YIELD PREDICTION IN COCONUT BASED ON FOLIAR N, P AND K VALUES

By

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THESIS

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Department of Soil Science and Agricultural Chemistry
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DECLARATION

I hereby declare that this thesis entitled "Yield prediction in coconut based on foliar N, P and K values" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any University or Society.

Vellanikkara,
December, 1983.

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CERTIFICATE

Certified that this thesis entitled "Yield prediction in coconut based on foliar N, P and K values" is a record of research work done by Shri. Krishnakumar, N. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Dr. A.I. JOSE,
Chairman,
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CERTIFICATE

We, the undersigned, members of the Advisory Committee of Shri. Krishnakumar, N., a candidate for the degree of Master of Science in Agriculture with major in Soil Science and Agrl. Chemistry, agree that the thesis entitled "Yield prediction in coconut based on foliar N, P and K values" may be submitted by Shri. Krishnakumar, N. in partial fulfilment of the requirement for the degree.

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CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF APPENDICES

Introduction

INTRODUCTION

The coconut palm (<u>Cocos nucifera</u> Linn.) is a crop that is most intimately connected with the tropical life. It is a regular supplier of food and other necessities to man. The importance of coconut cannot be confined to statistical figures as each and every part of the palm is used for some purpose or other. Currently it is grown in an area of 1.1 million ha in India. Among the states Kerala ranks first in the area and production of coconut. Coconut occupies 662657 ha in Kerala, with an annual production of 3032 million nuts.

Though essentially a tree crop of the humid tropics, coconut is versatile in its adaptability to a wide range of soil and climatic conditions. Because of the heterogeneous nature of the soils in which coconut is grown around the world, assessment of the fertility status of the soil becomes difficult. Moreover, a mere soil test data will not reflect the amount of nutrients that is actually available to the roots of the palm. Again, the capacity of the palm to absorb nutrients vary from palm to palm. A better index of the nutritional uptake by the palm can be obtained through the technique of foliar diagnosis. As pointed out by Manciot et al. (1980) prospection of foliar diagnosis allied to a thorough knowledge of the soils is an excellent means to study the nutritional status of the palm, to work out the nutrient balance, to discover the degree of response and the threshold of profitability of fertilizers and to define the linkage between elements.

The pioneering works in foliar diagnosis in coconut were done by the scientists of IRHO in West Africa and they have standardised different aspects of foliar analysis as a diagnostic tool in coconut. Ziller and Prevot (1963) have recommended the leaf lamina of the frond 14 as the index leaf for foliar analysis in coconut and they have defined the critical levels of different nutrient elements in this leaf. However, works of these scientists are confined to certain climatic conditions, so that, their observations cannot be applied in other parts of the world, where the soil and climatic conditions under which coconut is grown may be entirely different. Hence it becomes necessary to standardise the technique of foliar diagnosis for different conditions.

In India, works attempting to standardise foliar diagnosis is scanty, especially in the case of coconut. When we consider the importance of coconut in the economy of the country, the requirement of greater attention in this line becomes vivid. One of the important attempts in Kerala to standardise the foliar diagnostic technique in coconut is that of Gopi and Jose (1983). In order to find out the leaf that will best reflect the nutritional status of the palm, they sampled all the available leaves from the palms of a NPK fertilizer trial maintained at Balaramapuram. Their work emphasises the importance of standardisation of foliar diagnosis, as the index leaf that they suggested was different from the index leaf suggested by IRHO. However, their observations were limited to a few number of palms only and was confined to a particular coconut growing area of the state, namely Balaramapuram. The present study, therefore, aims at testing the results obtained by these scientists over a large number of palms and under different climatic and soil conditions. Such a work will help to determine which will be the leaf that can be recommended as the index leaf throughout the state, and to estimate the critical levels of different nutrients in that leaf based on which fertilizer schedules can be worked out. Therefore, the objectives of the present study are,

1. to standardise the index leaf for foliar diagnosis in coconut based on the analysis of a large

number of palms from different parts of the state.

2. to establish the critical levels of different nutrients in that leaf below which the application of that nutrient will show response.

3. to develop yield prediction models for forecasting the yield of a palm based on the contents of nutrients in the index leaf and other parameters related to yield.

Review of Literature

REVIEW OF LITERATURE

The present investigation, "Yield prediction in coconut based on foliar N, P and K values" was carried out with the objective of developing regression models for predicting the yield of coconut based on the foliar nutrient status. The review pertaining to the investigations on foliar diagnosis in coconut carried out in India and abroad is given below.

1. Foliar diagnosis

Foliar diagnosis is a technique of assessing the nutrient status of the plant by analysing a particular part of the plant tissue at a particular period of growth of the plant. Making use of this technique detection of nutrient level of the plant, assessment of the nutrient need of the crop and prediction of crop performance have been successfully followed in many crops.

The term "Diagnostic Foliare" was first used in France by Lagatu and Maume (1926) and their concept of tissue analysis as a diagnostic tool for nutrient deficiencies in plants gave a fundamental and scientific footing to the field of foliar diagnosis.

Wadleigh (1949) remarked that, for anygiven combination of environmental factors, within a plant tissue, there is an optimum content of mineral nutrients for maximum plant growth, and deviation from this affects it. This is the strong basis on which plant analysis as a diagnostic tool stands.

1.1 Sampling technique

Since leaf is the primary centre (Lundegardh, 1951) where the major synthetic processes and vital functions of the plant take place, changes in the nutrient pattern of the leaf can be related to the nutritional status of the soil and the level of fertilization to be adopted. Rogers *et al*. (1955) opined that leaf was as sensitive or even more sensitive than any other plant part as an index of the nutritional status of the crop.

The leaf samples are collected and analysed in a period when the leaf nutrient content remains relatively stable and the result is related to the final performance of the plant in quantity and quality. As a common practice, the critical levels of the different nutrients are determined by analysis of leaves which have not entered to phase of senescence and have fully matured physiologically. The leaf thus selected is termed as the reference or index leaf.

Evans (1979) stated the importance of identifying all factors that cause variation in leaf nutrient levels viz., climate, season, time of day, age of tree, age of foliage, between tree variation, position of the crown, nutrient balance, effects of diseases and other factors. This indicates the importance of standardization of sampling techniques for foliar diagnosis. Development and selection of sampling technique have been discussed by many investigators like Goodall (1949), Ulrich (1952) and Smith (1962). Suggested foliar sampling techniques for some important crops were reviewed by Gopi (1981).

1.2 Critical level of nutrients

Critical level of a nutrient can be defined as the concentration of that nutrient in the leaf above which a yield response from the element in the fertilizer is unlikely to occur (Prevot and Ollagnier, 1957). The term critical concentration actually indicates the optimum concentration of a given nutrient element in the sampled tissue above which response to further increment is doubtful or occurs at rapidly diminishing rate. A review of the critical concentrations of different nutrient elements for different crops has been done by Gopi (1981).

1.3 Foliar diagnosis vs. soil analysis

Leverington et al. (1962) reported that unless potassium is very deficient, soil analysis is more reliable than leaf analysis for assessing potassium requirement of sugarcane.

However, Jones (1963) established a general relationship between the micro-nutrients in the top soil and those in the leaves in apple and raspberry.

A comparison of foliar diagnosis with soil analysis for the estimation of phosphorus and potassium requirements of groundnut in Senegal was made by Ollagnier and Giller (1955) in which foliar diagnosis values were better correlated with yield and response to phosphorus and potassium, than soil analysis. Similar superiority of foliar diagnosis over soil analysis was reported by Lafevre (1965) and Ruer (1966). However, Champion (1966) remarked that foliar diagnosis and soil analysis are both necessary in judging fertilizer requirements in banana.

2. Foliar diagnosis in coconut

The pioneering works on foliar diagnosis in coconut were done at the Institute de Recherches pour les Huiles at Oleagineux (IRHO) in West Africa. This institute is doing routine foliar diagnosis in coconut since 1950.

According to Ziller and Prevot (1963), the aim of foliar diagnosis is to reveal, by chemical analysis of leaf, the needs of the plant and possible deficiencies in certain mineral elements.

Several works have been done by different scientists to ascertain the possibility of using different parts of the coconut palm as a material, the analysis of which will give a picture of the nutritional status of the palm. Nathanael (1955) indicated the possibility of using toddy as such a material. In an exhaustive study, he found that the N, P, Ca and Mg content of toddy remained remarkably constant between plants of similar yield characteristics. But this was contradicted by De Silva (1974) who found that toddy as a plant material was unsuitable for nutritional studies in coconut. Salgado (1948) obtained close correlation between the K and P contents of the liquid endosperm of ripe coconuts with nut yield and copra content. In his work, he indicated the possibility of directly analysing the fresh liquid endosperm for P and K without digestion or ashing.

Eventhough a few of such references as mentioned above utilising plant parts other than leaf for finding out the nutritional status of the palm are available majority of the works reveal the capacity of leaf to reflect the nutritional status of the palm. De Silva (1974) pointed out that, of all the different plant parts, leaf will be the best one to be selected for plant analysis.

2.1 Sampling

In foliar diagnosis, sampling procedure is very important and should be carefully standardised and followed so as to get a representative sample. Leaves must be taken from all the palms of an area to get a representative sample of that area. Romney (1964) in Jamaica recommended not less than 15 palms while Ziller and Prevot (1963) suggested 25 palms. From each palm, a sample of six leaflets (three from each side of the rachis) is taken without cutting the leaf. From each leaflet, the middle section of about 10 cm long, is taken. The margins of this segment (about 2 mm) are trimmed and the mid-rib removed leaving two halves (lamina) which are taken for analysis.

2.2 Index leaf

Palms below the age of 18 months after planting are not recommended for sampling. For palms upto four year old, the 9th leaf (taking the youngest leaf with the leaflets well separated as the leaf No.1) is recommended for sampling.

In the case of Malayan dwarf palms, Romney (1965) recommended the following leaves for foliar diagnosis according to the age of the palms.

Age of palm	Total living fronds per palm	Leaf recommended for foliar diagnosis
1 - 1½ years	6 - 9	Leaf 4
1½ - 2 years	9 - 12	Leaf 6
2 - 3 years	12 - 14	Leaf 8 or 9
3 - 4 years	14 - 17	Leaf 11
Bearing	16 - 30	Leaf 11 - 15

Ziller and Prevot (1963) suggested the 14th leaf as the index leaf for foliar diagnosis. They have described the 14th leaf as the one which carried nuts that are about the size of the fist. According to them it is that leaf which has attained full physiological maturity. De Silva (1973) revealed a low content of magnesium in the 14th frond of Mg deficient palms. Shanmuganathan and Loganathan (1976) also supported the use of 14th leaf for detecting the K deficiency in some K deficient soils of SriLanka. In one study by Jeganathan (1981), the leaf nutrient contents showed lesser variation in 13th to 16th fronds. From this, they concluded 14th frond as the index leaf of coconut. The IRHO is doing foliar diagnosis as a routine work making use of the 14th frond as the index leaf. The use of 14th frond as the index leaf in foliar diagnosis of coconut is more or less well accepted throughout the world.

However, works indicating the possibility of using other leaves for foliar diagnosis in coconut are also there. Nethsinghe (1963) detected Mg deficiency based on analysis of the 6th frond. De Silva (1974) pointed out the necessity of using different leaves for different elements. He recommended the mature fronds in determining iron and manganese, and the youngest fully opened leaf in case of copper and boron. Southern and Dick (1968) also supported the view that iron content of mature leaves gave a better index of Fe status of plants.

Gopi and Jose (1983) recommended the 2nd leaf as the best for the simultaneous detection of N and K, since he 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 nitrogen content of the 10th leaf followed by the 2nd leaf. In the case of potassium, maximum correlation was obtained between yield and the potassium content of 2nd leaf. The phosphorus content was not correlated significantly with yield, irrespective of the leaf position.

2.3 Critical level of nutrients

Critical level of an element was defined by Ziller and Prevot (1963) as the percentage on dry matter basis of that element, below which an application of the appropriate fertilizer had a fair chance in increasing the yield.

Ziller and Prevot (1963) showed that the content of nitrogen increased from 1st to 6th leaf, and thereafter decreased. The above finding was confirmed by Gopi et al. (1982).

There was a decrease in the contents of P and K as the age of the leaf increased while Ca and Mg contents increased (Ziller and Prevot, 1963). Jaganathan in 1981 also illustrated a steady decline in the concentration of P and K as the frond age increased. Ca showed an opposite effect. Gopi (1981) also indicated a decrease in the contents of P and K with increase in the age of the frond.

Southern and Dick (1968) found that there was an accumulation of Fe in the mature leaves. This view was supported by De Silva (1974) who revealed an increase of Fe content from 20 ppm to 40 ppm as the age of the frond increased. However, Eschbach and Manicot (1981) remarked that the Fe content of coconut leaf can vary from 40 to 100 ppm.

Manciot, Ollagnier and Ochs (1980) reported that Al content also increased with age of the frond. They reported a variation from 6 to 127 ppm. But in 1981 Eschbach and Manciot got a variation from 9 to 48 ppm in the Al content.

