available P and fraction 1 gave higher values in the average management situation.

4.1.3.2 Radial distance (L)

It shall be seen from the data presented in Table 13 that all the physico-chemical characteristics steadily declined in both the situations with increase in distance from the bole. However , the differences between the situations stood maintained.

Average management situation gave higher pH as well as lesser fine fraction while good management situation gave higher contents of organic carbon, available K and finer fraction of the soil and the mean increases were 3.5 per cent (pH) for average Situation and 16.7 per cent (organic carbon) and 77.8 per cent (available K) for good managed situation.

4.1.3.3 Season (S)

Variability in the chemical characteristics of the soil with season is presented in Table 14. The data showed that samples collected during October (S_2) tended to show higher test values of EC, organic carbon, available P and available K in both the situations. Well managed situation invariably gave higher values of organic carbon and available K, and the mean increases were 16.7 per cent and 77.8 per cent. Situation B gave 3.5 per cent and 14.6 per cent higher pH and available P respectively.

4.2 Comparison of physico-chemical properties of both situations

Studies were conducted to compare the physical properties of both situations and the data are presented in Table 15. It was observed that the two situations differed significantly in all the characters studied. Considering the percentage composition of different size fractions, coarser fractions like fraction-1 and fraction- 2 were more in soil of situation B while in situation A finer fractions (fraction-4 and fraction-5) dominated.

Chemical properties of both situations were also compared in all the three seasons. Data (Table 16) revealed that in the first season only the available P contents of both the situations were homogeneous. Situation A recorded higher values for organic carbon and available K content unlike available P, EC and pH.

Table 12. Effect of soil depth on physico-chemical properties of soil

Situation	RRC	pH	EC (dS m^{-1})	O.C. (%)	Av.P (ppm)	Av.K (ppm)	Particle size distribution, %				
							F_1	F_2	F_3	F_4	F_5
A	D_1	5.8	0.151	0.60	16.7	131.0	3.2	2.9	13.9	7.3	72.7
	D_2	5.8	0.137	0.58	13.7	132.0	2.9	3.1	12.7	7.1	74.2
	D_3	5.7	0.111	0.52	10.6	121.0	2.5	3.8	15.5	8.4	69.8
B	D_1	6.1	0.149	0.52	21.2	82.0	26.7	5.7	13.3	5.0	49.3
	D_2	6.0	0.131	0.49	16.6	73.0	25.8	4.8	12.8	4.8	51.8
	D_3	6.0	0.112	0.44	9.3	60.0	24.3	5.6	13.4	4.9	51.8

F - Soil size fraction

D - Depth from surface (cm)

Table 13. Effect of radial distance on physico-chemical properties of soil

Situation	RRC	pH	EC (dS m^{-1})	O.C. (%)	Av.P (ppm)	Av.K (ppm)	Particle size distribution, %				
							F_1	F_2	F_3	F_4	F_5
A	L_1	5.9	0.144	0.59	17.7	153	2.7	2.4	13.5	6.4	75.0
	L_2	5.8	0.138	0.57	13.8	129	2.8	3.1	13.1	7.2	73.8
	L_3	5.7	0.117	0.53	9.6	102	3.1	4.4	15.5	9.3	67.7
B	L_1	6.2	0.152	0.51	23.0	88	24.4	5.3	12.4	4.6	53.3
	L_2	6.0	0.134	0.48	14.9	71	26.2	5.4	13.0	4.9	50.5
	L_3	5.9	0.105	0.46	9.6	56	26.2	5.7	14.0	5.2	48.9

L - Radial position from the bole

F - Soil size fraction

Table 14. Effect of season on soil chemical properties

Situation	Season	pH	EC (dS m^{-1})	O.C. (%)	Av. P (ppm)	Av. K (ppm)
A	S_1	5.9	0.106	0.55	12.6	121
	S_2	5.7	0.153	0.59	15.3	143
	S_3	5.7	0.139	0.55	13.1	120
B	S_1	6.2	0.128	0.48	13.8	72
	S_2	6.1	0.140	0.48	18.7	74
	S_3	5.8	0.124	0.49	14.6	70

S - Season

Table 15. Comparison of soil physical properties of situation A and B

	Particle size distribution, %					Bulk density (g cm^{-3})
	F1	F2	F3	F4	F5	
Situation A	2.9	3.3	14.0	7.6	72.2	1.25
Situation B	25.6	5.4	13.2	4.9	30.9	1.65
Probability	0.000	0.000	0.0005	0.004	0.009	0.0004

F - Soil size fraction

In the second and third season EC and available P content of both situations did not differ significantly. The actual values for the different factors studied showed similar trend as in the case of first season.

4.3 Comparison of nutrient status in leaves

Results presented in Table 17 and Fig. 7 showed that leaf N content did not show much variation between seasons in both situations. The mean variation worked out to 2.4 per cent in situation A and 2.8 per cent in situation B and the corresponding ranges were 2.03 to 2.08 and 1.74 to 1.79 respectively. Between them situation A has recorded a higher content of leaf N irrespective of seasons.

The P content of leaf also showed not much variation between seasons and situations. The mean variation between the season worked out to 14.3 per cent in situation A and 15.3 per cent in situation B.

Potassium content appeared to be high in situation A than that of B. Leaf content of K was the least in second season. The highest content of 1.45 per cent was recorded in situation A during the season S_1, while that in situation B was 1.24 per cent. The mean variation worked out to 38.1 per cent in situation A and 22.7 per cent in situation B.

4.4 Comparison of palm characteristics

Data on the production of nuts, leaves and bunches in the palm, both total and seasonal in the two situations are presented in Table 18 and Fig. 8. Data showed that number of nuts in the palm as well as the production and pattern of

Table 16. Comparison of soil chemical properties of situation A and B

Season		pH	EC (dS m^{-1})	O.C. (%)	Av. P (ppm)	Av. K (ppm)
	Situation A	5.94	0.106	0.548	12.64	121.89
S_1	Situation B	6.23	0.127	0.480	13.81	72.42
	Probability	0.004	0.039	0.014	0.617	0.000
	Situation A	5.78	0.153	0.589	15.34	143.00
S_2	Situation B	6.12	0.140	0.483	18.71	72.48
	Probability	0.003	0.251	0.004	0.05	0.000
	Situation A	5.74	0.139	0.554	13.11	119.80
S_3	Situation B	5.84	0.124	0.487	14.60	69.49
	Probability	0.007	0.286	0.006	0.39	0.000

S - Season

Table 17. Content of leaf nutrients in seasons, per cent

Leaf nutrients	Situation A			Situation B		
	S_1	S_2	S_3	S_1	S_2	S_3
N	2.08	2.03	2.04	1.79	1.74	1.79
P	0.14	0.16	0.16	0.13	0.15	0.13
K	1.45	1.05	1.31	1.24	1.02	1.01

S - Season

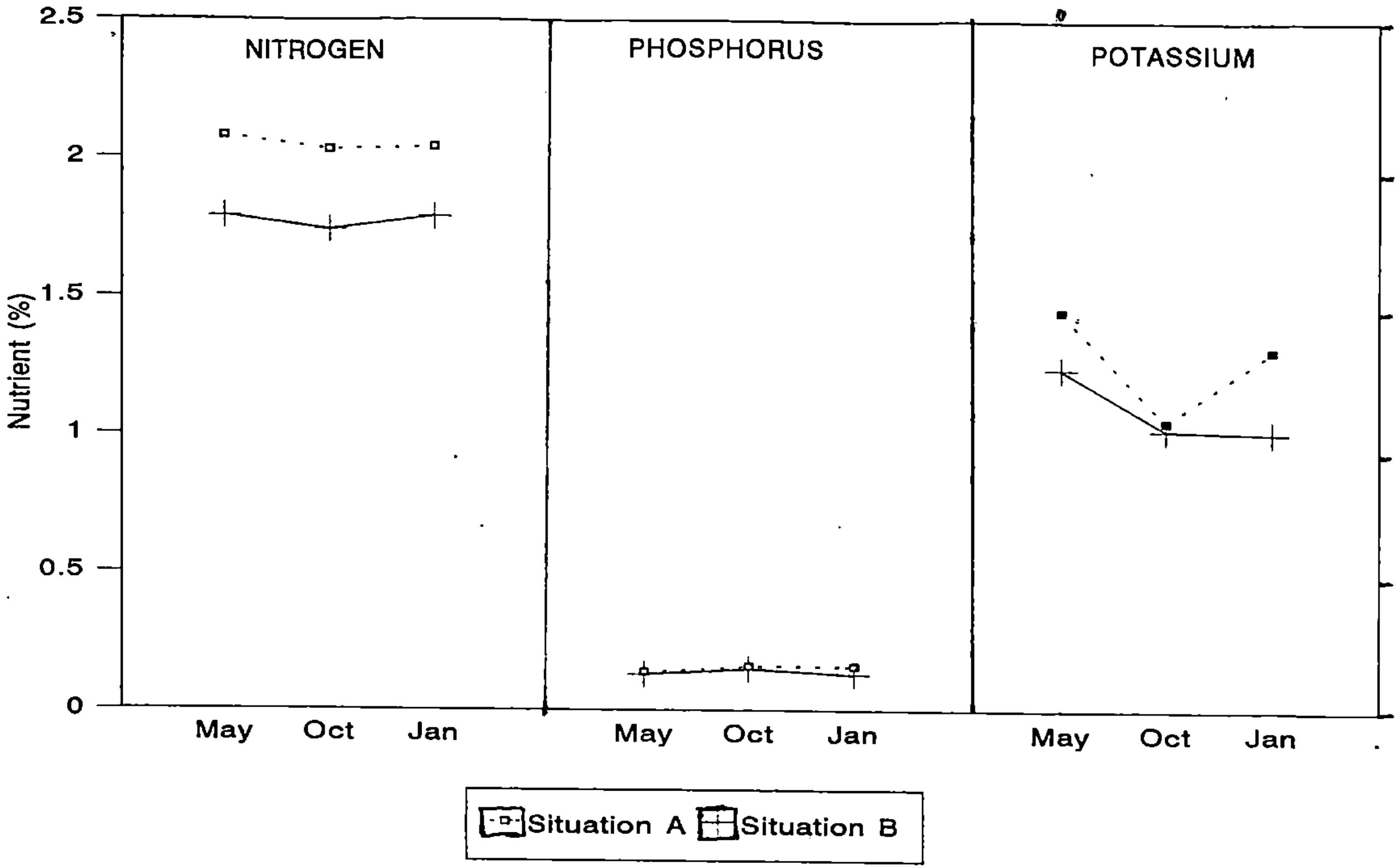


Fig.7. Distribution pattern of nutrients in coconut leaf

production in subsequent seasons varied within the same situation as well as between the situations.

It can be seen that total yield of nuts varied with season in both the situations. In situation A the variation was 18.3 per cent, while that in situation B, it was 55.5 per cent. The highest total was recorded during S_2 in situation A, while it was during S_1 in situation B.

The seasonal production of nuts was highest during S_2 in both the situations. The variation in seasonal nut production was 105 per cent in situation A and 181.8 per cent in situation B.

Situation A and B showed the same pattern in yield of total nuts per bunch. The yield was highest during S_1 and lowest during S_3. In situation A, the variation was only 16.4 per cent, while that in situation B, it was as high as 75 per cent. The pattern of seasonal nut production per bunch was also similar in both the situations. The maximum was noticed during S_2. The variation was 53.6 per cent in situation A and 40.9 per cent in situation B.

The variations in leaf and bunch production, both total and seasonal were low in both the situations. Situation B recorded lower values for yield and yield attributes than situation A.

4.5 Inter-relations among physico-chemical properties

Data on the correlation among physical properties as well as their relationship with chemical properties of situation A are presented in Table 19 to 23.

Table 18. Pattern of yield and yield attributes in seasons

Yield attributes	Yield *	Situation A			Situation B		
		S_1	S_2	S_3	S_1	S_2	S_3
No.of nuts	Total	71	84	72	42	36	27
	Seasonal	24	41	20	14	31	11
No.of leaves	Total	33	33	31	28	20	29
	Seasonal	4	4	3	3	4	3
No.of bunches	Total	11	14	13	8	9	9
	Seasonal	3	4	3	2	4	2
No.of nuts/ bunch	Total	6.45	6.00	5.54	5.25	4.00	3.00
	Seasonal	8.00	10.25	6.67	7.00	7.75	5.50

*Expressed production
S - Season

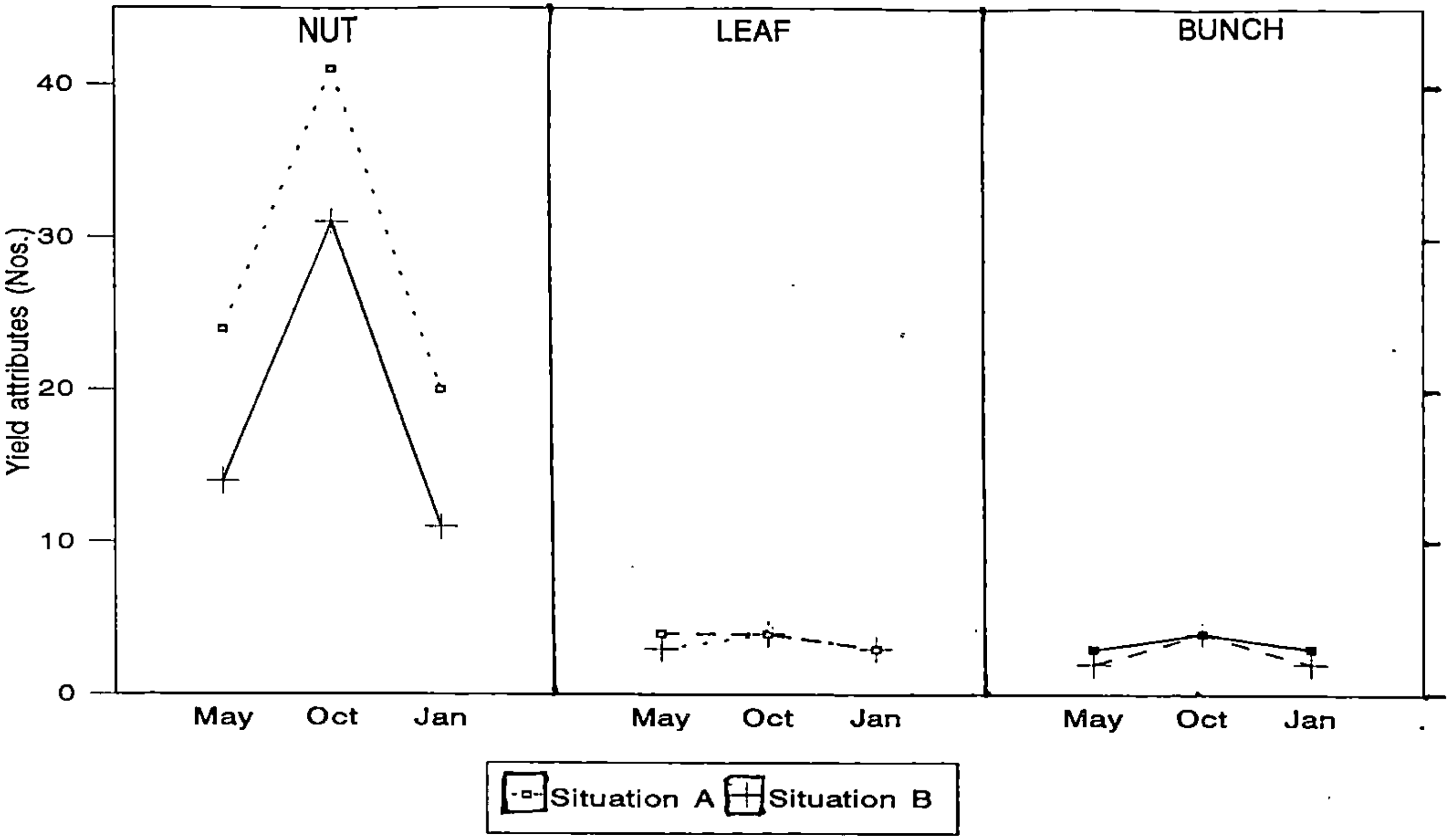


Fig.8. Seasonal distribution pattern of yield and yield attributes in coconut

Fraction-1 established negative relationship with particles of size less than 0.2 mm (fraction-5) at all depths and radial distances while other groups of separates were found to be positively related (Table 19). Correlation of fraction-1 with chemical characteristics studied were generally non significant. It was negative in the case of organic carbon and available K and tended to be negative with soil reaction also. Significant positive relationship was observed only with available P at L_1D_1 (0.521*).