De Silva (1974) reported that the Mn content ranged from 75 ppm in the 1st leaf to 175 ppm in the 14th leaf.

De Silva (1974) stated that the Cu content decreased with age of the leaf. He could not obtain a clear trend in the pattern of distribution of Zn in the leaves. However, he reported that Zn content of young leaves varied between 12 and 20 ppm and that of mature leaves, between 10 and 22 ppm. But he found that B content decreased with age of the leaf, from 15-38 ppm in the 1st leaf to 12-17 ppm in the 14th leaf.

Ziller and Prevot (1963) suggested the following critical levels based on the frond 14 sample of the variety typica.

N	-	1.70	Per cent dry matter
P	-	0.10	
K	-	0.45	
Ca	-	0.50	
Mg	-	0.40	

Fremond _et al_. (1966) modified the critical levels originally suggested by Ziller and Prevot. The Fremond's critical levels are given below.

N -	1.80 - 2.00	Per cent dry matter
P -	0.12	
K -	0.80 - 1.00	
Ca -	0.50	
Mg -	0.30	

In SriLanka, Nethesinghe (1966) suggested for four years old palms, the optimum leaf composition of 2.20 per cent nitrogen, 0.14 per cent phosphorus and 2.10 per cent potassium. Romney (1966) reported that Malayan dwarf palms have higher critical levels of nitrogen and potassium than Jamaican tall palms. Kanapathi (1971) suggested tentative optimum levels for tall, semi tall and dwarf palms as follows:

	N%	P%	K%	Ca%	Mg%
Tall	1.8	0.12	0.80-1.1	0.15-0.30	0.30
Semi-tall	1.8-2.0	0.12	0.80-0.9	0.15-0.30	0.30
Dwarf	1.9-2.0	0.12	0.75-1.0	0.15-0.30	0.30

In 1981, Manciot, Ollagnier and Ochs stated that the critical level of potassium of the 14th leaf was 0.80 - 1.0 per cent for tall varieties. For new hybrids, they suggested a value of 1.4 per cent.

Gopi and Jose (1983) worked out the critical level of nitrogen in the 2nd leaf as 3.31 per cent. The critical level for potassium was 2.17 per cent in the same leaf. These values are much higher than the values originally suggested by other scientists which is obviously because of the invariably higher content of potassium observed in the 2nd leaf as compared to that of the 14th leaf.

Manciot, Ollagnier and Ochs (1980) suggested the critical level of iron as 50 ppm in the 14th frond. They recommended the critical level of copper as 5 to 7 ppm. On the other hand Eschbach and Manciot (1981) fixed the critical level of copper at 4 to 5 ppm.

The optimum level of boron in the 14th leaf was suggested by Manciot, Ollagnier and Ochs (1980) as 5 to 10 ppm. In 1981 Eschbach and Manciot stated that the optimum level of boron is 10 ppm.

Manciot, Ollagnier and Ochs (1980) found that the critical level of sulphur is 0.15 to 0.20 per cent.

This was a modification of the critical level of sulphur originally suggested in 1968 by Southern and Dick which was 0.15 per cent.

Eschbach and Manciot (1981) fixed the critical level of manganese at 100 ppm and that of zinc at 15 ppm.

In the case of sodium, Ziller and Prevot (1963) fixed a level which was not desirable to exceed. This was 0.40 per cent in the 14th leaf.

Teffin and Quencez (1980) reported the critical level of chlorine as 0.5 to 0.6 per cent. On the other hand, Eschbach, Massimino and Mendoza (1982) found that, levels of chlorine below 0.1 per cent showed chlorine deficiency.

2.4 Importance of chlorine in coconut nutrition

The essentiality of chlorine in the nutrition of coconut palm was brought to the fore through foliar diagnosis. It was Ollagnier in 1971 who first recognised the importance of chlorine for coconut and oil palm. Ollagnier in 1971 remarked that, potassium is not always necessary and that response to muriate of potash (KCl) which hitherto attributed to K, should, in fact, have been credited to Cl.

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

Magat, Cadigal and Habana (1975) stated that, the correlation between the yield and the chlorine content of the leaf was higher than the correlation between yield and the potassium content of the leaf. Prudente and Mendoza (1976) found that the chlorine content of the leaf was highly correlated with nut/tree, wt./nut and copra/tree.

Manciot, Ollagnier and Ochs (1980) remarked that potassium, nitrogen and chlorine predominated in the mineral requirements of coconut. Because of the relative abundance in nature, deficiency of chlorine was generally limited to specific situations, sheltered from the influence of the sea.

Teffin and Quencez (1980) made a detailed study of the importance of chlorine for coconut. They got two types of responses to KCl application.

1. Only chlorine was assimilated in large quantities with positive effect on yield. Very little potassium was assimilated, or the level was even slightly depressed.

2. Potassium and chlorine both prefectly assimilated, both having positive correlation with yield.

Eschbach, Massimino and Mendoza (1982) found that chlorine deficiency affected the growth of young palms and the yield of mature ones. They said that levels of chlorine below 0.1 per cent in leaves showed deficiency.

Nair and Sreedharan (1983) stressed the importance of chlorine in the nutrition of oil palm and coconut. According to them, the effect of chlorine content of leaf tissue on morphological characters and yield is greater than that of potassium.

2.5 Nutrient interactions

Smith (1969) challenged the concept of independent critical levels of major nutrients in foliar diagnosis of coconut. He remarked that the yield was related to the interaction between nutrient elements.

Prevot and Ollagnier (1961) explained the interaction between potassium and sodium. They found that at low potassium levels (less than 0.5%) and at low sodium levels(less than 0.4%), the role of potassium in the palm could partly be substituted by sodium. When potassium level exceeded 0.5 per cent or sodium level exceeded 0.4 per cent, this synergism changed to antagonism.

Ziller and Prevot (1963) also pointed out the interaction between potassium and other cations. When potassium content was less than critical, potassium and sodium showed synergism ($r = +0.775^{**}$). When potassium content was more than critical, they showed antagonism ($r = -0.742^{**}$). Such double reciprocal relation was also noticed in the cases of potassium with calcium and potassium with magnesium.

Coomans (1974) also revealed potassium - magnesium antagonism. He was of the opinion that, only when potassium deficiency was corrected, magnesium manuring had a positive action on production. This finding was later confirmed by Manciot, Ollagnier and Ochs in 1981. In their study, application of 5 kg muriate of potash per tree resulted in a fall of magnesium content of the leaf from 0.567 per cent to 0.188 per cent. Loganathan and Balakrishnamurthi (1981) also noticed a decrease in calcium and magnesium content of the leaf upon application of muriate of potash.

Smith (1969) suggested that yield was related to the ratio between foliar nitrogen and potassium. He concluded that at low N levels (less than 1.8 per cent), K nutrition was of limited importance. As N content increased, K nutrition also attained importance. Based on this, he pointed out that the proposed critical level of K, i.e., 0.8 per cent was applicable only in case of adequate N supply. When N was less than 1.8 per cent, the critical level of K was determined by the N/K ratio which should not be less than a critical minimum. Ziller and Prevot (1963) pointed out that the correlation between N and P was negative for young leaves and positive for old leaves.

De Silva (1974) reported that uptake of manganese was high in palms starved of nitrogen. Palms deprived of all macronutrients (N, P, K, Ca and Mg) had a very high concentration of copper in leaves, causing toxicity.

In a study to ascertain the importance of chlorine to coconut, Teffin and Quencez (1980) found that, absorption of chlorine (Cl) was accompanied by an absorption of cations (K^+, Ca^{2+}, Mg^{2+}, NH_4^+ ...) to maintain an electric balance within the tissues. In soils with a high exchangeable calcium (more than 4 me/100 g), Cl uptake goes hand in hand with Ca^{2+} uptake, and potassium deficiency was noted. Thus, in such cases, there was

Cl^{-}- Ca^{2+} synergism and K^{+}- Ca^{2+} antagonism. In the case of soils with exchangeable calcium less than 4 me/100 g, there was Cl^{-}- K^{+} synergism. Their conclusion was that, in soils high in exchangeable Ca, application of potassium as KCl would result in poor response and we would have to go for other potassic fertilizers. But in soils low in exchangeable Ca, KCl was the best source as it supplied both K and Cl. They also indicated a possible superiority of NH_4Cl as a nitrogenous fertilizer than urea because of the supply of Cl and an increased uptake of NH_4^{+}.

Materials and Methods

MATERIALS AND METHODS

Coconut palms maintained in the K.A.U. Research Stations at three regions of the state, viz., Balaramapuram, Mannuthy and Pilicode, were made use of for the present study. Details of the palms maintained at these three different sites are given below.

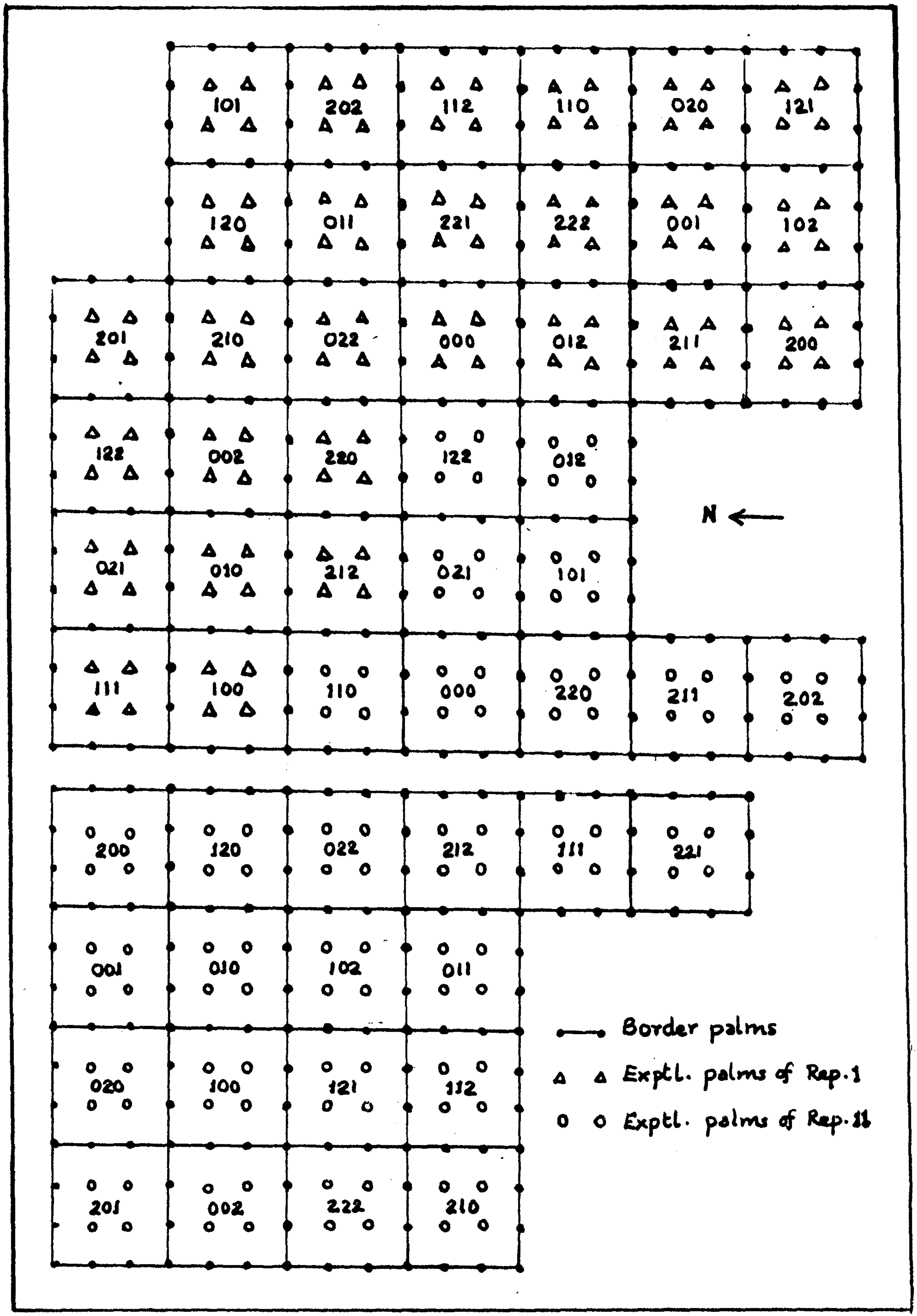
1.1 Balaramapuram

The Coconut Research Station, Balaramapuram is situated in Trivandrum district about 15 km south from Trivandrum city. The area enjoys a typical humid tropical climate.

The soil of the experimental area was deep red, well drained and moderately acidic sandy loam. The area represented a more or less level topography. The soil test data are given in Appendix I.

Coconut palms of a NPK fertilizer trial established since 1964 at the Coconut Research Station, Balaramapuram were made use of for the study. The details of the field experiment are (Fig.1):

Fig. 1. Lay out plan of the field experiment at Coconut Research Station, Balaramapuram



Design	:	3^3 confounded factorial
Total number of treatments	:	27 (N, P and K each at 3 levels)
Number of replications	:	2
Number of blocks	:	6
Total number of plots	:	54
Number of plots per block	:	9
Plot size	:	15 m x 15 m
Spacing	:	7.5 m x 7.5 m
Number of experimental trees per plot	:	4
Factors confounded	:	NPK^2 in replication I
		NP^2K^2 in replication II
Variety	:	West Coast Tall
Date of start	:	17.6.1964
Levels of nitrogen	:	n_0 0 g N/tree/year
		n_1 340 g N/tree/year
		n_2 680 g N/tree/year
Levels of phosphorus	:	p_0 0 g P_2O_5/tree/year
		p_1 225 g P_2O_5/tree/year
		p_2 450 g P_2O_5/tree/year
Levels of potassium	:	k_0 0 g K_2O/tree/year
		K_1 450 g K_2O/tree/year
		k_2 900 g K_2O/tree/year

Treatment combinations

Sl. No.	Notation	Treatment combination	Sl. No.	Notation	Treatment combination
1	000	$N_0P_0K_0$	15	112	$N_1P_1K_2$
2	001	$N_0P_0K_1$	16	120	$N_1P_2K_0$
3	002	$N_0P_0K_2$	17	121	$N_1P_2K_1$
4	010	$N_0P_1K_0$	18	122	$N_1P_2K_2$
5	011	$N_0P_1K_1$	19	200	$N_2P_0K_0$
6	012	$N_0P_1K_2$	20	201	$N_2P_0K_1$
7	020	$N_0P_2K_0$	21	202	$N_2P_0K_2$
8	021	$N_0P_2K_1$	22	210	$N_2P_1K_0$
9	022	$N_0P_2K_2$	23	211	$N_2P_1K_1$
10	100	$N_1P_0K_0$	24	212	$N_2P_1K_2$
11	101	$N_1P_0K_1$	25	220	$N_2P_2K_0$
12	102	$N_1P_0K_2$	26	221	$N_2P_2K_1$
13	110	$N_1P_1K_0$	27	222	$N_2P_2K_2$
14	111	$N_1P_1K_1$			

Nitrogen, phosphorus and potassium were applied in the form of amonium sulphate, superphosphate and muriate of potash, respectively. No organic manure was given to the experimental palms.

1.2 Mannuthy

The Agricultural Research Station, Mannuthy is situated in Trichur district. The area has a humid tropical climate.

The experimental area was having typical laterite soil. The soil test data is given in Appendix II.

Coconut palms of the variety West Coast Tall maintained at the Agricultural Research Station, Mannuthy were selected for the study. The palms were given NPK fertilization according to the Package of Practices Recommendations of the Kerala Agricultural University.

1.3 Pilicode

Coconut palms maintained at the Regional Agricultural Research Station, Pilicode were also included in the study. The Regional Agricultural Research Station, Pilicode is situated in Cannanore district.

The experimental area consisted of laterite soil. The soil test data is given in Appendix III.

The palms selected for the study were of the variety West Coast Tall. The palms were given NPK fertilization according to the Package of Practices Recommendations of the Kerala Agricultural University.

2. Selection of palms for the study

All the available palms in the NPK fertilizer trial at the Coconut Research Station, Balaramapuram, were selected for the study. There were four palms in each plot, thereby totalling to 216 palms from 54 plots. Thus all the 8 palms were selected for representing one treatment, four being from one replication, and four being from the other.

Sixty palms were selected from the Agricultural Research Station, Mannuthy. Similarly, 60 palms were selected from the Regional Agricultural Research Station, Pilicode.

Thus the total number of palms selected for the study was 336.

2.1 Collection of soil samples

Soil samples were collected from the base of the selected palms from four different spots within a radius of two metres. In the case of the palms of the Coconut Research Station, Balaramapuram, samples drawn from base of the four palms of the same plot were made into a single composite sample. Soil samples were separately collected for each individual palm in the case of the palms at Mannuthy and Pilicode.

2.2 Collection of leaf samples

Leaf samples were collected from all the selected 336 palms. The last fully opened leaf at the centre of the crown was referred to as the leaf No.1 and the leaves were numbered in the order of their increasing age. Leaf samples were taken from the 2nd, 10th and 14th leaves of the palm. For the preparation of leaf samples, sample from leaf was made by cutting two leaflets from the middle portion of the leaf from either side of the rachis with the help of a hook knife. So, four leaflets from each leaf were collected. The midrib as well as the marginal threads of the laminae were removed and the samples were taken by cutting 10 to 20 cm long strips from the middle of the laminae. The samples were cleaned and sun dried.

3. Analytical methods

3.1 Soil

The total nitrogen was determined by kjeldahl digestion - distillation procedure described by Jackson (1958). The available phosphorus was extracted using Bray No.1 extractant. The phosphorus content was determined colorimetrically by the chlorostannous-reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson, 1958). The available potassium was extracted by 1N neutral ammonium acetate. The exchangeable calcium, magnesium and sodium were extracted by leaching with 1N neutral ammonium acetate after washing the sample with water. The potassium and sodium contents were determined flame photometrically. The calcium and magnesium contents were determined by versene titration method using calcon and Erichrome Black T indicators described by Hesse (1972).

3.2 Plant material

The total nitrogen was determined by the micro-kjeldahl digestion-distillation method described by Jackson (1958). For the determination of total phosphorus, potassium, calcium, magnesium and sodium, the plant material was digested in a mixture of nitric acid, sulphuric acid and perchloric acid (9:2:1). The phosphorus content was determined colorimetrically by the vanadomolybdate yellow colour method in nitric acid medium (Jackson, 1958). The potassium and sodium contents were determined flame photometrically (Jackson, 1958). The calcium and magnesium contents were determined by versene titration (Hesse, 1972).

3.3 Statistical analysis

Statistical analysis of the data was carried out by adopting standard methods described by Panse and Sukhatme (1967). The effect of NPK treatment on the number of leaves retained and the yield of the palm was studied by analysing the observations from the 3^3 partially confounded factorial experiment at Balaramapuram, through analysis of variance technique.

The degree of relationship between yield and nitrogen, phosphorus, potassium, calcium, magnesium and sodium contents of the leaf lamina at 2nd, 10th and 14th leaf positions was estimated by calculating simple coefficients of linear correlation. Simple linear correlation coefficients were also worked out between yield and number of leaves retained. In addition, intercorrelations between all pairs of variables were worked out.

Yield prediction equations were worked out for forecasting the expected yield of the experimental palms on the basis of leaf nutrient contents. Simple linear regression equation of the form $Y = a + b X$ where Y is the yield and X is the amount of a particular nutrient in the leaf were fitted separately for each of the different leaf nutrients. Multiple linear regression equations were also worked out for predicting the expected yield on the basis of nutrient per cent for different nutrients and number of leaves retained. Coefficients of multiple determination (R^2) were calculated to know the percentage variability explained by the fitted model. The degree of relationship between observed yield and its best linear estimate was found out by using the multiple correlation coefficient.

Results

RESULTS

1. General characteristics of soil

Data on pH, content of nitrogen, phosphorus, potassium, calcium, magnesium and sodium of the experimental soil at Balaramapuram, in relation to the treatments of nitrogen, phosphorus and potassium are presented in Appendix I. In general, the pH of the soil varied from 5.4 to 7.1. The total nitrogen content of the soil varied from 0.056 to 0.168 per cent. The mean values for total nitrogen corresponding to n_0, n_1 and n_2 levels of application were 0.090, 0.118 and 0.168 per cents respectively. Available phosphorus content, as extracted by Bray No.1 varied from 1.92 to 42.13 ppm. The mean values corresponding to p_0, p_1 and p_2 treatments were 3.14, 12.79 and 29.57 ppm respectively. Such an increase in the content of the element with application of the element was noticed in the case of potassium also. The available potassium varied from 15.960 to 70.20 ppm. The mean values corresponding to k_0, k_1 and k_2 levels of potassium application were 23.01, 50.31 and 51.87 ppm respectively. The exchangeable calcium content of the soil varied from 0.49 to 1.95 me/100 g. The mean values corresponding to k_0, k_1 and k_2 levels of application of potassium were 1.12, 1.06 and 1.10 me/100 g respectively. On the other hand, the exchangeable magnesium content, which showed an overall variation from 0.14 to 0.91 me/100 g decreased with increasing levels of potassium application . The mean values for k_0, k_1 and k_2 were 0.61, 0.48 and 0.41 me/100 g respectively. The exchangeable sodium content varied from 0.05 to 0.13 me/100 g of soil. The mean values were 0.07, 0.07 and 0.08 me/100 g for k_0, k_1 and k_2 levels respectively.

Appendix II presents the observations on the general characters of soil at Mannuthy, such as pH, total nitrogen, available phosphorus and available potassium and exchangeable calcium, magnesium and sodium. The pH of the soil varied from 4.7 to 6.9 with a mean value of 5.5. The total nitrogen content of the soil ranged between 0.112 and 0.211 per cent. The average value was 0.168 per cent. The available phosphorus content of the soil, as extracted by Bray No.1, ranged from 32.83 to 44.70 ppm with a mean of 37.91. The available potassium content varied from 74.10 to 167.70 ppm with mean value of 120.90. The ranges for exchangeable calcium, magnesium and sodium were 0.25 - 0.93, 0.05 - 0.50 and 0.03 - 0.09 me/100 g soil respectively. The soil contained 0.88 me/100 g of calcium on an average. The mean magnesium content was found to be 0.21 me/100 g whereas the mean of sodium was 0.06 me/100 g.

Data pertaining to the general characteristics of soil at Pilicode are presented in Appendix III. The pH of the soil varied from 4.3 to 6.6 with a mean of 5.8. The total nitrogen content varied between 0.125 and 0.266 per cent with a mean value of 0.180 per cent. The available phosphorus content of the soil, as extracted by Bray No.1 ranged from 32.88 to 59.74 ppm with a mean of 44.32. The ranges of the available potassium and exchangeable calcium, magnesium and sodium contents were 331.50 - 565.50 ppm and 1.32 - 2.49, 0.03 - 0.09 and 0.15 - 0.49 me/100 g of soil respectively. The corresponding mean values were 518.70 ppm potassium and 2.25, 0.06 and 0.22 me/100 g calcium, magnesium and sodium respectively.

2. Effect of NPK treatment on the number of leaves retained by the experimental palms at Balaramapuram.

Data on the number of leaves retained by the palms receiving different levels of N, P and K are presented in Table 1. The analysis of variance is presented in Appendix IV.

2.1 Nitrogen

Nitrogen decreased the number of leaves retained by the palms. The n_0 treatment registered the highest number of leaves, 19.85. The numbers of leaves for n_1 and n_2 were 18.25 and 17.18 respectively. Thus, in this respect, n_0 treatment was superior to n_1 which was superior to n_2.

2.2 Phosphorus

Increasing levels of phosphorus application could not bring about any increase in the number of leaves retained by the palms. The values for average number of leaves retained per palm in the case of p_0, p_1 and p_2 treatments were 18.78, 18.13 and 18.37 respectively.

2.3 Potassium

Increasing levels of potassium application produced a drastic increase in the number of leaves retained by the palms. Palms receiving the k_0 treatment were able to retain only 11.75 leaves per palm whereas the corresponding values for k_1 and k_2 were 20.61 and 22.92 respectively. Thus, an increase in the amount of potassium given to the palm from 0 g K_2O per tree to 450 g K_2O per tree resulted in 75.40 per cent increase in the number of leaves whereas there was 95.06 per cent increase as the potassium application was increased from 0 g K_2O per tree to 900 g K_2O per tree.

2.4 NPK interaction

A study about the effect of interaction between levels of nutrients added on the number of leaves produced revealed that the interaction between the leaves of nitrogen and phosphorus was not significant. On the other hand, interaction between the levels of nitrogen and potassium was highly significant. When potassium was not applied, application of nitrogen decreased the number of leaves produced. This is because, the mean number of leaves produced steadily declined from 14.96 at n_0k_0 to 10.67 at n_1k_0 and then to 9.63 at n_2k_0. Thus n_0k_0 was superior to n_1k_0 and n_2k_0 in terms of the number of leaves produced. The maximum number of leaves which was 23.17, was registered by n_1k_2 combination which was on par with n_2k_2, n_0k_2 and n_0k_1. The effect of potassium in increasing the number of leaves produced was accelerated at higher levels of nitrogen. Application of 900 g K_2O per tree resulted in 52.34 per cent increase in the number of leaves produced at n_0 level whereas the corresponding value at n_2 level was 136.66 per cent.

The interaction between the levels of phosphorus and potassium was also significant. The maximum number of

Table 1. Number of leaves and nut yield of the experimental palms of Coconut Research Station, Balaramapuram.