Correlation of fraction-2 with other soil fractions also showed similar pattern though, the magnitude of relationship differed (Table 20). This fraction established significant correlation with available P at L_1D_1, L_2D_2 and L_3D_1. But failed to establish correlation with other soil chemical properties.

Fraction-3 manifested highly significant negative correlation with fraction-5 (Table 21). All other fractions established a positive relationship. Negative correlation with organic carbon can also be seen to have strengthened at L_2D_1 (-0.542*) and L_2D_3 (-0.470*). It also established a significant direct relation with available P at L_1D_2 (0.460*).

Size separates belonging to fraction-4 developed significant negative relationship with organic carbon only at L_1D_1 (Table 22). Available P was found to have significant positive correlation at L_1D_3. With other size fractions, it established similar relationship as in the case of fraction-3.

Data presented in Table 23 revealed a negative relationship of fraction-5 with all other size fractions. It was also found that it established significant positive relationship with bulk density and pH at L_3D_1, with EC at L_1D_2, with organic

Table 19. Correlation between soil fraction-1 and soil physico-chemical properties of situation A

RRC	F2	F3	F4	F5	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	0.601**	0.243	0.672**	-0.431	0.032	-0.509*	0.207	-0.057	0.521*	-0.091
L_1D_2	0.533*	0.474*	0.566**	0.187	0.007	-0.078	0.282	-0.244	0.314	0.003
L_1D_3	0.489*	0.485*	0.760**	-0.684**	0.118	-0.202	0.074	-0.251	0.432	-0.014
L_2D_1	0.268	0.370	0.644**	-0.456*	-0.122	-0.266	0.013	-0.209	0.008	-0.109
L_2D_2	0.611**	0.603**	0.532*	-0.679**	0.287	-0.042	-0.187	-0.519*	0.348	-0.183
L_2D_3	0.539*	0.573**	0.700**	-0.612**	-0.066	-0.074	-0.085	-0.318	0.424	-0.219
L_3D_1	0.177	-0.028	0.491*	-0.107	-0.159	0.056	-0.113	-0.552*	-0.128	-0.350
L_3D_2	0.262	0.215	0.354	-0.350	-0.019	-0.208	0.004	-0.549*	0.283	-0.318
L_3D_3	0.489*	0.626**	0.480*	-0.766**	-0.102	0.048	0.044	-0.146	0.013	-0.411

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 20. Correlation between soil fraction-2 and soil physico-chemical properties of situation A

RRC	F1	F3	F4	F5	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	0.601**	0.600**	0.577**	-0.768**	0.283	0.021	0.154	-0.226	0.592**	-0.434
L_1D_2	0.553*	0.183	0.454*	-0.274	-0.072	0.083	-0.049	-0.142	0.265	-0.019
L_1D_3	0.489*	0.299	0.467*	-0.535*	0.092	0.082	0.253	-0.400	0.304	-0.042
L_2D_1	0.268	0.487*	0.493*	-0.659**	-0.433	-0.145	-0.122	-0.270	0.260	-0.081
L_2D_2	0.611**	0.498*	0.355	-0.627**	0.129	-0.123	-0.206	-0.320	0.646**	-0.218
L_2D_3	0.539*	0.530*	0.485*	-0.688**	-0.110	0.072	-0.348	-0.482*	0.344	-0.594*
L_3D_1	0.172	0.434	-0.155	-0.532*	-0.523*	-0.267	0.093	-0.043	0.555*	0.109
L_3D_2	0.202	-0.221	0.071	-0.164	0.086	-0.022	-0.239	-0.127	0.206	0.060
L_3D_3	0.489*	0.009	0.019	-0.300	-0.226	-0.076	-0.300	-0.078	0.007	-0.423

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 21. Correlation between soil fraction-3 and soil physico-chemical properties of situation A

RRC	F1	F2	F4	F5	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	0.243	0.600**	0.370	-0.959**	-0.135	-0.020	0.082	-0.226	0.195	-0.211
L_1D_2	0.474*	0.183	0.514*	-0.908**	0.058	-0.128	-0.100	-0.144	0.460*	-0.067
L_1D_3	0.485*	0.299	0.519*	-0.921**	-0.175	0.105	-0.234	-0.272	0.193	-0.292
L_2D_1	0.370	0.487*	0.644**	-0.945**	-0.303	-0.056	0.093	-0.542*	-0.246	-0.417
L_2D_2	0.603**	0.498*	0.653**	-0.949**	0.133	0.059	-0.201	-0.402	0.172	-0.018
L_2D_3	0.573**	0.530*	0.578**	-0.939**	-0.006	0.221	-0.161	-0.470*	0.203	-0.054
L_3D_1	-0.028	0.434	-0.250	-0.846**	-0.382	-0.521*	-0.413	0.023	0.027	0.036
L_3D_2	0.215	-0.221	0.590**	-0.882**	-0.035	-0.078	-0.500*	-0.396	0.222	-0.238
L_3D_3	0.626**	0.009	0.376	-0.940**	0.036	0.080	0.215	-0.165	-0.123	0.100

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 22. Correlation between soil fraction-4 and soil physico-chemical properties of situation A

RRC	F1	F2	F3	F5	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	0.672**	0.577**	0.370	-0.583**	-0.002	-0.214	0.033	-0.452*	0.371	-0.125
L_1D_2	0.566**	0.454*	0.514*	-0.665**	-0.090	0.085	0.299	-0.220	0.348	0.229
L_1D_3	0.760**	0.467*	0.519*	-0.785**	-0.097	0.013	0.060	-0.235	0.509*	0.094
L_2D_1	0.644**	0.493*	0.644**	-0.804**	-0.340	-0.234	0.000	-0.124	-0.230	-0.181
L_2D_2	0.532*	0.355	0.653**	-0.822**	-0.208	0.141	0.025	-0.374	0.115	-0.129
L_2D_3	0.700**	0.485*	0.578**	-0.729**	-0.433	0.209	-0.369	-0.377	0.311	-0.335
L_3D_1	0.491*	-0.155	-0.250	-0.784**	-0.239	0.000	0.010	-0.239	-0.324	-0.274
L_3D_2	0.354	0.071	0.590**	-0.827**	-0.352	0.155	0.405	-0.408	0.063	-0.182
L_3D_3	0.480*	0.109	0.376	-0.541*	-0.373	-0.044	0.137	-0.157	0.064	-0.112

** - Significant at 1 per cent level

* - Significant at 5 per cent level

F - Soil size fraction

L - Radial position from the bole

D - Depth from surface (cm)

Table 23. Correlation between soil fraction-5 and soil physico-chemical properties of situation A

RRC	F1	F2	F3	F4	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	-0.431	-0.768**	-0.959**	-0.583**	0.048	0.051	-0.100	0.002	-0.328	0.272
L_1D_2	0.187	-0.274	0.008	0.065	0.145	0.317	0.602**	-0.086	0.305	0.280
L_1D_3	-0.684**	-0.535*	-0.921**	-0.785**	0.152	-0.083	0.087	0.351	-0.335	0.175
L_2D_1	-0.456*	-0.659**	-0.945**	-0.804**	0.387	0.138	-0.018	0.508*	0.175	0.342
L_2D_2	-0.679**	-0.627**	-0.949**	-0.822**	-0.037	-0.062	0.158	0.444*	-0.275	0.097
L_2D_3	-0.692**	-0.688**	-0.939**	-0.779**	0.159	-0.207	0.286	0.491*	-0.339	0.249
L_3D_1	-0.107	-0.532*	-0.846**	-0.184	0.597**	0.584**	0.283	0.043	-0.129	-0.019
L_3D_2	-0.350	-0.164	-0.882**	-0.827**	0.134	0.004	-0.444*	0.505*	-0.198	0.223
L_3D_3	-0.766**	-0.300	-0.940**	-0.541*	0.102	-0.045	-0.144	0.196	0.092	0.230

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

carbon at L_2D_1, L_2D_2 , L_2D_3 and L_3D_2. The correlation with available K was also tended to become positive.

Similar studies were also conducted in situation B and data presented in Tables 24 to 28.

It was observed that the correlation between fraction-1 and other fractions were found to be highly significant at all radial and vertical distances studied which is evident from Table 24. Fraction-4 and fraction-5 showed negative correlation with fraction-1. Data on correlation between fraction-1 with chemical characteristics (Table 24) revealed significant positive relationship with organic carbon and available P at 0-30 cm depth irrespective of radial distances from the bole of the palm. Significant positive relationship was also observed with pH at certain locations. But it failed to establish any relationship with EC and available K. Bulk density of the soil was also found to be influenced by the content of fraction-1 at D_1 and D_3.

Data on correlation between fraction-2 and other fractions presented in Table 25 showed similar trend as in the case of fraction-1. Among chemical properties significant relationship was established only with pH at all locations and organic carbon at L_1D_1 and L_1D_2.

Data presented in Table 26 showed strong positive relationship of fraction-3 with fraction-1 and fraction-2 irrespective of depth and lateral distance. It also developed significant but negative relationship with the finest fraction. It was also noticed that fraction-3 established better relationship with chemical properties like pH and organic carbon.

Table 24. Correlation between soil fraction-1 and soil physico-chemical properties of situation B

RRC	F2	F3	F4	F5	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	0.749**	0.655**	-0.353	-0.799**	0.426	0.579**	0.205	0.748**	0.215	0.315
L_1D_2	0.863**	0.746**	-0.226	-0.862**	0.095	0.399	0.289	0.501*	0.488*	0.190
L_1D_3	0.859**	0.454*	-0.485*	-0.741**	0.872**	0.279	0.063	0.426	0.076	0.175
L_2D_1	0.819**	0.722**	-0.438	-0.850**	0.471*	0.470*	-0.036	0.682**	0.117	0.069
L_2D_2	0.809**	0.763**	-0.549*	-0.867**	0.186	0.549*	0.008	0.453*	0.508*	-0.095
L_2D_3	0.897**	0.552*	-0.502*	-0.807**	0.871**	0.308	0.207	0.360	0.192	-0.194
L_3D_1	0.712**	0.629**	-0.253	-0.720**	0.499*	0.372	0.195	0.323	0.394	-0.230
L_3D_2	0.769**	0.751**	-0.412	-0.841**	0.299	0.440	0.145	0.530*	0.691**	-0.153
L_3D_3	0.824**	0.512*	-0.414	-0.760**	0.788**	0.120	0.356	-0.013	0.439	-0.146

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 25. Correlation between soil fraction-2 and soil physico-chemical properties of situation B

RRC	F1	F3	F4	F5	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	0.749**	0.474*	-0.264	-0.909**	0.332	0.634**	-0.117	0.512*	-0.008	0.031
L_1D_2	0.863**	0.688**	-0.344	-0.906**	-0.234	0.579**	0.090	0.602**	0.088	0.297
L_1D_3	0.859**	0.502*	-0.414	-0.874**	0.701**	0.449*	0.217	0.358	-0.042	0.048
L_2D_1	0.819**	0.614**	-0.522*	-0.923**	0.335	0.534*	-0.083	0.400	-0.125	-0.116
L_2D_2	0.890**	0.670**	-0.532*	-0.916**	0.013	0.665**	-0.172	0.325	0.259	-0.158
L_2D_3	0.897**	0.630**	-0.508*	-0.912**	0.709**	0.459*	0.282	0.217	0.203	-0.055
L_3D_1	0.712**	0.684**	-0.397	-0.903**	0.276	0.518*	0.037	0.140	0.119	-0.285
L_3D_2	0.769**	0.515*	-0.369	-0.882**	0.219	0.608**	-0.085	0.229	0.289	-0.110
L_3D_3	0.874**	0.519*	-0.279	-0.867**	0.550*	0.282	0.284	-0.020	0.409	-0.020

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 26. Correlation between soil fraction-3 and soil physico-chemical properties of situation B

RRC	F1	F2	F4	F5	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	0.655**	0.474*	-0.296	-0.773**	0.129	0.541*	0.278	0.532*	0.268	0.210
L_1D_2	0.746**	0.688**	0.063	-0.912**	-0.168	0.451*	0.507*	0.593**	0.104	0.163
L_1D_3	0.454*	0.502*	0.129	-0.845**	0.401	0.496*	0.218	0.659**	-0.020	0.216
L_2D_1	0.722**	0.614**	-0.354	-0.865**	0.125	0.602**	0.277	0.485*	0.195	0.131
L_2D_2	0.763**	0.670**	-0.199	-0.885**	-0.145	0.631**	0.309	0.550*	0.350	0.163
L_2D_3	0.552*	0.630**	0.147	-0.888**	0.539*	0.576**	0.564**	0.481*	0.140	-0.183
L_3D_1	0.629**	0.684**	-0.076	-0.918**	0.108	0.476*	0.371	0.243	0.314	-0.037
L_3D_2	0.751**	0.515*	-0.148	-0.839**	0.026	0.461*	0.311	0.527*	0.506*	-0.101
L_3D_3	0.512*	0.519*	0.250	-0.861**	0.425	0.423	0.385	0.129	0.272	-0.111