Sl. No.	Treatment n p k	No. of leaves retained Rep.I	Rep.II	Mean	Average yield of nuts/palm/year (1979 to 1982) Rep.I	Rep.II	Mean
1	0 0 0	19.25	17.00	18.13	8.56	6.56	7.56
2	0 0 1	24.00	20.00	22.00	6.00	15.94	10.97
3	0 0 2	21.25	19,50	20.38	6.75	31.31	19.03
4	0 1 0	14.00	12.00	13.00	4.56	3.81	4.19
5	0 1 1	20.75	21.50	21.13	13.25	33.50	23.38
6	0 1 2	21.75	23.50	22.63	9.81	12.75	11.28
7	0 2 0	13.75	13.75	13.75	2.31	1.94	2.13
8	0 2 1	20.75	23.75	22.25	10.69	13.13	11.91
9	0 2 2	26.75	24.00	25.38	18.81	29.50	24.16
10	1 0 0	10.25	13.50	11.88	1.75	4.50	3.13
11	1 0 1	22.00	22.25	22.13	30.44	32.06	31.25
12	1 0 2	23.00	20.50	21.75	3.13	35.69	19.41
13	1 1 0	13.50	9.75	11.63	4.56	0.69	2.63
14	1 1 1	21.75	19.75	20.75	52.13	50.69	51.41
15	1 1 2	25.00	22.25	23.63	49.25	82.56	65.91
16	1 2 0	9.50	7.50	8.50	0.06	0.19	0.13
17	1 2 1	20.75	19.00	19.88	20.44	22.63	21.54
18	1 2 2	24.25	24.00	24.13	39.56	44.38	41.97
19	2 0 0	10.50	9.25	9.88	1.75	8.13	4.94
20	2 0 1	23.75	19.50	21.63	53.19	35.06	44.13
21	2 0 2	23.25	19.25	21.25	43.25	56.31	49.78
22	2 1 0	9.50	8.75	9.13	6.75	0.00	3.38
23	2 1 1	18.25	16.00	17.13	52.44	60.19	56.32
24	2 1 2	24.75	23.50	24.13	69.75	68.94	69.35
25	2 2 0	9.25	10.50	9.88	2.38	0.44	1.41
26	2 2 1	19.50	17.67	18.59	52.44	71.75	62.10
27	2 2 2	24.00	22.00	23.00	83.25	64.38	73.82

leaves (24.17) was registered by p_2k_2 which was on par with p_1k_2. At k_0 level, application of phosphorus decreased the number of leaves retained as shown by the mean leaf number of 13.29 at p_0k_0 which decreased to 11.25 at p_1k_0 and 10.71 at p_2k_0. Application of potassium increased the number of leaves produced at all levels of phosphorus, and especially so at higher phosphorus levels. There was 58.99 per cent increase in the number of leaves produced from p_0k_0 to p_0k_2. But the increase from p_2k_0 to p_2k_2 was 125.68 per cent.

3. Effect of NPK treatment on the yield of the experimental palms at Balaramapuram.

The average yield of nuts/palm/year was worked out from the total yield of the palms during the last 4 years viz., 1979 to 1982. The yield data are presented in Table 1.

3.1 Nitrogen

Levels of nitrogen significantly influenced the yield. The yield obtained at n_2 level was 40.578 nuts/palm/year which was superior to the yield obtained at n_1 and n_0. Significantly increased yield was also registered by n_1 over n_0. Results showed an increase in yield by 107.15 per cent as the level of nitrogen increased fron n_0 to n_1.

The increase in yield from n_0 to n_2 was 218.78 per cent. This showed that, application of nitrogen at all levels of the experiment significantly influenced yield.

3.2 Phosphorus

The yield increased with an increase in the level of phosphorus application from p_0 to p_1. A further increase from p_1 to p_2 resulted in a reduction in yield. The yield registered at p_0, p_1 and p_2 levels was 21.13, 31.98 and 26.57 nuts/palm/year respectively. An increase in phosphorus level from p_0 to p_1 resulted in 51.35 per cent increase in yield whereas from p_0 to p_2 it was 25.75 per cent, with a decline of 16.92 per cent from p_1 to p_2.

3.3 Potassium

There was greatly pronounced influence of potassium on yield. The mean yield at k_0 level was only 3.27 nuts/palm/year, which was boasted to 34.76 at k_1 level of potassium applications. A further increase in potassium application to k_2 level also registered a significant increase in yield to 41.63 nuts/palm/year. But this increase was not as pronounced as that seen from k_0 to k_1. An increase in potassium application from k_0 to k_1 produced 963 per cent increase in the yield whereas the increase in yield from k_0 to k_2 was 1173.09 per cent.

3.4 NPK interaction

Among the interactions between levels of nitrogen, phosphorus and potassium, only the inter action between nitrogen and potassium was significant both at 5 per cent and 1 per cent levels. At k_0 level, application of nitrogen decreased the yield, but this decrease was not significant. The yields of nuts/palm/year at n_0k_0, n_1k_0 and n_2k_0 levels were 4.62, 1.96 and 3.24 respectively. But these three levels were statistically on par, showing that at k_0 level, application of nitrogen had no influence on yield. On the other hand at k_2 level, nitrogen markedly increased yield, a change from n_0k_2 to n_2k_2 registering an increase in yield of 254.13 per cent. Application of potassium increased the yield at all levels of nitrogen. But the influence of potassium was more pronounced at higher levels of nitrogen. At n_0 level, an increase in the level of potassium from k_0 to k_2 produced an increase in yield of 293.03 per cent whereas the corresponding value at n_2 level was 1884.88 per cent. Evidently, the highest yield of 64.31 nuts/palm/year was registered by n_2k_2 level which was on par with n_2k_1 level.

The interaction between nitrogen and phosphorus was significant at 5 per cent level. Application of nitrogen increased the yield at all levels of phosphorus, the effect being more pronounced at higher levels of phosphorus. At p_0 level, an increase in the nitrogen level from n_0 to n_2 produced an increase in yield from 12.52 to 32.95 nuts/palm/year. This was an increase of 163.18 per cent. On the other hand, a change in the level from n_0p_2 to n_2p_2 produced an increase in yield from 12.73 to 45.77, which was an increase of 259.54 per cent. Application of phosphorus had no effect at n_0 level as shown by the values of yield for n_0p_0, n_0p_1 and n_0p_2 which were 12.52, 12.95 and 12.73 respectively. At n_2 level, however, an increase in phosphorus application from p_0 to p_2 registered an increase in yield of 38.91 per cent. At both n_0 and n_1 levels, application of phosphorus increased the yield only upto p_1 level so that the highest yields at n_0 and n_1 levels were for n_0p_1 and n_1p_1 respectively. However, at n_2 level, the yield increased upto p_2 level, the highest yield being registered by n_2p_2 level.

The interaction between the levels of phosphorus and potassium was also found to be significant at 5 per cent level. At k_0 level, application of phosphorus decreased the yield, the mean yield for p_0k_0, p_1k_0 and p_2k_0 being 5.21, 3.40 and 1.22 nuts/palm/year respectively. On the other hand, at k_1 level, application of phosphorus increased the yield upto p_1 level only, and thereafter the yield was decreased. The mean yields for p_0k_1, p_1k_1 and p_2k_1 were 28.78, 43.70 and 31.85 nuts/palm/year respectively. At k_2 level also, the trend was similar as that shown at k_1 level, the mean yields for p_0k_2, p_1k_2 and p_2k_2 being 29.41, 48.84 and 46.65 nuts/palm/year respectively. Maximum yield of 48.84 nuts/palm/year was registered by p_1k_2 level, which was on par with p_2k_2 and p_1k_1 levels.

Among the NPK combinations, the highest yield of 73.82 nuts/palm/year was registered by $n_2p_2k_2$ followed by $n_2p_1k_2$ having an yield of 69.35 nuts/palm/year.

4. Effect of NPK treatment on the nutrient contents of the leaves of the experimental palms at Balaramapuram.

4.1 Nitrogen

Data on the nitrogen content of 2nd, 10th and 14th leaves (lamina) of the palms are given in Table 4. In general, application of nitrogen increased the nitrogen content of the leaves at all the three leaf positions. In the 2nd leaf, the mean values of nitrogen content were 1.45, 1.69 and 1.83 per cent at n_0, b_1 and n_2 levels. The 10th leaf also registered an increase in the nitrogen content with application of nitrogen, the values for n_0, n_1 and n_2 being 1.50, 1.79 and 1.85 per cent respectively The same effect was noticed in the 14th leaf also which recorded 1.31, 1.64 and 1.71 per cent of nitrogen at n_0, n_1 and n_2 levels respectively.

4.2 Phosphorus

Data on the phosphorus content of leaves of 2nd, 10th and 14th positions are given in Table 7. Application of phosphorus increased the phosphorus content of all the three leaf positions. In the 2nd leaf, the p_0, p_1 and p_2 levels showed phosphorus contents of 0.149, 0.161 and 0.169 per cent. The corresponding values at the leaf position 10 were 0.143, 0.152 and 0.159 per cent. The 14th leaf also registered an increase in phosphorus content from 0.142 per cent at p_0 level to 0.151 per cent at p_1 level. But further increase of phosphorus application to p_2 level resulted in a decline in the content of the element to 0.147 per cent. When the phosphorus content of the leaf lamina of the 2nd leaf increased by 13.42 per cent from p_0 to p_1 level of application, the correspon-ding increases in the case of 10th and 14th leaves were only 11.19 and 3.52 per cent respectively.

4.3 Potassium

Data on the potassium content of leaf lamina at 2nd, 10th and 14th leaf positions as influenced by the NPK treatment are presented in Table 10. Increasing levels of potassium application resulted in increased content of this nutrient in all the three leaf positions examined. In the 2nd leaf, the potassium contents at k_0, k_1 and k_2

levels were 1.19, 2.03 and 2.29 per cent respectively, whereas the corresponding values in the case of the 10th leaf were 0.53, 1.16 and 1.46 per cent and in the case of 14th leaf 0.64, 0.93 and 1.25 per cent. The increase in content of this element in the leaf due to its increased application was more conspicuous than in the case of phosphorus.

5. Number of leaves retained by the palms

Data on the number of leaves retained by the palms at Balaramapuram is presented in Table 1. The average number of leaves retained by the palms at Balaramapuram was 18.29. Palms at Mannuthy had a higher number of leaves, the mean being 32.23 as can be seen from Table 2. Palms at Pilicode were intermediary between the above two sites. As Table 3 shows, the mean number of leaves retained by the palms at Pilicode was 28.95.

The number of leaves retained was significantly correlated with yield at all sites. The correlation coefficients (r) were 0.465**, 0.635** and 0.794** for Balaramapuram, Mannuthy and Pilicode. A pooled analysis of all the palms at the three sites showed a correlation coefficient of 0.735**.

Table 2. Number of leaves and nut yield of coconut palms of Agricultural Research Station, Mannuthy.

Sl. No.	Number of leaves retained	Average yield of nuts/year (1979 to 1982)	Sl. No.	Number of leaves retained	Average yield of nuts/year (1979 to 1982)
1	22	32.00	31	34	76.50
2	28	41.50	32	40	56.25
3	26	42.50	33	37	81.00
4	25	28.00	34	41	77.00
5	20	31.50	35	36	106.00
6	29	37.75	36	32	89.75
7	25	47.00	37	38	99.75
8	33	40.00	38	29	30.00
9	22	32.25	39	35	92.50
10	29	51.25	40	34	90.25
11	33	66.50	41	32	73.33
12	31	37.75	42	35	40.50
13	33	45.75	43	33	81.75
14	31	38.50	44	37	64.25
15	28	38.50	45	34	83.50
16	24	30.50	46	30	74.25
17	36	60.25	47	35	70.25
18	41	101.50	48	35	52.50
19	38	90.50	49	25	38.50
20	35	101.25	50	32	94.00
21	35	71.00	51	36	82.00
22	34	123.00	52	32	92.50
23	38	71.50	53	31	78.00
24	39	99.25	54	22	31.25
25	35	125.75	55	33	70.25
26	40	105.75	56	24	36.50
27	39	95.25	57	22	37.25
28	28	120.50	58	33	76.00
29	38	111.25	59	32	52.25
30	40	64.50	60	34	32.75

Table 3. Number of leaves and nut yield of coconut palms of Regional Agricultural Research Station, Pilicode.

Sl. No.	Number of leaves retained	Average yield of nuts/year (1979 to 1982)	Sl. No.	Number of leaves retained	Average yield of nuts/year (1979 to 1982)
1	29	44.75	31	29	65.25
2	33	69.00	32	25	54.50
3	25	49.75	33	35	83.25
4	35	82.00	34	30	67.00
5	36	101.25	35	33	83.75
6	23	65.20	36	26	64.75
7	22	36.25	37	38	86.25
8	27	62.25	38	25	37.50
9	32	74.25	39	26	76.00
10	25	52.75	40	26	63.75
11	34	87.25	41	38	81.50
12	26	68.00	42	38	88.00
13	28	62.25	43	27	66.00
14	27	70.50	44	34	72.50
15	27	60.00	45	33	95.50
16	20	42.25	46	34	86.75
17	40	102.00	47	33	63.25
18	25	38.00	48	24	44.75
19	36	49.75	49	25	53.25
20	26	54.00	50	25	59.50
21	26	69.50	51	24	50.25
22	25	61.50	52	40	98.00
23	27	67.50	53	28	62.50
24	25	55.25	54	37	99.75
25	26	72.25	55	29	81.25
26	30	73.50	56	27	64.50
27	24	48.25	57	29	69.75
28	25	50.50	58	27	69.00
29	28	78.25	59	30	64.25
30	23	41.50	60	27	54.50

The number of leaves retained was significantly and positively correlated with the nitrogen, phosphorus and potassium contents of the 2nd, 10th and 14th leaves. It was negatively correlated with the calcium content of the 2nd leaf, magnesium and sodium content of the 10th leaf, and the magnesium content of the 14th leaf. On the other hand, it was positively correlated with the calcium and sodium content of the 14th leaf.