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 27. Correlation between soil fraction-4 and soil physico-chemical properties of situation B

RRC	F1	F2	F3	F5	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	-0.353	-0.264	-0.296	0.174	0.025	0.009	-0.427	-0.421	0.208	-0.313
L_1D_2	-0.226	-0.344	0.063	0.026	-0.088	0.054	0.345	-0.095	0.099	-0.178
L_1D_3	0.485*	0.414	0.129	0.074	-0.076	-0.068	0.025	0.168	-0.165	-0.226
L_2D_1	-0.438	-0.522*	-0.354	0.421	-0.135	-0.321	-0.363	-0.395	0.110	-0.175
L_2D_2	-0.549*	-0.532*	-0.199	0.330	-0.178	-0.046	-0.000	-0.065	-0.132	0.347
L_2D_3	-0.502*	-0.508*	0.142	0.180	-0.311	0.065	0.075	-0.081	-0.180	-0.152
L_3D_1	-0.253	-0.397	-0.076	0.139	-0.180	-0.093	-0.117	0.134	-0.060	0.233
L_3D_2	-0.412	-0.369	-0.148	0.170	-0.118	-0.060	0.352	-0.081	-0.105	0.222
L_3D_3	-0.414	-0.279	0.250	-0.089	-0.273	0.219	0.054	0.089	-0.419	0.076

* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 28. Correlation between soil fraction-5 and soil physico-chemical properties of situation B

RRC	F1	F2	F3	F4	m/v	pH	EC	O.C.	Av.P	Av.K
L_1D_1	-0.799**	-0.909**	-0.773**	0.174	-0.306	-0.719**	0.020	-0.558*	-0.155	-0.073
L_1D_2	-0.862**	-0.906**	-0.912**	0.026	-0.244	-0.592**	-0.363	-0.645**	-0.121	-0.238
L_1D_3	-0.741**	-0.874**	-0.845**	0.074	-0.622**	-0.538*	-0.259	-0.589**	0.064	-0.101
L_2D_1	-0.859**	-0.923**	-0.863**	-0.421	-0.270	-0.620**	-0.038	-0.465*	-0.020	0.035
L_2D_2	-0.887**	-0.916**	-0.885**	0.330	0.059	-0.727**	-0.019	-0.399	-0.354	0.023
L_2D_3	-0.807**	-0.912**	-0.888**	0.180	-0.692**	-0.517*	-0.450*	-0.307	-0.182	0.135
L_3D_1	-0.720**	-0.903**	-0.918**	0.139	-0.198	-0.546*	-0.192	-0.229	-0.323	0.158
L_3D_2	-0.841**	-0.882**	-0.839**	0.170	-0.171	-0.638**	-0.158	-0.413	-0.439	0.170
L_3D_3	-0.760**	-0.867**	-0.861**	-0.089	-0.526*	-0.827**	-0.381	-0.062	-0.337	0.058

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Relationships of fraction-4 with other size separates were not positively significant except with F1 (L_1D_3) which is evident from the data presented in Table 27. Similarly chemical properties were not associated with F4.

Fraction-5 was found to be negatively but significantly related with fraction-1, 2 and 3 (Table 28). Among chemical properties, pH showed significant negative correlation with the fraction at all locations. Organic carbon content of soil inside the basin also established significant relationship at all depths. It can also be seen from the table that other chemical properties like EC, available P and available K content were not associated with the quantity of fraction-5 in the soil.

4.6 Inter-relation between leaf nutrients and soil physical properties

Data on correlation between leaf nutrients and soil physical properties are presented in Table 29 to 34. In situation A it was noticed that leaf N and P did not show any significant relationship with any of the soil fractions (Tables 29 and 30). However, bulk density of D_2 was found to be linked with leaf N content irrespective of lateral distance. Unlike N and P leaf K percentage was related with fraction-1 at almost all locations Table 31. But other soil size fractions did not influence leaf K level.

Data presented in Table 32 revealed that leaf N content of situation B was influenced by size of soil separates, while coarser fractions like fraction-1, 2 and 3 influenced inversely, finer fractions showed positive correlation with leaf N content. Among different size groups, most prominent relationship was obtained with fraction-1. Leaf P did not show significant relationship with any soil fraction (Table 33). The data also revealed that leaf K was negatively correlated with

Table 29. Correlation between leaf N and soil physical properties of situation A

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	0.166	0.310	0.175	0.019	-0.199	0.217
L_1D_2	0.199	0.170	0.257	0.044	-0.239	0.494*
L_1D_3	0.235	0.174	0.230	0.011	-0.193	0.237
L_2D_1	0.096	0.392	0.409	0.081	-0.385	0.109
L_2D_2	0.260	0.296	0.265	0.074	-0.249	0.501*
L_2D_3	0.246	0.228	0.206	0.069	-0.228	0.268
L_3D_1	0.132	0.279	0.353	-0.106	-0.282	0.008
L_3D_2	0.253	0.126	0.241	0.186	-0.283	0.502*
L_3D_3	0.134	0.052	0.089	0.169	-0.120	0.480*

Table 30. Correlation between leaf P and soil physical properties of situation A

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	0.206	0.364	0.029	-0.024	-0.091	0.344
L_1D_2	0.191	0.155	0.178	-0.028	-0.130	0.264
L_1D_3	0.050	-0.047	0.260	0.071	-0.194	0.046
L_2D_1	0.202	0.132	0.129	0.208	-0.161	0.233
L_2D_2	0.159	0.214	0.243	0.168	-0.252	0.269
L_2D_3	0.076	-0.049	0.203	-0.021	0.166	0.102
L_3D_1	0.350	-0.097	0.072	-0.021	0.166	0.102
L_3D_2	0.112	0.070	0.129	0.219	-0.197	0.260
L_3D_3	0.130	-0.063	0.176	0.271	-0.163	-0.128

* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 31. Correlation between leaf K and soil physical properties of situation A

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	0.539*	0.263	0.012	0.254	-0.090	0.119
L_1D_2	0.498*	0.436	0.155	0.164	-0.242	-0.047
L_1D_3	0.527*	0.151	0.097	0.401	-0.232	0.337
L_2D_1	0.329	0.248	0.208	0.077	-0.180	-0.006
L_2D_2	0.520*	0.541*	0.295	0.065	-0.312	0.006
L_2D_3	0.504*	0.210	0.298	0.104	-0.254	0.288
L_3D_1	0.300	0.032	0.129	0.143	-0.172	-0.086
L_3D_2	0.550*	0.095	0.347	0.012	-0.284	0.059
L_3D_3	0.518*	0.175	0.308	0.076	-0.291	0.236

Table 32. Correlation between leaf N and soil physical properties of situation B

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	-0.620**	-0.498*	-0.234	0.253	0.433	-0.365
L_1D_2	-0.633**	-0.487*	-0.199	0.387	0.342	-0.191
L_1D_3	-0.544*	-0.367	-0.335	0.309	0.368	-0.638**
L_2D_1	-0.631**	-0.510*	-0.252	0.210	0.447*	-0.360
L_2D_2	-0.588**	-0.431	-0.445*	0.449*	0.461*	-0.282
L_2D_3	-0.555*	-0.303	-0.240	0.285	0.283	-0.566**
L_3D_1	-0.612**	-0.466*	-0.304	0.208	0.410	-0.320
L_3D_2	-0.590**	-0.324	-0.532*	0.314	0.444*	-0.310
L_3D_3	-0.529*	-0.315	-0.196	0.272	0.261	-0.416

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 33. Correlation between leaf P and soil physical properties of situation B

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	0.235	0.085	-0.080	0.099	-0.039	0.138
L_1D_2	0.092	0.061	0.042	-0.296	-0.008	-0.062
L_1D_3	0.262	0.143	0.181	-0.236	-0.149	0.297
L_2D_1	0.215	0.054	-0.003	0.013	-0.037	0.110
L_2D_2	0.134	0.045	0.046	-0.170	-0.057	0.160
L_2D_3	0.204	0.072	-0.011	-0.341	-0.008	0.322
L_3D_1	0.176	-0.023	0.024	-0.047	-0.009	0.063
L_3D_2	0.171	-0.030	0.033	-0.060	-0.013	0.322
L_3D_3	0.128	-0.049	-0.107	-0.215	-0.117	0.290

Table 34. Correlation between leaf K and soil physical properties of situation B

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	0.024	0.193	-0.254	0.208	-0.051	-0.091
L_1D_2	-0.043	-0.035	-0.410	-0.223	0.245	0.394
L_1D_3	0.039	-0.132	-0.417	-0.213	0.323	0.031
L_2D_1	0.006	0.134	-0.111	-0.050	0.043	-0.106
L_2D_2	0.035	0.055	-0.389	-0.294	0.175	0.468*
L_2D_3	0.049	-0.021	-0.468*	-0.476*	0.271	0.058
L_3D_1	-0.039	0.076	-0.095	-0.185	-0.068	-0.118
L_3D_2	-0.004	0.137	-0.403	-0.324	0.166	0.456*
L_3D_3	0.051	0.025	-0.286	-0.414	0.185	0.074

* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

fraction-3 and 4 at L_2D_3. It was also significantly associated with bulk density at L_2D_2 (0.468*) and L_3D_2 (0.456*) (Table 34).

4.7 Inter-relation between leaf and soil nutrients

Correlation of leaf content of nitrogen with various soil chemical parameters of situation A is presented in Table 35. From the result it is clear that leaf N has significant negative correlation with organic carbon at L_3D_2 in S_1 and S_2. However, in third season, leaf N was positively correlated with organic carbon at L_3D_1.

Leaf P content of situation A failed to show significant relationship with any soil characteristic in all the three seasons except available P at L_1D_1 in the third season (Table 36).

Leaf K content of situation A established a significant relationship with soil K only in the second season at L_1D_2 (Table 37). However, it was found to be associated with available P content of soil at L_1D_1, L_1D_3 and at L_2D_2 in the first season.

In situation B leaf N showed negative relationship with organic carbon content of the soil at L_1D_1 in the first season, while in the second season the relationship was significant at all vertical and radial distances (Table 38).

It can be seen from the Table 39 that leaf content of P showed significant negative relationship with available P at L_2D_3 and L_3D_1 in the second season and

Table 35. Correlation between leaf N and soil chemical parameters of situation A

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	0.381	-0.208	-0.212	0.054	-0.207
$L_1D_2S_1$	-0.113	0.031	-0.221	0.013	-0.089
$L_1D_3S_1$	-0.164	-0.036	-0.194	0.151	-0.394
$L_2D_1S_1$	0.337	-0.212	-0.390	0.038	-0.218
$L_2D_2S_1$	-0.047	0.056	-0.390	0.139	-0.171
$L_2D_3S_1$	0.160	-0.020	-0.222	0.259	-0.375
$L_3D_1S_1$	0.200	-0.047	-0.317	0.111	-0.071
$L_3D_2S_1$	-0.181	0.144	-0.463*	0.138	-0.236
$L_3D_3S_1$	-0.023	-0.034	-0.387	0.135	-0.079
$L_1D_1S_2$	0.049	-0.001	0.289	0.256	0.361
$L_1D_2S_2$	0.020	0.046	0.252	0.044	-0.148
$L_1D_3S_2$	0.125	-0.144	0.280	-0.031	0.398
$L_2D_1S_2$	0.141	-0.206	0.210	-0.001	0.255
$L_2D_2S_2$	0.027	-0.182	0.151	-0.057	0.135
$L_2D_3S_2$	0.176	-0.198	0.196	0.168	0.310
$L_3D_1S_2$	0.064	-0.267	0.189	-0.025	0.249
$L_3D_2S_2$	-0.151	-0.513*	-0.499*	-0.536*	0.217
$L_3D_3S_2$	0.058	-0.381	-0.132	-0.296	0.138
$L_1D_1S_3$	0.243	-0.080	0.360	0.156	-0.009
$L_1D_2S_3$	0.089	0.171	0.270	0.079	-0.186
$L_1D_3S_3$	0.115	0.115	0.324	-0.004	-0.074
$L_2D_1S_3$	0.278	0.080	0.286	0.279	0.082
$L_2D_2S_3$	0.024	0.203	0.185	0.039	0.029
$L_2D_3S_3$	0.033	0.196	0.176	-0.048	-0.102
$L_3D_1S_3$	0.102	0.314	0.505*	0.291	0.118
$L_3D_2S_3$	-0.011	0.251	0.156	0.050	0.207
$L_3D_3S_3$	-0.052	0.254	0.064	-0.384	-0.233

* - Significant at 5 per cent level; L - Radial position from the bole

S - Season; D - Depth from surface (cm)

Table 36. Correlation between leaf P and soil chemical parameters of situation A

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	0.105	-0.139	0.069	0.204	-0.293
$L_1D_2S_1$	0.359	-0.042	-0.172	0.248	-0.035
$L_1D_3S_1$	0.093	-0.119	-0.155	0.111	-0.076
$L_2D_1S_1$	0.262	-0.038	-0.053	0.207	-0.220
$L_2D_2S_1$	0.430	-0.158	-0.202	0.152	-0.220
$L_2D_3S_1$	0.436	0.008	-0.241	0.249	-0.077
$L_3D_1S_1$	0.394	-0.070	-0.311	-0.308	-0.041
$L_3D_2S_1$	0.290	-0.065	-0.289	-0.252	-0.308
$L_3D_3S_1$	0.463*	-0.248	-0.203	-0.062	-0.063
$L_1D_1S_2$	-0.338	0.395	0.365	0.361	-0.018
$L_1D_2S_2$	-0.225	0.247	0.095	0.238	-0.165
$L_1D_3S_2$	-0.170	0.415	0.125	0.107	-0.182
$L_2D_1S_2$	-0.161	0.366	0.236	0.144	0.056
$L_2D_2S_2$	-0.162	0.369	0.225	0.264	-0.194
$L_2D_3S_2$	-0.062	0.328	0.096	0.050	-0.043
$L_3D_1S_2$	-0.124	0.126	-0.137	0.025	0.010
$L_3D_2S_2$	-0.158	0.072	0.059	0.143	-0.385
$L_3D_3S_2$	-0.223	-0.001	-0.096	-0.129	-0.060
$L_1D_1S_3$	0.086	0.101	0.036	0.570**	-0.251
$L_1D_2S_3$	0.292	0.031	-0.187	0.210	0.256
$L_1D_3S_3$	0.084	0.058	-0.165	0.175	0.105
$L_2D_1S_3$	0.157	0.213	-0.293	0.107	0.127
$L_2D_2S_3$	0.237	0.195	-0.184	0.122	0.122
$L_2D_3S_3$	0.196	0.104	-0.197	0.149	0.149
$L_3D_1S_3$	0.204	0.237	-0.035	0.177	0.177
$L_3D_2S_3$	0.162	0.179	-0.021	0.046	0.046
$L_3D_3S_3$	0.194	-0.149	-0.421	-0.191	-0.191