6. Variation in the content of different nutrients in leaf (lamina) at different leaf positions.

6.1 Nitrogen

Variations in the nitrogen content of the 2nd, 10th and 14th leaves of the experimental palms at Balaramapuram are presented in Table 4. The content of nitrogen in the 2nd leaf varied from 1.23 to 2.28 per cent. In the case of the 10th leaf this range was from 1.10 to 2.33 per cent, whereas the 14th leaf showed a range from 0.91 to 2.05 per cent. In general, the 10th leaf contained the highest amount of nitrogen followed by the 2nd leaf. This was true in all the three levels of nitrogen application.

Table 5 presents the variation in the nitrogen content of 2nd, 10th and 14th leaves of the palms at Mannuthy. The 2nd leaf registered the highest nitrogen content of 2.14 per cent followed by the 10th leaf having 1.96 per cent

Table 4. Nitrogen content of leaves of the experimental palms of Coconut Research Station, Balaramapuram at different leaf positions.
(Nitrogen % on moisture free basis)

Sl. No.	Treatment n p k	Leaf position 2nd		10th		14th	
		Rep.I	Rep.II	Rep.I	Rep.II	Rep.I	Rep.II
1	0 0 0	1.73	1.26	1.65	1.41	1.40	1.52
2	0 0 1	1.40	1.44	1.70	1.51	1.40	1.45
3	0 0 2	1.23	1.35	1.30	1.73	1.37	1.59
4	0 1 0	1.59	1.28	1.75	1.33	0.91	1.40
5	0 1 1	1.37	1.42	1.52	1.59	1.43	1.09
6	0 1 2	1.52	1.32	1.66	1.37	1.31	1.17
7	0 2 0	1.67	1.45	1.24	1.10	1.40	0.93
8	0 2 1	1.66	1.63	1.52	1.45	1.31	1.46
9	0 2 2	1.30	1.40	1.61	1.47	1.12	1.23
10	1 0 0	1.65	1.94	1.49	1.68	-	1.56
11	1 0 1	1.42	1.68	1.28	1.79	1.56	1.58
12	1.0 2	1.45	1.84	1.37	1.73	1.49	1.58
13	1 1 0	1.54	1.54	1.83	1.75	1.93	-
14	1 1 1	1.98	1.89	2.33	2.15	1.72	1.77
15	1 1 2	1.72	1.88	1.79	1.89	1.54	1.68
16	1 2 0	1.72	1.82	1.51	-	-	-
17	1 2 1	1.37	1.38	1.68	1.98	1.59	1.93
18	1 2 2	1.78	1.70	1.92	2.06	1.61	1.37
19	2 0 0	2.01	1.86	1.75	1.72	-	1.54
20	2 0 1	1.79	1.30	1.89	1.63	1.73	1.61
21	2 0 2	1.56	1.91	1.56	1.97	1.42	1.49
22	2 1 0	1.54	2.03	1.73	1.68	-	-
23	2 1 1	1.75	1.56	2.26	1.65	1.87	1.35
24	2 1 2	1.93	2.28	2.23	2.05	1.65	2.05
25	2 2 0	1.80	1.75	1.65	1.38	-	-
26	2 2 1	1.77	1.93	1.80	2.08	2.04	1.70
27	2 2 2	2.12	2.00	2.15	2.00	1.99	1.72

Table 5. Nitrogen content of leaves of coconut palms of Agricultural Research Station, Mannuthy, at different leaf positions.
(Nitrogen % on moisture free basis)

Sl. No.	Leaf position			Sl. No.	Leaf position		
	2nd	10th	14th		2nd	10th	14th
1	2.43	2.05	2.10	31	2.43	1.99	1.93
2	2.00	1.88	1.93	32	2.05	1.93	2.23
3	2.36	2.05	2.10	33	1.88	1.60	1.51
4	2.36	1.99	2.05	34	1.88	1.78	1.93
5	1.93	1.69	1.55	35	2.36	2.23	1.88
6	1.88	1.69	1.88	36	2.23	2.36	2.16
7	2.00	1.88	1.60	37	2.10	2.05	1.69
8	1.88	1.74	1.93	38	1.99	1.69	1.78
9	2.05	1.88	1.74	39	2.43	1.88	1.64
10	2.00	1.88	2.36	40	2.10	2.05	1.88
11	1.88	1.60	2.00	41	2.10	2.10	1.99
12	2.43	2.43	2.16	42	1.88	1.60	1.69
13	2.05	1.93	1.74	43	2.23	2.10	1.88
14	2.00	1.74	2.23	44	2.05	1.93	2.36
15	1.88	1.69	1.93	45	2.10	1.99	1.69
16	1.93	1.69	1.69	46	2.00	1.88	1.99
17	2.05	1.93	1.78	47	2.10	1.99	1.99
18	2.05	1.69	2.36	48	2.00	1.88	1.88
19	2.43	2.23	2.43	49	1.88	1.72	1.69
20	2.10	2.05	1.93	50	2.36	2.23	1.93
21	2.10	1.99	1.73	51	2.10	1.88	1.69
22	2.36	2.23	1.69	52	2.43	2.16	1.88
23	2.10	1.93	1.83	53	2.23	2.10	1.64
24	2.10	2.10	1.60	54	1.93	1.88	1.69
25	2.43	2.36	2.43	55	2.10	1.99	1.99
26	2.43	2.23	1.60	56	1.99	1.69	1.78
27	2.23	2.10	1.93	57	2.05	2.10	1.93
28	2.36	2.43	2.10	58	2.23	2.16	1.99
29	2.05	1.60	0.55	59	2.36	2.23	2.16
30	2.36	2.23	2.05	60	1.65	1.65	1.93

Table 6. Nitrogen content of leaves of coconut palms of Regional Agricultural Research Station, Pilicode, at different leaf positions.

(Nitrogen % on moisture free basis)

Sl. No.	Leaf position			Sl. No.	Leaf position		
	2nd	10th	14th		2nd	10th	14th
1	1.33	1.05	0.91	31	1.96	1.82	1.68
2	2.43	1.96	1.96	32	1.33	2.03	1.33
3	1.19	0.91	0.96	33	2.05	1.96	1.68
4	1.68	1.40	1.61	34	2.05	1.89	1.82
5	1.96	1.82	1.61	35	2.05	1.96	1.33
6	1.82	2.05	1.82	36	1.82	1.82	1.26
7	1.96	0.96	1.33	37	2.05	1.25	1.05
8	1.82	1.96	1.33	38	1.26	1.33	1.26
9	2.05	2.05	1.89	39	1.96	1.82	1.33
10	1.82	1.33	1.26	40	1.26	1.12	1.05
11	1.33	0.42	1.33	41	2.33	2.05	1.82
12	2.05	1.96	1.82	42	1.96	2.05	1.68
13	1.82	1.89	1.40	43	1.40	1.68	1.40
14	2.43	1.96	1.89	44	2.05	1.33	1.40
15	1.89	1.89	1.33	45	2.05	1.33	1.26
16	2.05	1.05	0.96	46	1.82	2.03	1.68
17	2.43	2.34	1.96	47	2.36	2.05	1.89
18	1.33	1.61	1.82	48	1.96	1.68	1.40
19	1.96	1.46	1.33	49	2.43	1.96	1.33
20	1.96	1.82	1.89	50	1.82	1.33	1.26
21	1.40	1.96	1.26	51	2.05	1.82	1.68
22	1.26	1.89	1.26	52	2.43	2.36	1.96
23	1.61	1.82	1.82	53	1.82	1.54	1.33
24	1.89	1.33	1.26	54	2.05	2.43	1.96
25	1.61	1.33	1.25	55	1.82	1.75	1.68
26	2.05	1.96	1.82	56	1.68	1.82	1.40
27	1.75	1.96	2.05	57	1.96	2.03	1.82
28	1.33	1.82	1.68	58	1.33	1.26	1.12
29	2.34	2.05	1.82	59	1.68	1.40	1.33
30	1.26	1.26	0.96	60	1.96	1.82	1.33

nitrogen. The 14th leaf was having only 1.89 per cent nitrogen.

Table 6 shows the nitrogen content of 2nd, 10th and 14th leaves of the palms at Pilicode. Here also, the nitrogen content was highest in the 2nd leaf which showed a value of 1.84 per cent. The 10th leaf registered 1.70 per cent nitrogen, and the 14th leaf had only 1.50 per cent.

When all the palms at the three sites were pooled, the 2nd leaf had a nitrogen content of 1.77 per cent. The 10th leaf was only a little behind, registering a value of 1.75 per cent whereas the 14th leaf had only 1.60 per cent nitrogen.

In order to study the degree of relationship between the yield of coconut palms and the percentage of nitrogen in the leaf at the three leaf positions, simple linear correlation coefficients were calculated. These are presented in Table 22. The yield was significantly correlated with the nitrogen content of the 2nd and 10th leaves at all the three sites. There was significant correlation between yield and the nitrogen content of the 14th leaf also, in the palms of Balaramapuram and Pilicode whereas the palms at Mannuthy failed to show such a correlation. When all the palms at the three sites were pooled and analysed, the nitrogen content showed significant correlation with yield in the case of 2nd, 10th and 14th leaves. However, the 10th leaf registered the highest correlation coefficient of 0.518** followed by the 2nd leaf with a value of 0.475**.

The nitrogen content was significantly correlated with the number of leaves retained by the palm in all the three leaf positions studied. The highest correlation coefficient here was 0.297** which was shown by the 2nd leaf. The nitrogen content was also correlated significantly with the phosphorus content in the case of 2nd and 14th leaves. Here the highest correlation coefficient of 0.249** was obtained in the case of the 14th leaf. The nitrogen content was correlated with the potassium content only in the 10th leaf. The nitrogen content was correlated significantly with calcium content in the 14th leaf whereas the 2nd leaf showed significant correlation with the magnesium content. The data pertaining to the above correlations are presented in Table 23, 24 and 25.

6.2 Phosphorus

Data pertaining to the variation in the phosphorus content of the 2nd, 10th and 14th leaves of the experimental palms at Balaramapuram are presented in Table 7. The 10th

Table 7. Phosphorus content of leaves of the experimental palms of Coconut Research Station, Balaramapuram at different leaf positions.

(Phosphorus % on moisture free basis)

Sl. No.	Treatment n p k	Leaf position 2nd Rep.I	2nd Rep.II	10th Rep.I	10th Rep.II	14th Rep.I	14th Rep.II
1	0 0 0	0.180	0.173	0.127	0.163	0.141	0.154
2	0 0 1	0.111	0.146	0.093	0.183	0.141	0.141
3	0 0 2	0.148	0.139	0.139	0.144	0.162	0.121
4	0 1 0	0.161	0.169	0.130	0.157	0.174	0.092
5	0.1 1	0.184	0.154	0.166	0.134	0.150	0.140
6	0 1 2	0.153	0.169	0.168	0.139	0.167	0.152
7	0 2 0	0.168	0.163	0.171	0.162	0.122	0.120
8	0 2 1	0.176	0.158	0.160	0.142	0.145	0.148
9	0 2 2	0.201	0.190	0.178	0.175	0.165	0.191
10	1 0 0	0.157	0.149	0.129	0.129	-	0.149
11	1 0 1	0.186	0.165	0.138	0.152	0.143	0.163
12	1 0 2	0.135	0.150	0.131	0.149	0.123	0.141
13	1 1 0	0.173	0.160	0.163	0.116	0.110	-
14	1 1 1	0.169	0.148	0.140	0.159	0.149	0.163
15	1 1 2	0.147	0.146	0.168	0.146	0.167	0.145
16	1 2 0	0.153	0.146	0.166	-	-	-
17	1 2 1	0.163	0.150	0.177	0.143	0.162	0.131
18	1 2 2	0.175	0.157	0.171	0.146	0.159	0.155
19	2 0 0	0.142	0.162	0.134	0.144	-	0.116
20	2 0 1	0.137	0.158	0.146	0.177	0.140	0.165
21	2 0 2	0.119	0.127	0.141	0.146	0.129	0.135
22	2 1 0	0.191	0.179	0.174	0.166	-	-
23	2 1 1	0.180	0.161	0.169	0.157	0.198	0.158
24	2 1 2	0.136	0.166	0.127	0.158	0.121	0.174
25	2 2 0	0.168	0.148	0.146	0.164	-	-
26	2 2 1	0.156	0.211	0.155	0.152	0.157	0.124
27	2 2 2	0.182	0.155	0.165	0.136	0.132	0.149

Table 8. Phosphorus content of leaves of coconut palms of Agricultural Research Station, Mannuthy, at different leaf positions.