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

L - Radial position from the bole; S - Season;

D - Depth from surface (cm)

Table 37. Correlation between leaf K and soil chemical parameters of situation A

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	-0.194	0.286	-0.013	0.524*	-0.079
$L_1D_2S_1$	0.011	0.210	-0.219	0.439	0.017
$L_1D_3S_1$	0.100	0.285	0.008	0.453*	0.108
$L_2D_1S_1$	-0.181	0.423	-0.063	0.377	-0.247
$L_2D_2S_1$	-0.127	-0.114	-0.266	0.501*	0.030
$L_2D_3S_1$	0.036	0.126	-0.112	0.429	0.019
$L_3D_1S_1$	-0.109	0.143	-0.092	0.087	-0.097
$L_3D_2S_1$	0.417	-0.181	-0.066	0.411	-0.250
$L_3D_3S_1$	0.106	-0.157	-0.089	0.342	-0.104
$L_1D_1S_2$	-0.141	0.233	0.085	0.097	0.340
$L_1D_2S_2$	-0.010	0.029	0.018	0.185	0.495*
$L_1D_3S_2$	-0.106	0.076	0.169	0.227	0.280
$L_2D_1S_2$	0.029	0.157	0.073	0.015	0.274
$L_2D_2S_2$	-0.005	0.061	-0.110	0.134	0.386
$L_2D_3S_2$	-0.186	-0.054	0.003	0.030	0.259
$L_3D_1S_2$	0.208	0.074	0.044	0.213	-0.336
$L_3D_2S_2$	0.022	-0.249	-0.371	-0.063	0.020
$L_3D_3S_2$	-0.204	-0.164	-0.173	0.013	0.187
$L_1D_1S_3$	0.145	0.245	-0.017	0.058	0.423
$L_1D_2S_3$	0.300	0.081	0.139	0.049	0.277
$L_1D_3S_3$	0.107	0.078	-0.046	-0.164	0.009
$L_2D_1S_3$	0.117	0.264	-0.108	0.375	0.304
$L_2D_2S_3$	0.130	0.211	-0.208	0.190	0.306
$L_2D_3S_3$	0.085	0.095	-0.062	-0.084	0.064
$L_3D_1S_3$	0.304	0.195	0.164	0.424	0.114
$L_3D_2S_3$	0.056	0.105	-0.075	0.465*	0.163
$L_3D_3S_3$	0.015	0.223	-0.054	-0.038	-0.118

* - Significant at 5 per cent level; L - Radial position from the bole

S - Season; D - Depth from surface (cm)

Table 38. Correlation between leaf N and soil chemical parameters of situation B

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	-0.247	-0.097	-0.456*	0.253	-0.462*
$L_1D_2S_1$	-0.002	-0.106	-0.214	0.017	-0.267
$L_1D_3S_1$	-0.019	0.126	-0.102	0.053	-0.435
$L_2D_1S_1$	-0.109	0.036	-0.368	0.191	-0.289
$L_2D_2S_1$	-0.080	0.041	-0.121	-0.255	0.012
$L_2D_3S_1$	-0.128	-0.052	-0.103	0.021	0.009
$L_3D_1S_1$	-0.002	-0.017	-0.037	0.046	0.111
$L_3D_2S_1$	0.080	0.117	-0.141	-0.369	0.261
$L_3D_3S_1$	0.077	-0.055	0.047	-0.129	-0.163
$L_1D_1S_2$	0.308	0.170	-0.532*	0.508*	0.407
$L_1D_2S_2$	0.099	0.003	-0.538*	0.048	0.371
$L_1D_3S_2$	0.165	0.167	-0.485*	0.073	0.220
$L_2D_1S_2$	0.213	-0.042	-0.543*	0.398	0.360
$L_2D_2S_2$	0.070	0.025	-0.636**	-0.045	0.308
$L_2D_3S_2$	0.021	0.197	-0.444*	-0.104	0.300
$L_3D_1S_2$	0.201	0.025	-0.518*	-0.169	0.084
$L_3D_2S_2$	-0.072	0.019	-0.565**	-0.002	0.124
$L_3D_3S_2$	0.113	0.171	-0.499*	-0.041	-0.003
$L_1D_1S_3$	-0.208	0.180	0.260	0.048	-0.187
$L_1D_2S_3$	-0.150	0.066	0.266	0.227	-0.037
$L_1D_3S_3$	-0.226	-0.186	0.265	0.447*	-0.001
$L_2D_1S_3$	-0.172	0.039	0.325	0.045	-0.087
$L_2D_2S_3$	-0.173	0.026	0.085	0.163	-0.032
$L_2D_3S_3$	-0.022	-0.018	-0.278	0.309	-0.044
$L_3D_1S_3$	-0.321	-0.069	0.160	-0.048	-0.008
$L_3D_2S_3$	-0.149	-0.293	-0.036	0.030	-0.069
$L_3D_3S_3$	0.186	0.243	0.145	0.039	0.010

* - Significant at 5 per cent level; ** - Significant at 1 per cent level
L - Radial position from the bole; S - Season
D - Depth from surface (cm)

Table 39. Correlation between leaf P and soil chemical parameters of situation B

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	-0.142	0.024	0.197	-0.187	0.406
$L_1D_2S_1$	-0.102	-0.010	0.093	-0.064	0.025
$L_1D_3S_1$	-0.111	-0.061	-0.130	-0.104	0.158
$L_2D_1S_1$	-0.251	-0.033	0.256	0.104	0.403
$L_2D_2S_1$	-0.325	0.007	0.093	-0.038	0.174
$L_2D_3S_1$	-0.242	0.104	0.015	-0.041	0.244
$L_3D_1S_1$	-0.062	0.075	0.270	0.060	0.053
$L_3D_2S_1$	-0.174	0.064	0.141	0.170	-0.112
$L_3D_3S_1$	-0.139	0.168	0.244	-0.173	-0.144
$L_1D_1S_2$	-0.0.50	0.120	-0.271	-0.094	0.189
$L_1D_2S_2$	-0.108	0.237	-0.264	-0.245	0.573**
$L_1D_3S_2$	-0.115	0.435	-0.313	-0.252	-0.261
$L_2D_1S_2$	-0.176	-0.183	-0.217	-0.186	0.203
$L_2D_2S_2$	-0.332	-0.211	-0.335	-0.300	0.493*
$L_2D_3S_2$	-0.082	0.139	-0.236	-0.486*	-0.177
$L_3D_1S_2$	-0.098	0.093	-0.150	-0.484*	0.323
$L_3D_2S_2$	-0.260	0.241	-0.098	-0.221	0.482*
$L_3D_3S_2$	-0.081	0.261	-0.174	-0.308	0.315
$L_1D_1S_3$	-0.172	0.046	-0.227	-0.303	-0.016
$L_1D_2S_3$	-0.191	0.011	-0.118	-0.032	0.029
$L_1D_3S_3$	-0.337	0.031	-0.107	-0.007	-0.062
$L_2D_1S_3$	-0.275	0.104	-0.052	0.254	0.082
$L_2D_2S_3$	-0.189	0.114	-0.041	0.057	-0.023
$L_2D_3S_3$	-0.297	0.265	-0.062	0.015	-0.004
$L_3D_1S_3$	-0.203	0.202	0.067	0.441	0.120
$L_3D_2S_3$	-0.195	0.190	0.164	0.313	0.019
$L_3D_3S_3$	-0.130	0.105	-0.067	0.283	0.022

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

L - Radial position from the bole; S - Season

D - Depth from surface (cm)

Table 40. Correlation between leaf K and soil chemical parameters of situation B

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	0.014	-0.311	-0.142	0.116	-0.028
$L_1D_2S_1$	-0.137	-0.259	-0.442	0.125	0.168
$L_1D_3S_1$	-0.244	-0.366	-0.551*	-0.050	0.355
$L_2D_1S_1$	-0.234	-0.358	-0.102	-0.200	-0.052
$L_2D_2S_1$	-0.223	-0.231	-0.353	0.039	-0.256
$L_2D_3S_1$	-0.307	-0.406	-0.350	-0.012	0.229
$L_3D_1S_1$	-0.298	-0.426	-0.340	-0.161	-0.071
$L_3D_2S_1$	-0.293	-0.288	-0.333	-0.135	-0.133
$L_3D_3S_1$	-0.356	-0.254	-0.348	0.129	-0.101
$L_1D_1S_2$	0.047	-0.210	-0.147	-0.208	-0.150
$L_1D_2S_2$	-0.180	-0.141	-0.178	-0.394	-0.210
$L_1D_3S_2$	-0.109	0.266	-0.210	-0.189	-0.084
$L_2D_1S_2$	0.040	-0.002	-0.060	-0.161	-0.117
$L_2D_2S_2$	-0.135	-0.072	-0.117	-0.415	-0.233
$L_2D_3S_2$	-0.166	0.010	-0.299	-0.274	-0.219
$L_3D_1S_2$	0.018	-0.054	-0.182	-0.400	-0.082
$L_3D_2S_2$	-0.038	-0.142	0.061	-0.203	0.014
$L_3D_3S_2$	-0.095	-0.124	-0.107	0.060	-0.028
$L_1D_1S_3$	0.176	0.064	-0.086	0.070	0.076
$L_1D_2S_3$	0.108	-0.077	-0.198	0.039	-0.058
$L_1D_3S_3$	-0.010	-0.077	-0.288	-0.135	-0.006
$L_2D_1S_3$	0.075	-0.065	-0.126	0.247	0.090
$L_2D_2S_3$	0.158	-0.062	-0.180	0.005	-0.046
$L_2D_3S_3$	-0.144	-0.060	0.049	-0.079	-0.028
$L_3D_1S_3$	-0.030	-0.177	-0.091	-0.130	-0.065
$L_3D_2S_3$	-0.080	-0.062	-0.023	-0.047	-0.182
$L_3D_3S_3$	-0.158	-0.194	0.090	-0.021	-0.133

* - Significant at 5 per cent level; L - Radial position from the bole

S - Season; D - Depth from surface (cm)

strong positive relationship with available K at L_1D_2, L_2D_2 and L_3D_2. Leaf P content had no relationship with any other soil chemical parameter.

Leaf K percentage of situation B was found to be negatively correlated with organic carbon at L_1D_3 in the first season and it did not show significant relationship with any other soil chemical parameter (Table 40).

4.8 Inter-relation between seasonal yield parameters and soil physical properties

Data presented in Table 41 showed that in situation A, for number of leaves significant relation was obtained at L_2D_1 for fraction-2, 3 and 5 as well as bulk density. But the relation was negative for fraction-5 and bulk density. Fraction-3 also established positive and significant relationship at L_1D_1 (0.444*) and L_1D_3 (0.473*). Fraction 1 and 4 failed to develop significant relation at any locations.

Nut production of situation A was strongly influenced by the quantity of soil size fractions (Table 42). Negative relationship was obtained only with fraction-5. Relationship between fraction-2 and number of nuts was weaker when compared with other fractions.

Strong positive correlation was obtained between fraction-1 and number of bunches produced, at all positions. It also developed significant relation with fraction-3, 4 and 5 at certain position which is evident from the data presented in Table 43.

Table 41. Correlation between number of leaves and soil physical properties of situation A

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	0.375	0.112	0.444*	0.269	-0.414	-0.583**
L_1D_2	0.273	0.024	0.173	0.127	-0.060	-0.239
L_1D_3	0.158	-0.017	0.473*	0.001	-0.336	-0.344
L_2D_1	0.379	0.444*	0.468*	0.387	-0.513*	-0.528*
L_2D_2	0.233	0.073	0.179	0.287	-0.225	-0.273
L_2D_3	0.166	0.325	0.187	0.013	-0.197	-0.312
L_3D_1	0.318	0.345	0.084	0.328	-0.225	-0.358
L_3D_2	0.272	-0.136	0.106	0.379	-0.180	-0.298
L_3D_3	0.116	0.213	0.035	0.013	-0.107	-0.317

Table 42. Correlation between number of nuts and soil physical properties of situation A

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	0.646**	0.750**	0.491*	0.582**	-0.635**	0.154
L_1D_2	0.692**	0.319	0.460*	0.511*	-0.529*	0.166
L_1D_3	0.731**	0.161	0.600**	0.578**	-0.649**	-0.152
L_2D_1	0.721**	0.488*	0.613**	0.622**	-0.675**	0.084
L_2D_2	0.722**	0.482*	0.559*	0.595**	-0.648**	0.137
L_2D_3	0.744**	0.380	0.454*	0.616**	-0.565**	-0.275
L_3D_1	0.697**	0.195	0.132	0.485*	-0.309	0.026
L_3D_2	0.612**	0.057	0.303	0.486*	-0.420	0.108
L_3D_3	0.652**	0.403	0.287	0.470*	-0.443	-0.379

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 43. Correlation between number of bunches and soil physical properties of situation A

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	0.563**	0.332	0.414	0.461*	-0.470*	-0.436
L_1D_2	0.542*	0.331	0.185	0.395	-0.276	-0.155
L_1D_3	0.450*	0.384	0.429	0.219	-0.449*	-0.242
L_2D_1	0.689**	0.431	0.551*	0.576**	-0.608**	-0.367
L_2D_2	0.601**	0.303	0.279	0.438	-0.384	-0.171
L_2D_3	0.465*	0.292	0.335	0.174	-0.358	-0.228
L_3D_1	0.708**	0.228	0.176	0.484*	-0.380	-0.222
L_3D_2	0.488*	0.058	0.363	0.505*	-0.437	-0.170
L_3D_3	0.446*	0.211	0.191	0.258	-0.284	-0.242

Table 44. Correlation between number of leaves and soil physical properties of situation B

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	-0.364	-0.529*	-0.071	0.300	0.376	0.040
L_1D_2	-0.262	-0.430	-0.137	0.577**	0.247	-0.148
L_1D_3	-0.505*	-0.363	-0.096	0.528*	0.218	-0.214
L_2D_1	-0.317	-0.538*	-0.219	0.432	0.381	0.038
L_2D_2	-0.384	-0.503*	-0.148	0.661**	0.308	-0.057
L_2D_3	-0.471*	-0.455*	-0.024	0.548*	0.265	-0.296
L_3D_1	-0.263	-0.523*	-0.187	0.667**	0.319	0.041
L_3D_2	-0.369	-0.418	-0.221	0.596**	0.304	-0.233
L_3D_3	-0.427	-0.442	0.032	0.460*	0.201	-0.336

** - Significant at 1 per cent level
* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

Table 45. Correlation between number of nuts and soil physical properties of situation B

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	-0.142	-0.302	0.227	-0.045	0.118	-0.240
L_1D_2	-0.155	-0.121	0.152	-0.085	0.025	-0.225
L_1D_3	-0.097	-0.032	0.005	-0.221	0.054	-0.263
L_2D_1	-0.196	-0.224	0.191	-0.026	0.064	-0.277
L_2D_2	-0.159	-0.146	0.060	0.090	0.033	-0.234
L_2D_3	-0.154	-0.060	0.056	-0.103	0.029	-0.238
L_3D_1	-0.183	-0.124	0.017	-0.059	0.075	-0.302
L_3D_2	-0.122	-0.130	-0.059	0.275	0.075	-0.302
L_3D_3	0.014	0.005	0.200	0.034	0.104	-0.091

Table 46. Correlation between number of bunches and soil physical properties of situation B

RRC	F_1	F_2	F_3	F_4	F_5	m/v
L_1D_1	-0.284	-0.475*	-0.013	0.009	0.349	-0.495*
L_1D_2	-0.251	-0.384	-0.103	0.328	0.242	0.021
L_1D_3	-0.391	-0.199	0.049	0.135	0.095	-0.267
L_2D_1	-0.311	-0.382	-0.016	0.040	0.264	-0.508*
L_2D_2	-0.312	-0.412	-0.095	0.458*	0.195	0.075
L_2D_3	-0.407	-0.313	-0.090	0.162	0.160	-0.175
L_3D_1	-0.352	-0.364	-0.056	0.211	0.220	-0.504*
L_3D_2	-0.257	-0.413	-0.070	0.370	0.257	0.110
L_3D_3	0.321	-0.402	0.155	0.328	0.142	-0.078

* - Significant at 5 per cent level
F - Soil size fraction
L - Radial position from the bole
D - Depth from surface (cm)

In situation B, fractions F1, F2 and F4 were significantly correlated with number of leaves. Coarser fractions (F1 and F2) established negative relationship (Table 44). Compared with others, fraction-3, fraction-5 and bulk density failed to establish significant relationship with number of leaves produced.

Unlike in the case of situation A, physical properties did not influence number of nuts significantly in situation B (Table 45).

It was also noticed that in general, the number of bunches were also found to be unaffected by physical properties (Table 46).

4.9 Inter-relationship between seasonal yield parameters and soil chemical properties

Data presented in Table 47 revealed that in situation A, the number of leaves produced was significantly influenced by organic carbon and available K in the first season only at L_2D_3 and L_3D_3 respectively. Available P established significant relation in first and second seasons at L_2D_3 and L_3D_1 respectively. But all these relations were negative. Soil pH and EC failed to establish any significant relationship in any location and season.

In the first season nut production of situation A established significant negative relationship with organic carbon at L_2D_1, L_2D_2, L_3D_1 and L_3D_2. It also related significantly and negatively with available K content of first season at L_1D_1, L_2D_1, L_2D_2, L_3D_1 and L_3D_2 (Table 48). In the second and third seasons nut production was not significantly correlated with soil chemical properties.

It was also observed that number of bunches were significantly but negatively correlated with organic carbon at L_1D_2 (-0.575**), L_2D_2 (-0.482*) and L_3D_2 (-0.469*) and available K at L_3D_3 (-0.643**) in the first season (Table 49). In the second season available P at L_3D_1 (-0.490*) established significant relationship. But in the following season all soil chemical properties failed to develop any relationship with bunch production.

In situation B number of leaves were not affected by soil chemical properties in any season (Table 50). But production of nuts in second season was found to be significantly associated with the organic carbon status of soil (Table 51). It was also related with available P at L_3D_3 (0.471*) and available K at L_2D_1 and L_3D_1 in the third season. Number of bunches were influenced by available P content at L_2D_1 (0.506*) in the first season and negatively at L_1D_2, L_1D_3, L_2D_2 , L_2D_3 and L_3D_1 in the second season (Table 52). Organic carbon was also found to be negatively associated with bunch production in the second (L_3D_3) and third (L_2D_3) season. Only in the third season available K content of L_2D_2 (0.570**) established significant relationship. Soil pH had no influence on bunch production except at $L_2D_3S_2$ (-0.452*) but EC established positive significant relationship in the first season.

4.10 Inter-relation among leaf nutrients

Coefficients of correlation among leaf nutrients in different seasons are presented in Table 53a, b and c. Results showed that in situation A leaf N showed significant positive correlation with leaf P in first season (0.569**) and leaf K content in third season (0.449*).

Table 47. Correlation between number of leaves and soil chemical properties of situation A

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	-0.271	0.288	-0.169	-0.204	-0.057
$L_1D_2S_1$	-0.324	0.088	-0.326	-0.399	-0.296
$L_1D_3S_1$	0.015	0.176	-0.142	-0.407	-0.043
$L_2D_1S_1$	-0.269	0.184	-0.434	-0.185	-0.219
$L_2D_2S_1$	-0.106	0.200	-0.419	-0.233	-0.251
$L_2D_3S_1$	-0.206	-0.072	-0.521*	-0.549*	-0.046
$L_3D_1S_1$	-0.088	-0.092	-0.333	-0.071	-0.122
$L_3D_2S_1$	-0.203	-0.023	-0.324	-0.239	-0.156
$L_3D_3S_1$	-0.136	-0.142	-0.291	-0.170	-0.476*
$L_1D_1S_2$	-0.418	0.131	0.096	-0.207	-0.379
$L_1D_2S_2$	-0.138	0.070	-0.151	-0.013	-0.306
$L_1D_3S_2$	-0.127	0.241	0.052	-0.274	-0.189
$L_2D_1S_2$	-0.257	0.273	0.082	-0.404	-0.195
$L_2D_2S_2$	-0.129	0.220	0.262	-0.018	-0.296
$L_2D_3S_2$	-0.115	0.175	0.118	-0.128	-0.182
$L_3D_1S_2$	-0.039	0.014	0.105	-0.454*	0.188
$L_3D_2S_2$	-0.056	0.216	0.341	-0.097	0.197
$L_3D_3S_2$	-0.130	0.216	-0.076	-0.058	0.106
$L_1D_1S_3$	0.338	0.133	-0.211	-0.013	0.442
$L_1D_2S_3$	0.404	0.080	-0.127	0.026	0.267
$L_1D_3S_3$	0.387	0.030	-0.259	-0.194	0.230
$L_2D_1S_3$	0.273	0.215	-0.208	0.179	0.441
$L_2D_2S_3$	0.252	0.189	-0.086	0.087	0.307
$L_2D_3S_3$	0.312	0.080	-0.148	-0.077	0.352
$L_3D_1S_3$	0.375	0.102	-0.093	0.375	0.230
$L_3D_2S_3$	0.128	0.151	-0.159	0.329	0.212
$L_3D_3S_3$	0.324	0.116	-0.139	0.067	0.260

* - Significant at 5 per cent level; L - Radial position from the bole

S - Season; D - Depth from surface (cm)

Table 48. Correlation between number of nuts and soil chemical properties of situation A

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	-0.074	-0.075	-0.251	0.387	-0.453*
$L_1D_2S_1$	-0.075	0.005	-0.138	0.138	-0.226
$L_1D_3S_1$	-0.361	-0.146	-0.278	0.125	-0.183
$L_2D_1S_1$	-0.173	-0.076	-0.499*	0.022	-0.490*
$L_2D_2S_1$	-0.001	-0.076	-0.663**	0.076	-0.479*
$L_2D_3S_1$	-0.065	-0.315	-0.413	0.073	-0.311
$L_3D_1S_1$	-0.166	-0.042	-0.590**	0.006	-0.547*
$L_3D_2S_1$	-0.262	0.049	-0.635**	0.051	-0.557*
$L_3D_3S_1$	-0.221	-0.032	-0.430	-0.024	-0.319
$L_1D_1S_2$	-0.455*	0.213	0.321	0.172	0.142
$L_1D_2S_2$	-0.288	0.136	0.120	0.044	0.235
$L_1D_3S_2$	-0.071	0.206	0.290	0.047	0.429
$L_2D_1S_2$	-0.324	0.245	0.256	0.300	0.317
$L_2D_2S_2$	-0.360	0.244	0.248	0.119	0.156
$L_2D_3S_2$	-0.176	0.150	0.254	0.386	0.395
$L_3D_1S_2$	-0.272	-0.215	-0.041	-0.114	0.125
$L_3D_2S_2$	-0.347	-0.136	0.008	0.233	-0.220
$L_3D_3S_2$	-0.351	-0.131	-0.161	0.247	0.103
$L_1D_1S_3$	0.108	-0.151	-0.034	0.000	0.006
$L_1D_2S_3$	0.098	-0.044	-0.142	-0.150	-0.102
$L_1D_3S_3$	0.016	0.148	-0.122	0.036	0.072
$L_2D_1S_3$	0.174	-0.092	-0.124	0.028	0.036
$L_2D_2S_3$	0.255	-0.060	-0.054	-0.038	0.002
$L_2D_3S_3$	0.118	0.103	-0.024	0.242	0.254
$L_3D_1S_3$	0.070	-0.024	-0.084	0.285	0.184
$L_3D_2S_3$	0.278	-0.082	-0.228	0.194	0.092
$L_3D_3S_3$	0.411	-0.128	-0.187	0.257	0.311

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

L - Radial position from the bole S - Season

D - Depth from surface (cm)

Table 49. Correlation between number of bunches and soil chemical properties of situation A

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	-0.021	0.239	-0.297	-0.105	-0.060
$L_1D_2S_1$	-0.216	0.154	-0.575**	-0.212	-0.094
$L_1D_3S_1$	-0.034	0.228	-0.391	-0.240	0.048
$L_2D_1S_1$	-0.028	0.035	-0.442	-0.269	-0.274
$L_2D_2S_1$	0.006	0.213	-0.482*	-0.015	-0.179
$L_2D_3S_1$	-0.079	-0.020	-0.342	-0.282	-0.116
$L_3D_1S_1$	-0.093	-0.031	-0.399	-0.024	-0.315
$L_3D_2S_1$	-0.184	0.274	-0.469*	-0.022	-0.188
$L_3D_3S_1$	-0.084	-0.060	-0.140	-0.106	-0.643**
$L_1D_1S_2$	-0.366	-0.012	0.117	-0.147	-0.237
$L_1D_2S_2$	-0.240	-0.102	0.054	0.030	-0.168
$L_1D_3S_2$	-0.100	0.162	0.232	-0.158	-0.017
$L_2D_1S_2$	-0.192	0.140	0.177	-0.390	-0.028
$L_2D_2S_2$	-0.207	0.060	0.323	-0.005	-0.086
$L_2D_3S_2$	-0.194	0.018	0.256	-0.018	0.017
$L_3D_1S_2$	-0.167	-0.176	0.115	-0.490*	0.337
$L_3D_2S_2$	-0.220	0.014	0.164	0.037	0.290
$L_3D_3S_2$	-0.323	-0.019	0.080	-0.024	0.257
$L_1D_1S_3$	0.338	0.133	-0.211	-0.013	0.442
$L_1D_2S_3$	0.404	-0.080	-0.127	0.026	0.267
$L_1D_3S_3$	0.387	0.030	-0.259	-0.194	0.238
$L_2D_1S_3$	0.273	0.215	-0.208	0.179	0.441
$L_2D_2S_3$	0.252	0.189	-0.086	0.087	0.307
$L_2D_3S_3$	0.312	0.080	-0.148	-0.077	0.352
$L_3D_1S_3$	0.375	0.102	-0.083	0.375	0.230
$L_3D_2S_3$	0.128	0.151	-0.159	0.329	0.212
$L_3D_3S_3$	0.158	-0.160	-0.185	-0.221	-0.103

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

L - Radial position from the bole S - Season

D - Depth from surface (cm)

Table 50. Correlation between number of leaves and soil chemical properties of situation B

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	-0.110	0.062	-0.340	0.043	-0.238
$L_1D_2S_1$	-0.114	0.126	-0.277	0.084	-0.202
$L_1D_3S_1$	0.074	0.201	-0.085	0.101	-0.318
$L_2D_1S_1$	-0.010	0.006	-0.354	0.345	-0.175
$L_2D_2S_1$	-0.177	0.124	-0.204	0.136	-0.010
$L_2D_3S_1$	-0.071	0.109	-0.218	0.031	-0.245
$L_3D_1S_1$	-0.152	0.030	-0.323	0.038	-0.004
$L_3D_2S_1$	-0.150	0.050	-0.178	0.014	-0.062
$L_3D_3S_1$	-0.081	0.086	-0.126	0.083	-0.243
$L_1D_1S_2$	-0.084	-0.004	0.372	-0.084	0.173
$L_1D_2S_2$	-0.251	0.172	0.176	-0.075	0.251
$L_1D_3S_2$	-0.182	0.319	0.162	0.032	0.293
$L_2D_1S_2$	-0.063	-0.073	0.377	-0.123	0.135
$L_2D_2S_2$	-0.260	-0.090	0.159	-0.307	0.246
$L_2D_3S_2$	-0.192	-0.050	0.218	0.072	0.203
$L_3D_1S_2$	-0.180	0.053	0.179	0.035	0.438
$L_3D_2S_2$	-0.157	-0.141	0.287	0.084	0.390
$L_3D_3S_2$	0.048	0.337	0.194	0.376	0.354
$L_1D_1S_3$	-0.013	0.101	0.000	-0.081	0.117
$L_1D_2S_3$	-0.137	-0.137	-0.066	-0.238	0.125
$L_1D_3S_3$	-0.107	-0.183	-0.140	-0.210	0.210
$L_2D_1S_3$	-0.040	-0.069	-0.137	-0.394	0.084
$L_2D_2S_3$	-0.083	-0.012	-0.101	-0.229	0.175
$L_2D_3S_3$	0.027	-0.038	-0.221	-0.212	0.211
$L_3D_1S_3$	-0.039	-0.012	-0.274	-0.244	0.190
$L_3D_2S_3$	0.062	-0.038	-0.225	-0.372	0.347
$L_3D_3S_3$	-0.005	-0.119	-0.125	-0.408	0.343

L - Radial position from the bole
S - Season
D - Depth from surface (cm)

Table 51. Correlation between number of nuts and soil chemical properties of situation B