(Phosphorus % on moisture free basis)

Sl. No.	Leaf position			Sl. No.	Leaf position		
	2nd	10th	14th		2nd	10th	14th
1	0.200	0.077	0.177	31	0.295	0.223	0.319
2	0.247	0.211	0.177	32	0.211	0.200	0.200
3	0.154	0.211	0.177	33	0.211	0.200	0.200
4	0.223	0.177	0.177	34	0.200	0.177	0.177
5	0.200	0.319	0.247	35	0.211	0.271	0.247
6	0.247	0.247	0.343	36	0.320	0.271	0.295
7	0.200	0.154	0.200	37	0.154	0.200	0.177
8	0.320	0.165	0.177	38	0.247	0.211	0.165
9	0.223	0.211	0.200	39	0.235	0.177	0.177
10	0.211	0.211	0.177	40	0.319	0.271	0.247
11	0.200	0.211	0.271	41	0.295	0.223	0.223
12	0.320	0.223	0.211	42	0.131	0.177	0.211
13	0.177	0.177	0.154	43	0.235	0.223	0.247
14	0.200	0.154	0.200	44	0.200	0.200	0.223
15	0.223	0.211	0.319	45	0.247	0.223	0.295
16	0.271	0.223	0.223	46	0.235	0.211	0.223
17	0.200	0.177	0.177	47	0.295	0.247	0.247
18	0.295	0.223	0.211	48	0.200	0.177	0.177
19	0.320	0.211	0.223	49	0.319	0.271	0.235
20	0.165	0.200	0.154	50	0.247	0.223	0.200
21	0.177	0.211	0.223	51	0.235	0.200	0.247
22	0.223	0.211	0.200	52	0.271	0.223	0.320
23	0.235	0.235	0.295	53	0.200	0.177	0.177
24	0.295	0.211	0.223	54	0.177	0.164	0.131
25	0.211	0.200	0.165	55	0.211	0.271	0.247
26	0.154	0.154	0.109	56	0.164	0.223	0.177
27	0.223	0.211	0.200	57	0.131	0.164	0.154
28	0.200	0.211	0.177	58	0.247	0.223	0.223
29	0.177	0.177	0.154	59	0.177	0.177	0.177
30	0.154	0.211	0.200	60	0.211	0.200	0.200

Table 9. Phosphorus content of leaves of coconut palms of Regional Agricultural Research Station, Pilicode, at different leaf positions.

(Phosphorus % on moisture free basis)

Sl. No.	Leaf position			Sl. No.	Leaf position		
	2nd	10th	14th		2nd	10th	14th
1	0.205	0.193	0.180	31	0.141	0.110	0.086
2	0.153	0.155	0.174	32	0.205	0.197	0.183
3	0.061	0.116	0.159	33	0.153	0.147	0.166
4	0.183	0.116	0.116	34	0.166	0.147	0.128
5	0.205	0.174	0.183	35	0.183	0.153	0.147
6	0.180	0.153	0.159	36	0.166	0.153	0.128
7	0.193	0.166	0.166	37	0.172	0.134	0.116
8	0.231	0.180	0.187	38	0.153	0.116	0.128
9	0.149	0.174	0.205	39	0.259	0.183	0.187
10	0.187	0.166	0.153	40	0.205	0.128	0.187
11	0.140	0.128	0.116	41	0.153	0.116	0.104
12	0.212	0.149	0.180	42	0.245	0.211	0.205
13	0.172	0.187	0.134	43	0.159	0.140	0.128
14	0.134	0.180	0.205	44	0.166	0.166	0.140
15	0.153	0.134	0.116	45	0.147	0.159	0.187
16	0.166	0.166	0.166	46	0.147	0.140	0.104
17	0.187	0.153	0.166	47	0.259	0.166	0.166
18	0.134	0.128	0.128	48	0.187	0.153	0.128
19	0.231	0.197	0.187	49	0.116	0.166	0.205
20	0.197	0.098	0.056	50	0.205	0.159	0.116
21	0.159	0.140	0.110	51	0.211	0.205	0.183
22	0.231	0.166	0.180	52	0.185	0.166	0.104
23	0.116	0.147	0.183	53	0.122	0.116	0.140
24	0.183	0.205	0.153	54	0.149	0.140	0.147
25	0.205	0.141	0.134	55	0.172	0.187	0.205
26	0.213	0.166	0.166	56	0.183	0.140	0.092
27	0.213	0.166	0.183	57	0.134	0.166	0.180
28	0.141	0.128	0.128	58	0.153	0.134	0.116
29	0.183	0.197	0.183	59	0.174	0.147	0.140
30	0.166	0.166	0.166	60	0.172	0.183	0.092

leaf had the highest content of phosphorus, the mean value being 0.17 per cent. The 2nd leaf contained 0.16 per cent phosphorus on an average whereas the 14th leaf had 0.14 per cent.

Table 8 presents the data on the phosphorus content of the 2nd, 10th and 14th leaves of the palms at Mannuthy. In general, the 2nd leaf registered the highest content of phosphorus, 0.22 per cent. The 10th as well as the 14th leaf had 0.21 per cent phosphorus.

Data on the phosphorus content of leaf lamina of the 2nd, 10th and 14th leaf positions of the palms at Pilicode are presented in Table 9. Results showed that, in general, the 2nd leaf had the highest content of the element, the mean phosphorus content in that leaf being 0.18 per cent. As in the case of the palms at Mannuthy, the 10th and the 14th leaves had similar phosphorus contents showing a value of 0.15 per cent in both.

When all the palms at the three different sites were analysed together, there also the 2nd leaf had the highest content of phosphorus, the value being 0.18 per cent on an average, followed by the 10th leaf which had an average content of 0.17 per cent. The 14th leaf had only 0.16 per cent phosphorus on an average.

The degree of relationship between the yield of coconut palm and the percentage of phosphorus in the leaf lamina at the three leaf positions was examined by way of simple linear correlations. The coefficients of correlation are presented in Table 22. When the relationship was studied for each site independently, the phosphorus contents of all the three leaf positions were not significantly correlated with yield. In some cases even negative correlations were noted though not significant. For example, the phosphorus content of the 2nd leaf was negatively correlated with yield in the case of palms at Balaramapuram and Pilicode. The phosphorus content of the 10th leaf was also negatively correlated with yield in the case of palms at Pilicode, whereas at Balaramapuram, the phosphorus content of the 14th leaf was negatively correlated with yield. On the contrary, an analysis of all the palms at the three sites together showed that the phosphorus contents of the leaf lamina at all the three leaf positions were significantly correlated with yield. The highest correlation here was obtained for the 14th leaf, the coefficient of correlation being 0.205**. The coefficient of correlation in the case of the 10th leaf was 0.199** whereas the 2nd leaf registered a value of 0.164**.

The phosphorus content was significantly correlated with the number of leaves retained by the palm, the highest correlation being shown by the 14th leaf followed by the

10th leaf. The coefficient of correlation between the phosphorus content of the 14th leaf and the leaf number was 0.322**. The phosphorus contents of the 2nd and 14th leaves were significantly correlated with the nitrogen content of the same leaf, the highest correlation coefficient of 0.249** being registered by the 14th leaf. The phosphorus content was also significantly correlated with the potassium content in the case of the 10th and 14th leaves, the highest coefficient of correlation of 0.315** being registered in the case of the 14th leaf. It is interesting to note that the phosphorus content of the 2nd leaf showed a high degree of correlation with the magnesium content. This was the same case with sodium, though the coefficient of correlation was a little lower. Data pertaining to the above correlations are presented in Tables 23, 24 and 25.

6.3 Potassium

Table 10 shows the variation in the content of potassium of the 2nd, 10th and 14th leaves of the experimental palms at Balaramapuram. The content of potassium was higher in the 2nd leaf which showed a mean value of 1.81 per cent. The 2nd leaf was followed by the 10th leaf with a mean value of 1.11 per cent and the 14th leaf with a mean value of 1.02 per cent.

Table 10. Potassium content of leaves of the experimental pälms of Coconut Research Station, Balaramapuram at different leaf positions.

(Potassium % on moisture free basis)

Sl. No.	Treatment n p k	Leaf position 2nd Rep.I	2nd Rep.II	10th Rep.I	10th Rep.II	14th Rep.I	14th Rep.II
1	0 0 0	2.02	2.86	0.78	1.85	0.66	1.38
2	0 0 1	2.86	2.11	1.85	1.23	1.38	1.34
3	0 0 2	2.24	2.21	1.31	1.73	1.24	1.56
4	0 1 0	1.63	0.88	0.56	0.43	1.48	0.30
5	0 1 1	2.17	2.12	1.46	1.22	1.18	0.93
6	0 1 2	2.40	2.64	1.68	1.88	1.39	1.71
7	0 2 0	1.23	1.21	0.54	0.47	0.44	0.27
8	0 2 1	2.06	2.29	1.54	1.58	1.44	1.19
9	0 2 2	2.86	2.45	1.68	1.31	1.44	1.26
10	1 0 0	0.93	1.07	0.50	0.52	-	0.29
11	1 0 1	2.14	2.10	1.40	1.13	1.31	0.93
12	1 0 2	2.26	2.08	1.98	1.43	1.77	1.01
13	1 1 0	1.38	0.94	0.35	0.28	0.48	-
14	1 1 1	2.19	1.93	1.01	0.94	0.93	0.69
15	1 1 2	2.30	1.98	1.54	1.37	1.08	1.22
16	1 2 0	0.94	0.62	0.31	-	-	-
17	1 2 1	1.94	1.81	1.28	0.85	1.13	0.46
18	1 2 2	2.28	2.44	1.55	1.25	1.31	1.26
19	2 0 0	1.09	0.71	0.24	0.38	-	0.35
20	2 0 1	2.18	1.78	0.83	1.13	0.60	0.89
21	2 0 2	2.58	1.89	1.70	1.40	1.35	1.36
22	2 1 0	0.94	0.96	0.68	0.18	-	-
23	2 1 1	1.75	1.34	0.89	0.74	0.68	0.53
24	2 1 2	2.92	2.04	0.99	1.26	0.74	0.91
25	2 2 0	0.92	1.04	0.41	0.36	-	-
26	2 2 1	1.94	1.75	0.79	0.93	0.40	0.64
27	2 2 2	2.18	2.13	1.31	1.30	0.88	0.95

Table 11. Potassium content of leaves of coconut palms of Agricultural Research Station, Mannuthy, at different leaf positions.

(Potassium % on moisture free basis)

Sl. No.	Leaf position 2nd	10th	14th	Sl. No.	Leaf position 2nd	10th	14th
1	2.05	1.35	1.33	31	2.38	1.68	1.98
2	2.05	1.68	1.50	32	2.05	1.68	1.55
3	1.63	1.35	1.20	33	1.70	1.63	1.05
4	2.40	2.05	1.45	34	2.38	2.18	1.85
5	1.65	1.35	0.90	35	2.45	2.05	2.00
6	2.05	1.80	1.35	36	1.98	1.63	1.45
7	2.18	1.98	1.45	37	2.48	1.78	1.75
8	1.98	1.63	1.35	38	2.05	1.80	1.60
9	1.63	1.55	1.35	39	1.95	1.63	1.05
10	1.63	1.35	1.35	40	2.05	2.18	1.30
11	1.98	1.80	1.65	41	2.18	1.98	1.83
12	2.05	1.80	1.05	42	1.98	2.05	1.95
13	2.40	1.98	1.53	43	2.35	1.88	1.75
14	2.05	2.18	1.60	44	2.35	1.98	1.55
15	1.85	1.63	1.48	45	2.48	1.78	1.70
16	2.05	1.35	1.65	46	2.18	1.83	1.80
17	1.98	1.30	1.50	47	2.40	2.05	2.18
18	2.38	2.25	1.55	48	2.10	1.78	1.85
19	2.40	1.73	2.05	49	2.05	2.18	1.85
20	2.38	1.98	1.73	50	2.40	1.98	2.03
21	2.48	1.80	1.60	51	2.38	2.18	2.10
22	2.05	1.80	1.80	52	2.38	2.13	1.65
23	2.18	1.88	1.75	53	2.05	1.80	1.80
24	1.63	1.75	1.85	54	2.40	2.05	1.45
25	2.40	1.98	1.70	55	2.38	1.83	1.60
26	1.63	1.55	1.30	56	2.48	1.80	1.65
27	2.40	2.05	1.45	57	1.98	1.35	1.50
28	2.15	2.05	1.85	58	2.05	1.63	1.60
29	2.05	1.35	1.55	59	2.38	1.98	1.90
30	1.70	1.45	1.20	60	2.38	2.05	2.15

Table 12. Potassium content of leaves of coconut palms of Regional Agricultural Research Station, Pilicode, at different leaf positions.

(Potassium content on moisture free basis)

Sl. No.	Leaf position			Sl. No.	Leaf position		
	2nd	10th	14th		2nd	10th	14th
1	1.45	1.25	1.40	31	1.85	1.43	1.08
2	2.05	1.98	1.43	32	1.58	1.15	1.15
3	1.63	1.35	1.05	33	2.20	1.68	1.43
4	2.25	2.00	1.88	34	1.85	1.40	1.45
5	2.35	2.08	1.85	35	2.05	1.48	1.23
6	1.45	1.03	1.00	36	1.73	1.65	1.05
7	1.40	1.35	1.03	37	2.40	2.03	1.25
8	1.65	1.40	1.65	38	1.38	1.18	1.23
9	2.05	1.63	1.30	39	1.75	1.03	1.35
10	1.45	1.00	1.48	40	1.55	1.05	1.35
11	2.13	1.55	0.98	41	2.35	1.98	1.65
12	1.43	1.05	1.10	42	2.40	2.10	1.35
13	1.83	1.60	1.10	43	1.70	1.95	1.18
14	1.68	1.58	1.50	44	1.90	1.33	1.65
15	1.63	1.25	1.20	45	2.20	1.50	1.33
16	1.25	1.10	1.28	46	2.18	1.40	1.55
17	2.43	1.90	1.38	47	2.13	1.23	1.00
18	1.58	1.55	1.55	48	1.38	1.20	1.38
19	2.15	1.95	1.30	49	1.45	1.10	1.23
20	1.50	1.55	1.05	50	1.58	1.25	1.40
21	1.63	1.40	1.30	51	1.43	1.50	1.30
22	1.53	1.25	1.45	52	2.55	2.13	1.33
23	1.83	1.25	1.33	53	1.70	1.40	1.13
24	1.45	1.35	1.15	54	2.15	2.15	1.53
25	1.75	1.58	1.40	55	1.93	1.70	1.30
26	2.03	1.70	1.40	56	1.93	1.70	1.30
27	1.40	1.33	1.50	57	1.88	1.70	1.40
28	1.43	1.53	1.50	58	1.63	1.93	1.18
29	1.88	1.20	1.05	59	2.00	1.25	1.28
30	1.38	1.45	1.68	60	1.68	1.38	1.33

Data on the variation in the content of potassium of the 2nd, 10th and 14th leaves of the palms at Mannuthy are presented in Table 11. As in the case of the palms at Balaramapuram, the 2nd leaf had the highest content of potassium followed by the 10th leaf. In general, the content of potassium of all the three leaves was higher than the potassium content encountered at Balaramapuram. The mean potassium content for the 2nd leaf was 2.14 per cent, that of the 10th leaf 1.81 per cent and that of the 14th leaf 1.61 per cent.

Variations in the content of potassium of the 2nd, 10th and 14th leaves of the palms at Pilicode are presented in Table 12. Here also, as in the case of the palms at Balaramapuram and Mannuthy, the 2nd leaf had the highest potassium content, the mean value being 1.80 per cent. The 10th leaf had 1.50 per cent potassium and the 14th leaf, 1.32 per cent.

Analysis of all the palms at the three different sites also showed that the 2nd leaf had the highest content of potassium, registering a mean of 1.87 per cent. The 10th leaf came next with an average of 1.32 per cent. The average potassium content of the 14th leaf was 1.21 per cent.

In order to study the relation between the potassium content of the leaf and yield of the palm, simple correlation coefficients were worked out which are presented in Table 22. The potassium contents of the 2nd and 10th leaves of the palms at Balaramapuram were significantly correlated with yield, the highest correlation of 0.319** being registered by the 2nd leaf. The potassium content of the 14th leaf was negatively correlated with yield at Balaramapuram. At Mannuthy, no significant correlation was obtained between the potassium content and yield for the 2nd and 10th leaf positions. In the case of the palms at Pilicode, the potassium content of the 2nd leaf showed a high correlation with yield. The 10th leaf also showed significant correlation with yield.

When all the palms at the three sites were pooled and analysed, significant correlation coefficients were obtained between the potassium content and yield for all the three leaf positions. The highest coefficient of correlation, however, was registered by the 10th leaf, the value being 0.448**. The 2nd leaf came next with a correlation coefficient of 0.355** and the 14th leaf with 0.223**.

The potassium contents of all the three leaves were highly correlated with the number of leaves retained by the palm. The highest correlation of 0.710** was obtained in the case of the 10th leaf. The coefficient of correlation of the potassium content of the 2nd leaf and the number of leaves retained was 0.622^{**} whereas the value for the 14th leaf was 0.579^{**}. The potassium content of the 10th leaf had significant correlation with the nitrogen content of the same leaf. The potassium content was correlated significantly with the phosphorus content in the case of the 10th and 14th leaves, the coefficient of correlation for the 14th leaf being higher than that for the 10th leaf.

There was antagonism noticed between potassium and the other cations, namely calcium, magnesium and sodium. Potassium content was negatively correlated with the calcium content in all the three leaf positions, the negative correlation coefficient in the case of the 2nd leaf being highly significant with a value of -0.432^{**}. The potassium content was negatively correlated with the magnesium content in the 10th and 14th leaf positions, the coefficient of correlation for the 14th leaf being -0.521^{**}. Potassium content was negatively correlated with the sodium content in all the leaf positions, the correlation coefficient for the 10th leaf being -0.441^{**}. Data pertaining to the above correlations are presented in the Tables 23, 24 and 25.

6.4 Calcium

Table 13 presents the variation in the content of calcium of the 2nd, 10th and 14th leaves of the experimental palms at Balaramapuram. Contrary to nitrogen, phosphorus and potassium, the calcium content was highest in the 14th leaf, the mean value being 0.42 per cent. This was followed by the 10th leaf with a value of 0.41 per cent and the 2nd leaf with 0.27 per cent.

Data relating to the variation in the content of calcium of the 2nd, 10th and 14th leaves of the palms at Mannuthy are presented in Table 14. As in the case of the palms at Balaramapuram, the 14th leaf registered the highest calcium content, with a mean value of 0.61 per cent. On an average, the 10th leaf and 0.60 per cent and the 2nd leaf 0.30 per cent calcium.

The palms at Pilicode also showed the same trend, the data pertaining to which are presented in the Table 15. Here the mean calcium contents of the 2nd, 10th and 14th leaves were 0.32, 0.45 and 0.63 per cent, respectively.

When all the palms of the three different sites were pooled and analysed, the same trend that was seen for each site individually, was obtained. The mean values of

Table 13. Calcium content of leaves of the experimental palms of Coconut Research Station, Balaramapuram, at different leaf positions.

(Calcium % on moisture free basis)

Sl. No.	Treat-ment n p k	Leaf position 2nd Rep.I	2nd Rep.II	10th Rep.I	10th Rep.II	14th Rep.I	14th Rep.II
1	0 0 0	0.271	0.312	0.333	0.471	0.355	0.510
2	0 0 1	0.168	0.354	0.347	0.291	0.353	0.380
3	0 0 2	0.232	0.323	0.422	0.355	0.425	0.355
4	0 1 0	0.358	0.395	0.380	0.416	0.360	0.500
5	0 1 1	0.178	0.189	0.387	0.370	0.388	0.393
6	0.1 2	0.327	0.147	0.285	0.318	0.403	0.283
7	0 2 0	0.281	0.371	0.463	0.490	0.490	0.483
8	0 2 1	0.260	0.173	0.283	0.370	0.333	0.335
9	0 2 2	0.189	0.178	0.350	0.401	0.383	0.400
10	1 0 0	0.302	0.314	0.503	0.486	-	0.423
11	1 0 1	0.178	0.330	0.273	0.475	0.483	0.415
12	1 0 2	0.188	0.193	0.230	0.341	0.278	0.453
13	1 1 0	0.305	0.291	0.416	0.333	0.610	-
14	1 1 1	0.218	0.183	0.383	0.432	0.388	0.568
15	1 1 2	0.188	0.260	0.260	0.380	0.333	0.438
16	1 2 0	0.348	0.357	0.534	-	-	-
17	1 2 1	0.233	0.281	0.327	0.413	0.355	0.543
18	1 2 2	0.229	0.164	0.349	0.384	0.403	0.400
19	2 0 0	0.250	0.291	0.548	0.369	-	0.670
20	2 0 1	0.209	0.312	0.441	0.326	0.585	0.397
21	2 0 2	0.229	0.260	0.270	0.335	0.425	0.443
22	2 1 0	0.282	0.347	0.497	0.485	-	-
23	2 1 1	0.337	0.291	0.443	0.541	0.623	0.535
24	2 1 2	0.264	0.260	0.425	0.445	0.540	0.523
25	2 2 0	0.333	0.314	0.522	0.497	-	-
26	2 2 1	0.240	0.343	0.531	0.441	0.655	0.500
27	2 2 2	0.222	0.261	0.374	0.378	0.480	0.493

Table 14. Calcium content of leaves of coconut palms of Agricultural Research Station, Mannuthy, at different leaf positions.

(Calcium % on moisture free basis)

Sl. No.	Leaf position			Sl. No.	Leaf position		
	2nd	10th	14th		2nd	10th	14th
1	0.291	0.585	0.650	31	0.250	0.556	0.600
2	0.250	0.550	0.450	32	0.208	0.585	0.750
3	0.425	0.333	0.500	33	0.525	0.511	0.800
4	0.208	0.325	0.500	34	0.166	0.425	0.600
5	0.525	0.545	1.050	35	0.166	0.466	0.500
6	0.333	0.495	0.500	36	0.166	0.555	0.550
7	0.374	0.455	0.450	37	0.166	0.511	0.550
8	0.291	0.556	0.550	38	0.291	0.499	0.550
9	0.250	0.560	0.600	39	0.374	0.550	0.500
10	0.375	0.566	0.600	40	0.350	0.391	0.500
11	0.291	0.485	0.500	41	0.350	0.325	0.750
12	0.350	0.499	0.850	42	0.166	0.365	0.550
13	0.475	0.425	0.950	43	0.166	0.456	0.550
14	0.333	0.345	0.450	44	0.391	0.491	0.450
15	0.412	0,549	0.700	45	0.166	0.511	0.550
16	0.325	0.585	0.650	46	0.250	0.525	0.600
17	0.425	0.565	0.550	47	0.166	0.385	0.600
18	0.291	0.400	0.450	48	0.325	0.500	0.850
19	0.374	0.525	0.800	49	0.212	0.391	0.550
20	0.312	0.466	0.450	50	0.250	0.485	0.650
21	0.208	0.511	0.550	51	0.208	0.385	0.650
22	0.250	0.500	0.600	52	0.212	0.388	0.600
23	0.400	0.485	0.850	53	0.325	0.499	0.550
24	0.374	0.511	0.600	54	0.333	0.425	0.550
25	0.166	0.465	0.450	55	0.325	0.511	0.800
26	0.425	0.565	0.550	56	0.130	0.525	0.700
27	0.208	0.385	0.550	57	0.333	0.575	0.650
28	0.325	0.365	0.650	58	0.208	0.555	0.700
29	0.291	0.577	0.550	59	0.250	0.491	0.500
30	0.375	0.566	0.550	60	0.414	0.411	0.550

Table 15. Calcium content of leaves of coconut palms of Regional Agricultural Research Station, Pilicode, at different leaf positions.

(Calcium % on moisture free basis)

Sl. No.	Leaf position			Sl. No.	Leaf position		
	2nd	10th	14th		2nd	10th	14th
1	0.425	0.477	0.600	31	0.333	0.411	0.790
2	0.333	0.411	0.580	32	0.374	0.485	0.760
3	0.525	0.500	0.800	33	0.250	0.444	0.500
4	0.374	0.375	0.400	34	0.333	0.432	0.590
5	0.212	0.325	0.320	35	0.208	0.477	0.670
6	0.333	0.521	0.800	36	0.333	0.443	0.790
7	0.374	0.485	0.780	37	0.208	0.375	0.660
8	0.325	0.444	0.490	38	0.374	0.411	0.650
9	0.300	0.435	0.640	39	0.425	0.511	0.640
10	0.425	0.500	0.590	40	0.425	0.500	0.430
11	0.208	0.444	0.820	41	0.208	0.405	0.450
12	0.325	0.521	0.730	42	0.212	0.395	0.600
13	0.312	0.432	0.740	43	0.374	0.400	0.650
14	0.300	0.450	0.550	44	0.300	0.475	0.440
15	0.300	0.455	0.650	45	0.250	0.475	0.640
16	0.374	0.311	0.640	46	0.291	0.485	0.550
17	0.250	0.425	0.630	47	0.208	0.485	0.810
18	0.212	0.465	0.430	48	0.374	0.491	0.660
19	0.208	0.420	0.670	49	0.374	0.491	0.670
20	0.425	0.425	0.800	50	0.350	0.491	0.610
21	0.325	0.465	0.620	51	0.333	0.411	0.630
22	0.374	0.511	0.590	52	0.208	0.385	0.620
23	0.330	0.499	0.600	53	0.333	0.475	0.750
24	0.425	0.485	0.750	54	0.250	0.400	0.510
25	0.325	0.411	0.620	55	0.291	0.430	0.630
26	0.291	0.422	0.590	56	0.325	0.475	0.640
27	0.425	0.475	0.500	57	0.333	0.425	0.590
28	0.391	0.455	0.510	58	0.325	0.411	0.700
29	0.325	0.499	0.800	59	0.250	0.444	0.650
30	0.450	0.495	0.510	60	0.325	0.326	0.600

calcium content of the 2nd, 10th and 14th leaves were 0.28, 0.43 and 0.52 per cent respectively.