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	0.057	0.053	-0.151	0.380	0.191
$L_1D_2S_1$	0.065	-0.048	-0.117	0.152	-0.061
$L_1D_3S_1$	0.155	0.128	-0.149	0.275	-0.157
$L_2D_1S_1$	0.151	0.336	-0.093	0.276	0.314
$L_2D_2S_1$	0.067	0.003	-0.103	-0.179	0.316
$L_2D_3S_1$	0.217	0.073	-0.073	0.154	0.075
$L_3D_1S_1$	0.051	0.289	-0.095	0.249	0.317
$L_3D_2S_1$	0.040	0.178	-0.196	0.033	0.416
$L_3D_3S_1$	0.188	0.156	-0.360	0.195	0.166
$L_1D_1S_2$	-0.090	-0.180	0.617**	-0.387	-0.400
$L_1D_2S_2$	-0.086	0.195	0.617**	-0.108	-0.242
$L_1D_3S_2$	-0.106	-0.072	0.713**	0.089	-0.129
$L_2D_1S_2$	0.047	0.139	0.624**	-0.177	-0.366
$L_2D_2S_2$	0.117	0.247	0.597**	0.098	-0.212
$L_2D_3S_2$	-0.052	-0.211	0.530*	0.311	-0.146
$L_3D_1S_2$	-0.101	0.188	0.597**	0.135	-0.104
$L_3D_2S_2$	0.202	0.174	0.681**	0.421	-0.178
$L_3D_3S_2$	0.166	0.065	0.453*	0.438	-0.140
$L_1D_1S_3$	0.175	0.150	0.064	-0.385	-0.300
$L_1D_2S_3$	0.220	0.018	0.115	0.141	-0.404
$L_1D_3S_3$	-0.014	-0.212	0.047	-0.053	-0.133
$L_2D_1S_3$	0.290	0.316	0.190	0.202	-0.476*
$L_2D_2S_3$	0.107	0.099	0.352	0.279	-0.441
$L_2D_3S_3$	-0.075	-0.079	0.260	0.080	-0.397
$L_3D_1S_3$	0.191	0.118	0.340	0.054	-0.491*
$L_3D_2S_3$	-0.153	-0.050	0.439	0.285	-0.389
$L_3D_3S_3$	-0.062	-0.017	0.319	0.471*	-0.424

* - Significant at 5 per cent level; ** - Significant at 1 per cent level
L - Radial position from the bole S - Season
D - Depth from surface (cm)

Table 52. Correlation between number of bunches and soil chemical properties of situation B

RRC	pH	EC	O.C	Av.P	Av.K
$L_1D_1S_1$	-0.029	0.497*	-0.342	0.273	0.254
$L_1D_2S_1$	0.075	0.340	-0.302	0.296	-0.038
$L_1D_3S_1$	0.375	0.480*	-0.161	0.264	-0.216
$L_2D_1S_1$	0.209	0.507*	-0.235	0.506*	0.349
$L_2D_2S_1$	-0.033	0.291	-0.252	0.173	0.343
$L_2D_3S_1$	0.299	0.481*	-0.162	0.300	0.081
$L_3D_1S_1$	0.139	0.489*	-0.096	0.184	0.391
$L_3D_2S_1$	0.038	0.299	-0.159	0.138	0.368
$L_3D_3S_1$	0.263	0.257	-0.139	0.023	0.106
$L_1D_1S_2$	-0.179	0.160	-0.076	-0.281	0.349
$L_1D_2S_2$	-0.380	0.068	-0.142	-0.473*	0.313
$L_1D_3S_2$	-0.430	-0.125	-0.197	-0.686**	0.387
$L_2D_1S_2$	-0.270	-0.210	-0.151	-0.321	0.330
$L_2D_2S_2$	-0.264	-0.172	-0.339	-0.510*	0.278
$L_2D_3S_2$	-0.452*	-0.254	-0.317	-0.744**	0.363
$L_3D_1S_2$	-0.208	0.130	-0.347	-0.510*	0.376
$L_3D_2S_2$	-0.232	-0.142	-0.227	-0.114	0.281
$L_3D_3S_2$	-0.120	0.122	-0.504*	-0.039	0.309
$L_1D_1S_3$	-0.042	-0.268	-0.267	-0.133	0.328
$L_1D_2S_3$	-0.104	-0.213	-0.251	-0.126	0.434
$L_1D_3S_3$	-0.000	-0.191	-0.313	0.026	0.145
$L_2D_1S_3$	-0.122	0.340	-0.423	-0.148	0.286
$L_2D_2S_3$	-0.323	-0.294	-0.325	-0.103	0.570**
$L_2D_3S_3$	-0.049	-0.349	-0.583**	-0.002	0.373
$L_3D_1S_3$	-0.286	-0.242	-0.401	-0.108	0.336
$L_3D_2S_3$	-0.204	-0.259	-0.364	-0.239	0.418
$L_3D_3S_3$	-0.101	-0.229	-0.401	-0.167	0.434

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

L - Radial position from the bole S - Season

D - Depth from surface (cm)

Table 53. Interaction among leaf nutrients in season

(a) Leaf N Vs P and K

Season	Situation A		Situation B	
	N x P	N x K	N x P	N x K
S_1	0.569**	0.102	-0.293	-0.176
S_2	0.096	-0.071	0.211	-0.102
S_3	0.365	0.449*	-0.040	-0.280

(b) Leaf P Vs N and K

Season	Situation A		Situation B	
	P x N	P x K	P x N	P x K
S_1	0.569**	0.154	-0.293	0.243
S_2	0.096	-0.155	0.211	0.199
S_3	0.365	0.237	-0.040	0.150

(c) Leaf K Vs P and N

Season	Situation A		Situation B	
	K x N	K x P	K x N	K x P
S_1	0.102	0.154	-0.176	0.243
S_2	-0.071	-0.155	-0.102	0.199
S_3	0.449*	0.237	-0.280	0.150

** Significant at 1 per cent level

* Significant at 5 per cent level

S - Season

In situation B none of the three nutrients had any significant relationship in any season.

4.11 Inter-relation among leaf nutrients to yield

Data on the relationship between yield and leaf nutrients are presented in Table 54. In situation A, leaf N content in the first season was found to be associated with total number of nuts produced. Leaf P content in first and second seasons also influenced total nut production significantly. Leaf K failed to establish relationship. At the same time it was noticed that leaf nutrients and seasonal yield were not associated.

In situation B leaf nutrient content in any season and total yield did not show significant relationship. But leaf K established a significant negative relation with seasonal production of nuts in the first season.

4.12 Inter-relation among yield attributes to yield

Correlation between yield attributes (bunches and leaves) and yield was studied and results are presented in Table (55).

In situation A total number of nuts produced was found to be associated with number of bunches produced (both total and seasonal) in the first season whereas the number of nuts produced seasonally failed to show any relationship with the yield attributes in all the seasons.

Table 54. Correlation between yield and leaf nutrients

Situation	Season	Total yield			Seasonal yield		
		N	P	K	N	P	K
A	S_1	0.447*	0.497*	0.247	0.202	0.343	-0.102
	S_2	0.272	0.471*	0.066	0.203	0.355	0.003
	S_3	0.171	0.060	-0.034	0.112	0.085	-0.048
B	S_1	0.287	0.041	-0.257	0.246	-0.071	-0.470*
	S_2	-0.316	-0.251	-0.101	-0.363	-0.097	-0.156
	S_3	-0.220	0.068	-0.232	-0.133	0.039	-0.254

Table 55. Correlation between yield and yield attributes

Situation	Season	Total yield Vs yield attributes				Seasonal yield Vs yield attributes			
		$L_{(T)}$	$L_{(S)}$	$B_{(T)}$	$B_{(S)}$	$L_{(T)}$	$L_{(S)}$	$B_{(T)}$	$B_{(S)}$
A	S_1	0.360	0.244	0.458*	0.561**	0.308	0.173	0.248	0.387
	S_2	0.106	0.137	0.154	0.322	0.183	0.135	0.290	0.347
	S_3	0.188	-0.172	0.272	-0.243	0.248	-0.282	0.281	-0.254
B	S_1	0.095	-0.010	0.349	0.453*	-0.079	0.210	0.192	0.203
	S_2	-0.228	0.485*	-0.102	-0.239	-0.264	0.498*	0.013	-0.045
	S_3	-0.239	0.480*	-0.103	-0.082	-0.111	0.239	-0.136	0.010

** - Significant at 1 per cent level

* - Significant at 5 per cent level

$L_{(T)}$ - Total leaf

$L_{(S)}$ - Seasonal leaf

$B_{(T)}$ - Total bunch

$B_{(S)}$ - Seasonal bunch

S - Season

In situation B total nut production established relationship with number of leaves produced in the second and third season as well as number of bunches produced in first season. It was also noticed that number of nuts produced in the second season showed significant positive relationship with leaf production of that season.

Discussion

5. DISCUSSION

Investigations were conducted during 1994-95 to study the nutritional soil-plant interaction in relation to productivity of coconut plams so as to develop a soil testing system to suit the unique habit of the palm. The study involved estimation of available nutrients in the soil, role of physical characteristics on the availability, leaf levels of nutrients and productivity of palms belonging to two different situations. The salient features of the results are discussed in the following pages.

5.1 Validity of soil test

Observations on the nutritional status of the soil in the two situations have indicated differences between them (Tables 6, 7 and 8). Role and requirement of N and K and their limiting influence on coconut productivity have been established (Muliyar and Nelliyat, 1971). The fact that palms in situation A have recorded a higher content of these elements in their leaves (Table 17) and also a higher nut yield (Table 18) would suggest that nutritional management based on soil test values would be meaningful and valid. This result is in line with the observations recorded by Krishnakumar (1983).

Majority of the root system of coconut is confined to a radius of 2 m from the bole. The data (Table 3) evidently confine to the feeding zone of the palm. The lack of correlation between the soil nutrient availability status and leaf nutrient status in any of the two situations (Table 35 to 40) would suggest unsuitability of intoto application of present soil test method as such for a perennial crop like coconut.

5.2 Soil characteristics and availability

Data presented in Tables 1 and 2 as well as 4-8 showed that though, the situations were separated by less than a kilometer and that the soil belonged to the same order and series, the status of major available nutrients and physical properties varied widely. Status of available nutrients is a function of a series of chemical reactions taking place in the soil, the rate and extent of which are governed by physical properties which are affected by variations in fractional composition of soil. Brady (1984) has reported that porous and sandy soils facilitate oxidation reactions, percolation etc. and are poor in nutrient status and increasing levels of finer fractions retain higher levels of nutrients. Since soil test values are to indicate the resource power of the soil to supply nutrients throughout the growth period of a crop, a system giving due consideration to physical properties and fractional composition of soil may likely to have more precise applicability.

Data in Table 1 and 2 indicated that very coarse and coarse fractions were unusually high even to a depth of 45 cm from the surface. Queiroz (1963) reported that loose fractions are concentrated only in upper layers and finer fractions increase downwards. However, laterite soils are highly leached out soils, rich in hydrous oxides of Fe and Al, coarser particles are soil minerals coated with oxides of Fe. This unique phenomenon that differentiates it from other soils may vitiate the precision of conventional methods of soil testing in laterite soil.

Inter-relationship between physical and chemical properties (Tables 19 to 28) have revealed that they are not identical in the two situations. In situation A, finer fraction (F5) showed positive and coarser fraction showed negative correlations with organic carbon. The reverse was the case in situation B where coarser fractions had positive and finer fraction had negative relationship with organic carbon. Positive correlation of organic carbon content with finer fractions of the soil is natural and is to be expected. Similar results have also been reported by Bastin (1985). In situation B, the relationship may appear to be confusing. A perusal of the seasonal fluctuation in organic carbon content in two situations (Table 14) showed that organic carbon level has been rather static and the fluctuation level was only 2.0 per cent in situation B as against 7.3 per cent in situation A. Thus it can be seen that situtation B had the organic carbon content at the lowest and near static level, where the influence on nutrition is marginal. In situation A the fluctuation is over 7 per cent indicating that the reactivity of orgainc matter and its influence on nutrition are significant as evidenced from yield. This further points out to the necessity that soil productivity should be judged within specific limits of fractional composition and would mean more than absolute values. Reactivity of organic carbon and factors affecting it are important which call for using weighted indices for physical properties. This situation in all probability is due to the instability of organic matter due to oxidative losses from heavy aeration.

Observation on available P indicate that relationship of physical properties is similar in both situations, but of lesser magnitude in situation B. In the case of K the relationship was non significant in both the situations. These results will mean that separate indices for organic carbon, available P and available K will have to be worked out.

Investigation of variation in the organic carbon content of the soil and leaf N content (Table 6 and 17) on one side and available K in soil and K in leaf (Table 8 and 17) on the other show that variation patterns are subject to some critical levels below and above of which the pattern may be different. Critical level appears to be influenced by the extent of porosity of the soil which modify the stable levels through oxidation of organic carbon and leaching of K respectively. This would further suggest that some standardization based on physical characteristics of the soil especially porosity along with root spread of plant is necessary to get true relation of available status of soil to that of leaf nutrients. One of the most significant results generated in the present study has been the almost exclusive relationship of organic carbon to coconut productivity, though the relationship was negative in high yield environment and positive in low yield environment. The cyclically changing pattern of organic carbon through the seasons presented in Table 16 would probably suggest that this is linked to the static and non dynamic level of organic carbon and its influence on the dynamic pool. Assuming that the static or near static level of the dynamic pool is 0.48 per cent, situation A which had the advantage of higher alternating build up and degradation which did not touch the lowest static level. As such it had been related to a higher mineralisation of nutrients from 0.548 to 0.589 per cent. On the other case availability has to depend on build up and degradation in a very small range (0.480 to 0.487%).

This diametrically opposite but basically same effect may be attributed to the porous nature of the soil in the second situation where coarser fractions have constituted 44.15 percentage of the soil volume. The data also indicated that coarser fraction F3 (0.5 - 1.0 mm) is more related with organic carbon of the soil here (Table 26).

Varying interrelation of organic carbon with different fractions of soil on one side simultaneously with its direct bearing on productivity would point out to the necessity of evolving texture linked indices to get reliable information. This result could not come out of the present study due to insufficient sample size. So, further investigations should be done in this direction.

5.3 Sampling technique

The technique of soil sampling has to take into account at least four factors viz, where, when and how to take soil sample for anlaysis as well as the dependability of the information.

Data on the interrelationship of available nutrient status of soil to yield components and yield are presented in Table 47 to 52. Yield of coconut palms is considered in numbers and not based on weight and the data on interrelationship suggested that maximum relationship to yield of nuts was manifested by organic carbon content recorded in the second season and potassium content in the third season in the low yielding situation, whereas organic carbon content recorded in the first season was negatively related with yield in the high yield environment. This would suggest that time of sampling and present productivity has very high importance in governing the reliability of the data generated. Study on the specific nutritional preferences of coconut have shown that it is from potassium through nitrogen to phosphorus in low yielding to high yielding (Pillai and Davis, 1963; Nathanael, 1969). Organic carbon is the index of soil nitrogen and general productivity (Singh and Brar, 1973). Nitrogen is reported to increase the number of nuts through increasing production of female flowers (Nelliyat *et al.*, 1972). Mean yield per palm in the two situations had worked out to 76 and 35 respectively (Table

18). The fact that soil organic carbon content of Situation A was higher compared to Situation B (Table 6) is further proof of this. Thus it would be seen that the data is reliable.

High variation between the seasons for expression of significant relationship may be attributed to general fertility status of the soil. A perusal of the annual march of organic carbon content shows that maximum carbon level is attained in the second season which declines continuously through the third and first season (Table 6). The decline in the high yield situation is worked out to 7.3 per cent as against 2 per cent in low yield situation. Decline in organic carbon content is an inverse index of mineralisation of nitrogen and other elements. Thus high yield in situation A and the negative relation appears to be the resultant of higher mineralisation and consequent availability of nutrients and *vice versa* in situation B.

In the low yield situation the organic carbon content itself is low and the build up and decline is confined to 2 per cent. It is possible that 0.48 per cent may be the basic organic carbon status below which it is not prone to degradation. This would mean that 0.48 per cent of organic carbon can be treated as the base level.

Number of leaves and bunches, though are yield contributory factors cannot have absolute influence on crop yield as the final expressed yield is often the balance between originally produced and subsequently lost after opening of spathe due to several reasons like water stress and pest incidence etc.

A perusal of the data will show that sample should be collected from a depth of at least 30 cm. This is to be naturally expected as the root system is confined to the basins. Kushwah *et al.*, (1973) have reported that more than 74 per cent of the root system is confined in the basin from 30 cm from surface to 1 m depth. Distribution pattern of roots in the soil core in the two situations (Table 3) shows that root fractions increased with depth though the rate of increase tended to be more in poor soils. The apparent contradiction between root distribution and sampling depth may be because of the mobility of the organically mineralised elements in the soil. Among the interrelations obtained more than $2/3^{rd}$ are from soil depth up to 30 cm and also correlation at still deeper depths were simultaneously manifested in upper layers also, it appears to be safe to conclude that depth of sampling irrespective of productivity shall be confined to 30 cm .

A comparison between radial distances of the two situations revealed that second radial distance (L_2) is more expressive than L_1 irrespective of productivity of situation. In high yielding situation, while L_1 expressed only the relationship of available K, L_2 showed significant relation for organic carbon and available K (Table 48). Pillai and Davis (1963) and Nathanael (1969) have reported that K is the element removed by the coconut palm in largest quantities followed by N while P is the least, in quantity required. Soil sampling from outside basin is also misleading since more than 75 per cent of the roots reside within a radius of 2 m. Hence mixed composite sampling including inside and outside basin soil is more representative of the fertility status of the coconut rhizosphere.

From the foregoing discussions the following conclusions can be drawn.

The conventional method of soil sampling is not suitable for coconut, roots of which explores deeper soil layers. In the present study it was concluded that soil samples should be collected at least from a depth of 0 - 30 cm: Composite sampling including both inside and outside basin soils is more appropriate compared with inside or outside basin sampling. Time of sampling is also important and it differ between yield group and the nutrient to be analysed. Another important conclusion of the study is that some correction factors should be added to soil test values to account the anomalies caused by the coarser soil fraction which is not having a direct role in production and productivity.

Summary

6. SUMMARY

A study was conducted during 1994-95 in two standing coconut gardens in laterite soil, grown under good management [situation A] and average management [situation B] practices. The coconut gardens were located at Mulam-kunnathukavu (Thrissur district), within a distance of about one kilometer. About 75 WCT palms in the age group of 15-20 years were present in each group. Among these twenty healthy palms from each situation were selected for the study. The objective of the study was to standardize soil sampling technique for coconut and to work out fertilizer recommendation system considering physical nature of the soil as well as the nutrient levels, based on correlation with plant uptake values. The study involved identifying the sampling techniques and the factors to be considered to get a reliable and indicative information from the soil test values generated.

Composite soil samples were collected using soil tube from three depths from surface viz. 0-15 cm (D_1), 0-30 cm (D_2) and 0-45 cm (D_3), from three radial positions from the bole of the palm viz. within the basin (L_1), basin cum outside (L_2) and outside basin (L_3). Samples were collected during the months of May (S_1), October (S_2) and January (S_3) to account the effect of seasons on the chemical properties of soil. Soil fractions were separated and designated as F1 (>2 mm), F2 (1-2 mm), F3 (0.5-1 mm), F4 (0.2-0.5 mm) and F5 (<0.2 mm). Leaf samples from 10th frond, and bio-metric observations on yield and yield attributes were also collected along with soil samples.

The salient results are summarized below:

1. The two situations A and B showed much variation in the physical properties. The coarser fraction F1 occupied only 3 per cent by weight in situation A, while that in situation B was 26 per cent. The finer fraction F5 occupied 72 per cent as agaisnt 51 per cent in situation B. The variations of other fractions were marginal. The bulk density (m/v) of situation A was 1.25 g cm^{-3} and the value for situation B was 1.65 g cm^{-3}.

2. The root fractions collected along with soil columns indicated that the root activity was more in situation A than B. In both the situations the maximum root activity was confined to a depth of 0-30 cm within the basin (L_1D_2).

3. The pH of the soils of situation B showed a higher value (6.0) than situation A (5.8). pH decreased with increase in depth from surface and radial distance from the bole of the palm. In both the situations the soils were more acidic during January (S_3).

4. Electrical Conductivity (EC) also decreased with depth and distance from the palm in both the situations. Compared to situation B, situation A recorded higher values. The variation in situation A was from 0.077 to 0.218 (dS m^{-1}) while that in situation B was from 0.083 to 0.187 (dS m^{-1}). In both the situations October samples (S_2) recorded maximum values.

5. In both situations organic carbon content decreased with depth and radial distance. The organic carbon content varied from 0.48 per cent to 0.66 per cent in situation A. The variation in situation B was from 0.42 per cent to 0.58 per cent. In both the situations the higher content was recorded in the samples collected during October (S_2) at L_1D_1.

6. In situation A and B available P decreased with increase in depth the radial distance. The available P content varied from 6.3 to 24.5 ppm in situation A, and from 4.1 to 37.8 ppm in situation B.

7. In situation A, the available K content varied from 87 to 184 ppm, while in situation B, it was only from 43 to 102 ppm. In situation A, the highest value (184 ppm) was recorded at L_1D_2 during October (S_2) while in situation B the highest value (102 ppm) was recorded at L_1D_1 during October itself (S_2). The minimum value was recorded at L_3D_3 in both the situations and all the seasons.

8. Palms of situation A recorded higher content of leaf N, P and K compared with situation B. Corresponding differences were also reflected in nut production.

9. In situation A, leaf N and P failed to establish significant relationship with any of the soil fraction. But leaf K content was related with F1. In situation B, N content of leaf established significant negative correlation with coarser fraction (F1).

10. Situation A gave 16.7 and 77.8 per cent higher value for organic carbon and available K respectively. Palms in situation A has recorded a higher content of these elements in their leaves and also a higher nut yield would suggest that nutrient management based on soil test values would be meaningful and is valid.

11. In both situations soil nutrient levels failed to establish correlation with leaf nutrients in most of the cases. Lack of correlation would suggest the unsuitability of *in toto* application of present soil test method as such for a perennial crop like coconut.

12. In situation A, finer fractions (F5) showed positive and coarser fractions (F1, F2, F3 and F4 showed negative correlation with organic carbon. Reverse was the case in situation B where coarser fractions (F1, F2 and F3) had positive and finer fractions (F4 and F5) had negative relation. As the available status of a nutrient is governed by physical properties which are affected by variation in fractional composition of soil, a system giving due consideration to physical properties of soil may likely to have more precise applicability.

13. In situation B organic carbon level has been static and the fluctuation was only two per cent in situation B as against eight per cent in situation A. Reactivity of organic carbon and factors affecting it is important which calls for using weighted indices for physical properties.

14. Seasonal variation in available P showed similar trend as organic carbon but the influence is of less magnitude. In the case of available K the relationship was opposite. These results will mean that separate indices for organic carbon, available P and available K will have to be worked out.

15. The cyclically changing pattern of organic carbon through the seasons suggest that it is linked to the static and nondynamic level of organic carbon.

16. In high yield situation organic carbon was found to be negatively correlated with nut production but in situation B positive correlation was obtained. This

may be the resultant of higher mineralisation and consequent availability of nutrients in situation A and *vice versa* in situation B.

17. In situation B organic carbon manifested maximum relationship to yield of nuts in the second season and potassium content in the third season whereas organic carbon content recorded in the first season was related with yield in high yield situation. This would suggest that time of sampling is also important which differ between yield group and nutrient to be analysed.

18. In situation A, leaf N showed significant positive correlation with leaf P in first season and leaf K content in third season. In situation B, all the three nutrients failed to establish any significant relationship in all seasons.

19. In situation A, leaf N content was significantly associated with total number of nuts in the first season only, while P established relationship during first and second seasons. In situation B, leaf nutrient content and total nut yield did not show significant relationship in any season. But leaf K established a significant negative relationship with seasonal production in the first season.

20. In situation A, total nut yield was related to total and seasonal bunch yield during first season only. In situation B, total yield was related to leaf production of second and third season and bunch production of first season.

21. Soil samples should be collected from a depth of atleast 30 cm as the maximum root activity was confined to this depth.

22. Mixed composite sampling including both inside and outside basin soils is more appropriate compared with inside or outside basin sampling alone.

References

REFERENCES

Anilkumar, K.S. 1987. Chemistry of coconut rhizosphere. M.Sc. (Ag.) thesis, Kerala Agricultural Univeristy, Thrissur

Amma, M.K. 1989. *Plant and Soil Analysis - Laboratory Manual*. Rubber Research Institute, Rubber Board, Kottayam

Apacible, A.R. 1974. Chlorine - its effects on coconut. *Cocon. tech. J.* **1**:32-37

Balaguru, T. 1970. Studies on the forms, distribution, status and relationships of various soil properties in respect of manganese, iron and molybdenum in typical soil profiles of Tamil Nadu. M.Sc.(Ag.) dissertation, University of Madras, Tamil Nadu

Balakrishnamurthy, J. 1971. Radio-isotope studies on efficiency of fertiliser utilization by coconut palms. *Ceylon Cocon. Quart.* **22**:37

Bastin, B. 1985. Physico-chemical characterisation of red soils in different regions of Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur

Bernard, R.O. and Stabbert, M.J. 1988. Soil depth, the third dimension. *Yearbook*, South African Avocado Growers Association **11**:23-24

Biswas, P.P., Joshi, O.P. and Rajput, M.S. 1987. Establishment of critical leaf nutrient concentration of mango cultivar Dashehari based on soil test. *J. Indian Soc. Soil Sci.* **35**:331-334

Bolland, M.D.A. 1992. Effect of sampling depth on bicarbonate soil P test values. *Fert. Res.* **32**:121-124

Brady, N.C. 1984. *The Nature and Properties of Soils*. 9th ed. Macmillann Publishing Co., Inc., New York, USA

Brar, M.S. and Sekhon, G.S. 1987. Vertical distribution of K in five benchmark soil series in Northern India. *J. Indian Soc. Soil Sci.* **35**:732-35

Cecil, S.R. and Pillai, N.G. 1973. Note on the mineral losses from coconut leaves by foliar leaching. *Indian J. agric. Sci.* **43**:611-612

Chibba, I.M. and Sekhon, G.S. 1985. Effect of pH and organic carbon on availability of nutrients in acid soils. *J. Indian Soc. Soil Sci.* **33**:409-411

Deepa, K.P. 1995. Fertility investigations and taxonomy of the soils of Regional Agricultural Research Station, Pattambi. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur

Devi, C.B.K. and Pandalai, K.M. 1968. Note on the leaf composition in relation to poor vegetative characters and yield in the coconut palm. *Indian J. agric. Sci.* **38**:876-880

Devi, C.B.K. and Velayudhan, M. 1977. Leaf nutrient concentration in coconut following fertilizer application. *Philipp. J. Cocon. Stud.* **2**:26-33

Dongale, J.H. 1993. Depthwise distribution of different forms of P in lateritic soils of coastal region. *J. Indian Soc. Soil Sci.* **4**:62-66

Eden, T., Gower, T.C. and Salgado , M.L.M. 1963. A factorial fertilizer experiment on coconut. *J. exp. Agric.* **31**:283-295

Ekambaran, S., Kothandaraman, G.V. and Krishnamurthy, K.K. 1975. Studies on the distribution of different forms of potassium in red soil. *Madras agric. J.* **62**:243-247

Felizardo, B.C. 1965. Bimonthly variation of some of the macro-elements in the leaves of differently fertilized coconut. M.Sc. thesis, UPCA College, Laguna

Ghosh, A.B. and Hassan, R. 1980. Nitrogen fertility status of soils of India. *Fert. News* **25**:19-24

Gopalaswamy, V. 1969. Studies on the profile morphology analytical characteristics and micromorphology of some laterites and lateritic soils of Kerala. Ph.D. thesis, Kerala University, Thiruvananthapuram

Gopi, C.S. 1981. Foliar diagnosis in coconut (*Cocos nucifera* Linn.) in relation to nitrogen, phosphrous and potassium. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur

Gopi, C.S. and Jose, A.I. 1983. Foliar diagnosis in coconut in relation to *N, P and K. Proc. 6th International Scientific Conference on Problems of an Optimum Nutrient Supply to Tropical Crops*, Institute of Tropical Agriculture, Karl Max University, Leipzing, G.D.R., 112-119

Gupta, R.K., Dhillon, N.S. and Devi, G. 1989. Profile distributions of various forms of soil nitrogen and their relationship with rice grain yield. *J. Indian Soc. Soil Sci.* **37**:174-176

Hameed, A. 1975. Fertility investigations in the kole soils of Kerala, M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur

Hassan, M.A. 1977. Fertility investigation on the laterite soils of Kerala state, M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur

* Heyn, J., Ellinghanus, R., Schanf, H. and Witzel, D. 1992. *Der Einfluss von Boprobungzeit Entnalimetiefe and Trocknung auf die Aussage von call$_2$-N. Bodenunt tersuchungen gemessen an Ergetmissen vole Teld Vercuchen. Verband Dentscher Landwitstschaftlicher unter suchungs- lind. Forchungsanstaller, Reite Kangress berichte* **32**:321-320

IAEA, 1975. Root activity patterns of tree crops. *Tech. Rep.* 170, IAEA, Vienna. 154

Indirakutty, K.N. and Pandalai, K.M. 1968. Influence of soil types on foliar nutrient composition in coconut. *Indian J. agric. Sci.* **38**:492-496

Jackson, M.L. 1958. *Soil Chemical Analysis.* Prentice Hall, Inc. Engle Wood Cliffs, N.J., USA

Jose, A.I., Krishnakumar, N. and Gopi, C.S. 1991. Yield Prediction in coconut based on foliar nutrients levels. *Coconut Breeding and Management.* (Eds. E.G.Silas, M.Aravindakshan and A.I.Jose), Kerala Agricultural University, Thrissur

Kadrekar, S.B. 1973. The study of acid soils of Maharashtra state with special reference to their potash content. *Proc. Symp. on Acid Sulphate and Other Acid Soils of India*, I.S.S.S., Thiruvananthapuram. p.101-105

Kanapathy, K. 1977. Leaf analysis and fertilizer requirements of coconuts. *Malay. agric. J.* **50**:322-339

Karim, A. and Khan, D.H. 1956. Vertical distribution of N, P and K in some soils of East Pakistan. *Soil Sci.* **81**:1-6

Krishnakumar, N. 1983. Yield prediction in coconut based on foliar NPK values. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur.

Krishnakumar, P.G. 1991. Taxonomy and fertility capability assessment of the soils in command area of Edamalayar project. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur.

Kurup, T.K.B. and Aiyer, R.S. 1973. Seasonal variation in soil reaction and soluble salt content of Kuttanadu rice soils, Kerala state. *Agric. Res. J. Kerala* **10**:127-138

Kushwah, B.L., Nelliyat, E.V., Marcose, V.T. and Sunny, A.P. 1973. Rooting pattern of coconut (*Cocos nucifera* L.). *Indian J. Agron.* **18**:71-74

* Leverington, K.C., Sedl, J.M. and Burge, J.R. 1962. Some problems in predicting potassium requirement of sugarcane. *Proc. 11th Congr. Int. Soc. Sugarcane Tech.* Mauritius. 123-129

Liebhardt, W.C. and Teel, M.R. 1977. Fluctuations in soil test values for potassium as influenced by time of sampling. *Commun. Soil Sci. Pl. Anal.* **8**:591-597

Loganathan, P. and Atputharajah, P.P. 1986. Effect of fertilizers on yield and leaf nutrient concentrations in coconut. *Trop. Agric.* **63**:143-148

Loganathan, P. and Balakrishnamurthi, T.S. 1980. Effects of NPK fertilizers on young coconut (*Cocos nucifera*) on a sandy soil in Sri Lanka. *Exp. Agric.* **16**:41-48

Magat, S.S., Cadigal, V.L. and Habana, J.A. 1975. Yield improvement of coconut in elevated inland area of Davavo (Philippines). *Oleagineux* **30** : 413-418

* Magnaye, A.B. 1969. Studies on root system of healthy and cadang-cadang affected coconut trees. *Philipp. J. Pl. Indus.* **34**:143-154

Marar, M.M.K. and Pandalai, K.M. 1961. A comparison of chilean nitrate with ammonium sulphate as a nitrogen source for the coconut palm. *Indian Cocon. J.* **17**:114-119

Mathai, G., Nair, P.P.V. and Thampi, A.M. 1979. Fractional application of fertilizer for coconut seedlings. *Agric. Res. J. Kerala* **16**:126-128

Mathew, C. and Ramadasan, A. 1964. Effect of nitrogen, phosphorus and potassium nutrients on the growth of coconut seedlings. *Indian Cocon. J.* **17**:114-117

Miura, K., Tulaphitat, T. and Kyuma, K. 1992. Pedogenetic studies on some selected soils in Northeast Thailand. *Soil Sci. Pl. Nutr.* **38**:485-493

Molleguard, M. 1971. Results of a fertilizer trial on mixed colluvial soil at the Ulu Beram estate in West Malaysia. *Oleagineux* **26**:449-453

Mosi, A.D. 1960. Studies on profile characteristics of some red soils of south India. M.Sc.(Ag.) dissertation, University of Madras, Tamil Nadu.

Muliyar, M.K. and Nelliyat, E.V. 1971. Response of coconut palm to N, P and K application on the west coast of India. *Oleagineux* **26**:687-691

Muliyar, M.K. and Wahid, P.A. 1973. Note on the movement and availability of phosphorus in laterite soil as influenced by heavy phosphorus application with special reference to coconut. *Ind. J. agric. Sci.* **43**:527-528

Nair, K.H. 1973. Studies on the fertility status of the red soils of Kerala and the effect of adding nitrogen in combination with MnO_2 on the growth, yield and composition of rice. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur.

Nair, P.S. 1977. Studies on rice growing soils of Wyanad. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur.

Nair, T.J., Nambiar, I.P. and Money, N.S. 1966. Studies on Keen Raczkowski measurements and their relation to soil test values in cultivated soils of Kerala. *Agric. Res. J. Kerala* **4**:50-54

Nathanael, W.R.N. 1969. The application of fertilizer to adult coconut palm in relation to theoretical concepts. *Fertilite* **35**:11-27

Nelliyat, E.V. 1972. NPK nutrition of coconut palm - A review. *J. Pln. Crops* (Suppl.) p.70-80

Nye, P.H. 1961. Organic matter and nutrient cycles under moist tropical forest. *Pl. Soil* **13**:333-46

Ochs, R., Olivin, J., Quencez, P. and Harnus, P. 1991. Response to K fertilizers on acid sands of tertiary sediments. *Oleagineux* **46**:1-11

Ollagnier, M. and Giller, P. 1955. Comparison between foliar diagnosis and soil analysis in determining the fertilizer requirement of groundnut in Senegal (Phosphorus and potassium). *Oleagineux* **20** :513-516

Ollagnier, M., Ochs, R. and Marton, G. 1970. Manuring of oil palm in the world. *Fertilite* **36**:33-63

Ouvrier, M. and Ochs, R. 1978. Mineral exploitation of the hybrid coconut PB 121. *Oleagineax* **33**:437-443

Pal, S.K. and Mukhopadhyay, A.K. 1992. Distribution of different forms of potassium in profiles of Entisols. *J. Indian Soc. Soil Sci.* **40**:371-373

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Workers*. 4th ed. Indian Council of Agricultural Research, New Delhi, p.341

Parthasarathy, K. 1959. Studies on genetic inter-relationship between black and red soils occurring close proximity as affected by parent material. *Assoc. I.A.R.I. thesis*, New Delhi

Patel, J.M. and Mehta, B.V. 1962. Vertical distribution of total and available phosphorus in some typical soil profiles of Gujarat. *Indian J. agric. Sci.* **32** :178-188

Pillai, N.G. and Davis, T.A. 1963. Exhaust of micronutrients by the coconut palms - A preliminary study. *Indian Cocon. J.* **16**:81-87

* Queiroz, N.J.P. De. 1963. Distribution of sand fractions of serade santen. *Bragentoa* **22**:3-12

Raguraj, R. 1981. Studies on physico-chemical properties of major soil series of Madurai district. M.Sc.(Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore

Rajagopalan, V. 1969. Distribution of manganese and molybdenum in soils of Kerala and the effect of molybdenum on the growth of cowpea. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur

Ramdas, C. 1970. Study of the physico-chemical properties of saline, saline alkali and alkali soils adjoining Kazhuvely swamp, South Arcot district of Tamil Nadu and their reclamation. M.Sc.(Ag.) thesis, University of Madras, Tamil Nadu

Raychaudhury, S.P. and Anantharaman, P.V. 1960. Characteristics of some Indian acid soils. *J. Indian Soc. Soil Sci.* **8**:223-228

Raychaudhury, S.P. and Reddy, P.S.A. 1963. Rating of some red soils of Banglore district, Mysore State. *J. Indian Soc. Soil Sci.* **11**:311-319

* Salgado, M.L.M. 1955. The nutrient content of nut water in relation to available nutrients as a guide to the manuring of the coconut palm (*Cocos nucifera*). A new diagnosis method. *Proc. 8th Congr. Int. Bot. Collog. Pl. Fertil. Probl.* p.217-238

Sampath, P. 1987. Morphological, physical and chemical properties of the major red and lateritic soil series of Sivaganga taluk, Tamil Nadu. M.Sc.(Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore

Sharma, P.K., Sethi, A. S., Misra, V.K. and Sharma, O.K. 1980. Effect of organic matter, clay and silt on some physical parameters and CEC in some acid soils of Himachal Pradesh. *Indian J. agric. Res.* **14** :241-246

Sharma, U.C. 1992. Effect of soil mixture and precipitation on P leaching in Alfisol of Meghalaya. *J. Indian Soc. Soil Sci.* **40**:415-419

Singh, J.P., Dahiya, D.J., Kumar, V. and Singh, M. 1992. Distribution and status of different forms of nitrogen in soils of Haryana. *J. Indian Soc. Soil Sci.* **40**:698-709

Singh, K. and Ahuja, R.L. 1990. Distribution of primary nutrients in relation to soil characteristic in the Ghaggar river basin. *J. Indian Soc. Soil Sci.* **38**:733-735

Singh, K., Tripathi, D. and Tomar, K.P. 1993. Pedogenesis and taxonomy of soils in topo-sequence of Central Himalaya. *Agropedology* **3**:29-38

Singh, R. and Brar, S.P.S. 1973. Correlation of different soil tests with maize response for Nitrogen and Phosphorus at different fertility levels of soil. *J. Indian Soc. Soil Sci.* **21**:320-324

Sood, R.D. and Kanwar, B.S. 1986. Distribution of organic and total phosphorus in some soil profiles of different agro climatic zones of Himachal Pradesh. *J. Indian Soc. Soil Sci.* **34**:404-406

Teffin, G. De. and Quencez, P. 1980. An aspect of ammonia nutrition in the oil palm and coconut: Problem of chlorine. *Oleagineux* **35**:539-546

* Thomas, K.M. and Nandra, S.S. 1974. Nutrient composition of coconut leaves and its relation to nut yeilds in Tanzania . *Tor. J.* **39**:170-175

Tomar, K.P. 1987. Chemistry of pedogenesis in Indo-Gangetic alluvial plains. *J. Soil Sci.* **38**:405-414

Turner, T.R., Waddington, D.V. and Duich, J. M. 1978. The effect of sampling depth on soil test results of turfgrass areas. *Commun. Soil Sci. Pl. Anal.* **9**:89-104

Ushakumari, K. 1983. Aggregate size distribution and its relation to physical and chemical properties of some typical soils of Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur

Viswanatha , J. and Doddamani, V.S. 1993. Distribution of P fractions in some Vertisols. *J. Indian Soc. Soil Sci.* **39**:441-445

Wahid, P.A., Devi, C.B.K., Philip, G. and Pillai, N.G. 1975. Effects of discontinuation of fertilizer application on the NPK nutrition of coconut palm. *J. Pln. Crops* **3**:58-60

Wahid, P.A., Devi, C.B.K. and Pillai, N.G. 1974. Interrelationships among root CEC, yield and mono and divalent cations in coconut (*Cocos nucifera* L.). *Pl. Soil* **40**:607-617

Wahid P.A., Kannan, K., Kamalam, N.V. and Venugopal, V.K. 1981. Genotypic and seasonal variation in the mineral nutrition of coconut palms. *J. Pln. Crops* **9**:105-111

Wahid, P.A. and Nambiar, C.K. 1978. Nutrient uptake index for evaluating nutrient removal by coconut palm (*Cocos nucifera* L.) during pre - bearing stage. *Proc. PLACROSYM I*, PLACROSYM Standing Committee, Kottayam, p.173

Warrier, S.M. and Piggot, C.J. 1973. Rehabilitation of oil palms by corrective manuring based on leaf analysis. *Advances in oil palm cultivation.* (Eds. R.L. Wastic and D.A. Earp). Incorporated Society of Planters, Kuala Lumpur

Watanabe, F.S. and Olsen, S.R. 1965. Test of an ascorbic acid method for determinging phosphorus in water and $NaHCO_3$ extracts from soil. *Proc. Soil Sci. Soc. Am.* **29**:677

* Ziller, R. and Prevot, P. 1961. The diagnosis of leaf. Method of study of mineral nutrition: its application to coconut palm. *Institute de Recherches pour les Hiules et Oleagineux,* Paris. Personal Communication to the Director, CPCRI, Kayamgulam.

*Originals not seen

STANDARDISATION OF SOIL SAMPLING AND FERTILIZER RECOMMENDATION TECHNIQUES FOR COCONUT GARDENS

By

E. F. NIMBA FRANGO

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 654

1998

ABSTRACT

An investigation was carried out during 1994-95 to standardise soil sampling technique for coconut and to work out fertilizer recommendation system considering physical/textural nature of soil as well as nutrient levels. Two standing populations of WCT palms grown under good and average management practices (situation A and B respectively) located at Mulamkunnathukavu (Thrissur district) was utilised for the study. From each plot twenty healthy palms were selected for the study. The coconut gardens were separated by a distance of about 1 km and the soil of the site was laterite (Oxisol).

Composite soil samples were collected from three depths from the surface and from three radial positions from the bole of the palm. Samples were collected in May, October and January. Leaf samples were collected from the 10th frond and observations on yield and yield attributes were also recorded along with soil samples. Physico-chemical properties of soil, root activity pattern, leaf nutrient content and yield and yield attributes of both situations were compared. Correlation between physical and chemical properties of soil, correlation between soil parameters, leaf nutrient content, yield and yield attributes were also worked out.

Both situations showed much variation in physico-chemical properties of soil. Coarser soil fractions were more in situation B while, in situation A finer fractions dominated. High yield situation (situation A) recorded higher values for organic carbon and available K compared with situation B. Depthwise as well as radial distance wise differences were also noticed in the nutrient content. In both

situations soil nutrient content decreased as the sampling depth from the surface as well as radial distance from the bole of the palm increased.

A perusal of seasonal variation of nutrients in soil indicated that maximum organic carbon, available P and available K content was attained in the second season (in October) which declines continuously through the third and first season except organic carbon of situation B.

Comparison of leaf nutrient status of two situations revealed that palms of situation A recorded higher N, P and K content in their leaves. Corresponding differences were also reflected in the production of nuts.

Root fractions collected from different depths have indicated that in both situations maximum root activity was confined to a depth of 0-30 cm. Hence conventional method of fertilizer recommendation based on soil testing now practised in the state is not suitable for coconut which takes into account the nutrient status of the top 15 cm layer only.

Comparing the radial distance L_1 established significant relationship only with N while L_2 established significant relation with N and K. Since > 75 per cent of the roots are residing inside the basin, sampling from outside the basin alone (L_3) is also misleading. Hence mixed composite sampling (L_2) including both inside and outside basin soils is more appropriate.

Based on the above observations the most suitable sampling technique for coconut is composite sampling containing both inside and outside basin soils from a depth of 0-30 cm from the surface (L_2D_2).

In situation A organic carbon manifested maximum relationship to yield of nuts in the second season and potassium content in the third season whereas organic carbon content of the first season was related with yield in high yield situation. This would suggest that time of sampling is also important which differ between yield group and nutrient to be analysed.

Results also indicated that organic carbon content was related to soil fractions in both situations though, the relationship was in opposite direction. In situation A, finer fractions showed positive and coarser fractions showed negative correlations with organic carbon. The reverse was the case in situation B where coarser fraction had positive and finer fraction had manifested negative relations. It has also been noticed that organic carbon content was linked with nut production in both situations.

Varying interaction of organic carbon with different fractions of soil on one side simultaneously with its direct bearing on productivity would point out to the necessity of evolving texture linked indices to get reliable information about nutrient availability status of soil. Therefore, some correction factor should be added to soil test values to account the anomalies caused by the coarser soil fraction which is not having a direct role in production and productivity.