As can be noted from the Table 22 the calcium contents of the 2nd and 10th leaves were negatively correlated with yield in all the three sites. In the case of the 14th leaf, the calcium content was negatively correlated with yield only at Mannuthy and Pilicode whereas at Balaramapuram, the correlation was positive and statistically significant. When all the palms of the three sites were pooled and analysed, significant positive correlation was obtained between yield and the calcium content of the 14th leaf.

The calcium content of the 2nd leaf was negatively correlated with the number of leaves retained whereas there was significant positive correlation in the case of the 14th leaf. The calcium content was significantly correlated with the nitrogen content in the case of the 14th leaf. This was the same case for the correlation between the calcium content and the phosphorus content also. The calcium content was negatively correlated with the potassium content, especially in the case of the 2nd leaf. There was significant positive correlation between the calcium content and the magnesium content in the case of the 2nd and 10th leaves. There was significant correlation between the calcium and sodium contents only in the 14th leaf. Data pertaining to the above correlations are presented in Tables 23, 24 and 25.

6.5 Magnesium

Data relating to the variation in the content of magnesium of the 2nd, 10th and 14th leaves of the experimental palms at Balaramapuram are presented in Table 16. The content of magnesium was, on an average, 0.34 per cent in the 2nd leaf which increased to 0.41 per cent in the 10th and the 14th leaves.

The magnesium content of the leaves of the palms at Mannuthy, as can be seen from Table 17 was 0.37 per cent for the 2nd leaf, 0.41 for the 10th leaf, and 0.29 for the 14th leaf.

Table 18 presents the variation in the content of magnesium of the 2nd, 10th and 14th leaves of the palms at Pilicode, The contents of magnesium in the 2nd, 10th and 14th leaves were 0.38, 0.36 and 0.33 per cent respectively.

When all the palms of the three sites were pooled and analysed, the mean values for the magnesium content of the 2nd, 10th and 14th leaves were, 0.35, 0.40 and 0.37 per cent respectively.

Table 16. Magnesium content of leaves of the experimental palms of Coconut Research Station, Balaramapuram at different leaf positions.

(Magnesium % on moisture free basis)

Sl. No.	Treatment n p k	Leaf position 2nd Rep.I	2nd Rep.II	10th Rep.I	10th Rep.II	14th Rep.I	14th Rep.II
1	0 0 0	0.269	0.294	0.321	0.455	0.508	0.425
2	0 0 1	0.316	0.281	0.378	0.338	0.288	0.305
3	0 0 2	0.254	0.313	0.373	0.394	0.388	0.345
4	0 1 0	0.477	0.450	0.459	0.438	0.300	0.380
5	0 1 1	0.297	0.303	0.404	0.379	0.373	0.385
6	0 1 2	0.324	0.285	0.433	0.362	0.399	0.290
7	0 2 0	0.392	0.413	0.412	0.452	0.403	0.603
8	0 2 1	0.294	0.250	0.306	0.390	0.325	0.338
9	0 2 2	0.219	0.259	0.340	0.429	0.350	0.400
10	1 0 0	0.394	0.369	0.478	0.492	-	0.397
11	1 0 1	0.321	0.263	0.438	0.353	0.315	0.440
12	1 0 2	0.319	0.283	0.291	0.306	0.225	0.563
13	1 1 0	0.366	0.394	0.483	0.500	0.375	-
14	1 1 1	0.300	0.344	0.409	0.410	0.428	0.498
15	1 1 2	0.288	0.381	0.344	0.300	0.403	0.383
16	1 2 0	0.527	0.489	0.475	-	-	-
17	1 2 1	0.306	0.363	0.419	0.386	0.473	0.510
18	1 2 2	0.313	0.313	0.369	0.377	0.365	0.365
19	2 0 0	0.288	0.302	0.492	0.475	-	0.460
20	2 0 1	0.394	0.313	0.525	0.324	0.475	0.493
21	2 0 2	0.225	0.275	0.338	0.335	0.375	0.448
22	2 1 0	0.371	0.392	0.444	0.525	-	-
23	2 1 1	0.314	0.425	0.453	0.437	0.395	0.488
24	2 1 2	0.435	0.338	0.415	0.388	0.480	0.470
25	2 2 0	0.444	0.349	0.508	0.475	-	-
26	2 2 1	0.323	0.496	0.488	0.450	0.465	0.510
27	2 2 2	0.242	0.292	0.367	0.415	0.240	0.420

Table 17. Magnesium content of leaves of coconut palms of Agricultural Research Station, Mannuthy, at different leaf positions.

(Magnesium % on moisture free basis)

Sl. No.	Leaf position 2nd	10th	14th	Sl. No.	Leaf position 2nd	10th	14th
1	0.412	0.500	0.300	31	0.333	0.485	0.270
2	0.208	0.325	0.180	32	0.400	0.495	0.360
3	0.208	0.325	0.180	33	0.425	0.500	0.360
4	0.374	0.333	0.270	34	0.412	0.411	0.330
5	0.525	0.525	0.480	35	0.425	0.400	0.330
6	0.325	0.511	0.240	36	0.525	0.325	0.330
7	0.425	0.325	0.290	37	0.312	0.475	0.240
8	0.212	0.300	0.150	38	0.333	0.411	0.270
9	0.450	0.511	0.390	39	0.399	0.400	0.330
10	0.166	0.525	0.090	40	0.466	0.325	0.360
11	0.625	0.400	0.630	41	0.166	0.300	0.030
12	0.412	0.466	0.330	42	0.400	0.291	0.300
13	0.250	0.411	0.180	43	0.333	0.222	0.210
14	0.325	0.325	0.270	44	0.425	0.400	0.330
15	0.300	0.485	0.210	45	0.625	0.425	0.540
16	0.291	0.455	0.150	46	0.312	0.411	0.210
17	0.660	0.499	0.780	47	0.208	0.325	0.150
18	0.291	0.399	0.180	48	0.333	0.491	0.270
19	0.291	0.485	0.330	49	0.250	0.325	0.120
20	0.425	0.411	0.240	50	0.291	0.400	0.120
21	0.333	0.400	0.300	51	0.645	0.366	0.600
22	0.425	0.425	0.120	52	0.333	0.325	0.210
23	0.208	0.411	0.120	53	0.300	0.425	0.270
24	0.465	0.500	0.510	54	0.333	0.400	0.240
25	0.466	0.425	0.360	55	0.625	0.485	0.240
26	0.374	0.400	0.270	56	0.333	0.411	0.270
27	0.325	0.300	0.240	57	0.130	0.325	0.060
28	0.412	0.325	0.330	58	0.376	0.500	0.270
29	0.525	0.499	0.270	59	0.325	0.425	0.270
30	0.412	0.499	0.330	60	0.450	0.325	0.330

Table 18. Magnesium content of leaves of coconut palms of Regional Agricultural Research Station, Pilicode, at different leaf positions.

(Magnesium % on moisture free basis)

Sl. No.	Leaf position			Sl. No.	Leaf position		
	2nd	10th	14th		2nd	10th	14th
1	0.425	0.370	0.330	31	0.325	0.300	0.410
2	0.474	0.311	0.300	32	0.374	0.411	0.300
3	0.325	0.425	0.500	33	0.425	0.211	0.370
4	0.333	0.291	0.180	34	0.350	0.200	0.270
5	0.333	0.250	0.100	35	0.414	0.325	0.380
6	0.350	0.421	0.560	36	0.350	0.343	0.420
7	0.312	0.444	0.450	37	0.291	0.367	0.310
8	0.425	0.325	0.220	38	0.350	0.525	0.320
9	0.416	0.333	0.370	39	0.425	0.411	0.410
10	0.450	0.400	0.320	40	0.525	0.425	0.210
11	0.466	0.325	0.540	41	0.425	0.400	0.550
12	0.333	0.411	0.450	42	0.414	0.299	0.220
13	0.374	0.311	0.460	43	0.325	0.321	0.270
14	0.300	0.322	0.270	44	0.374	0.411	0.180
15	0.412	0.350	0.370	45	0.333	0.425	0.290
16	0.300	0.300	0.360	46	0.333	0.450	0.320
17	0.425	0.375	0.350	47	0.425	0.444	0.420
18	0.414	0.365	0.220	48	0.325	0.450	0.300
19	0.325	0.311	0.400	49	0.350	0.350	0.320
20	0.450	0.325	0.450	50	0.395	0.311	0.300
21	0.425	0.388	0.350	51	0.333	0.325	0.290
22	0.450	0.400	0.320	52	0.250	0.291	0.210
23	0.374	0.325	0.330	53	0.374	0.425	0.390
24	0.208	0.375	0.300	54	0.400	0.325	0.220
25	0.214	0.311	0.250	55	0.300	0.411	0.300
26	0.425	0.300	0.220	56	0.350	0.425	0.320
27	0.450	0.365	0.200	57	0.321	0.325	0.190
28	0.425	0.355	0.210	58	0.425	0.300	0.330
29	0.374	0.375	0.420	59	0.414	0.411	0.420
30	0.525	0.377	0.510	60	0.525	0.325	0.210

In order to study the relationship between the leaf magnesium content and yield, simple linear correlation coefficients were worked out which is presented in Table 22. The magnesium content was significantly and positively correlated with yield only in the case of the 14th leaf at Balaramapuram. In no other site, and in case of no other leaf position, significant correlation was noticed between the magnesium content of leaf lamina and yield.

The magnesium content of the 10th and 14th leaves was negatively correlated with the number of leaves retained by the palm. The magnesium content of the 2nd leaf was positively correlated with the nitrogen content and the phosphorus content of the same leaf. The magnesium content had a negative correlation with the potassium content in the case of the 10th and 14th leaves whereas there was a positive correlations with the calcium content in the case of the 2nd and 10th leaves. In the 10th leaf, the magnesium content was positively correlated with the sodium content. Tables 23, 24 and 25 present the observations pertaining to the above relationships.

6.6 Sodium

Table 19 shows the variation in the content of sodium of the 2nd, 10th and 14th leaves of the experimental

Table 19. Sodium content of leaves of the experimental palms of Coconut Research Station, Balaramapuram, at different leaf positions.

(Sodium % on moisture free basis)

Sl. No.	Treatment n p k	Leaf position 2nd Rep.I	2nd Rep.II	10th Rep.I	10th Rep.II	14th Rep.I	14th Rep.II
1	0 0 0	0.151	0.152	0.171	0.159	0.149	0.123
2	0 0 1	0.065	0.080	0.117	0.089	0.107	0.126
3	0 0 2	0.060	0.069	0.091	0.077	0.070	0.060
4	0 1 0	0.166	0.167	0.195	0.109	0.140	0.200
5	0 1 1	0.098	0.105	0.119	0.131	0.109	0.076
6	0 1 2	0.039	0.081	0.050	0.115	0.021	0.086
7	0 2 0	0.152	0.163	0.167	0.193	0.163	0.143
8	0 2 1	0.086	0.102	0.076	0.129	0.081	0.143
9	0 2 2	0.052	0.099	0.098	0.144	0.099	0.135
10	1 0 0	0.209	0.170	0.147	0.171	-	0.123
11	1 0 1	0.102	0.094	0.125	0.121	0.145	0.133
12	1 0 2	0.039	0.067	0.014	0.085	0.040	0.074
13	1 1 0	0.145	0.146	0.132	0.092	0.143	-
14	1 1 1	0.116	0.109	0.154	0.138	0.151	0.120
15	1 1 2	0.029	0.113	0.052	0.119	0.096	0.097
16	1 2 0	0.151	0.166	0.132	-	-	-
17	1 2 1	0.103	0.101	0.157	0.142	0.123	0.114
18	1 2 2	0.092	0.094	0.144	0.158	0.125	0.149
19	2 0 0	0.196	0.268	0.204	0.188	-	0.186
20	2 0 1	0.110	0.094	0.143	0.115	0.115	0.111
21	2 0 2	0.042	0.073	0.065	0.110	0.061	0.076
22	2 1 0	0.151	0.123	0.145	0.100	-	-
23	2 1 1	0.068	0.102	0.138	0.119	0.114	0.089
24	2 1 2	0.125	0.064	0.153	0.101	0.125	0.071
25	2 2 0	0.140	0.136	0.137	0.130	-	-
26	2 2 1	0.113	0.100	0.127	0.143	0.073	0.117
27	2 2 2	0.042	0.088	0.078	0.106	0.058	0.106

Table 20. Sodium content of leaves of coconut palms of Agricultural Research Station, Mannuthy, at different leaf positions.

(Sodium % on moisture free basis)

Sl. No.	Leaf position 2nd	10th	14th	Sl. No.	Leaf position 2nd	10th	14th
1	0.092	0.032	0.120	31	0.011	0.096	0.096
2	0.092	0.110	0.112	32	0.091	0.080	0.130
3	0.112	0.116	0.132	33	0.111	0.080	0.202
4	0.050	0.003	0.100	34	0.050	0.056	0.113
5	0.168	0.092	0.135	35	0.042	0.092	0.062
6	0.080	0.132	0.122	36	0.125	0.100	0.132
7	0.070	0.140	0.112	37	0.025	0.080	0.112
8	0.108	0.100	0.125	38	0.092	0.086	0.126
9	0.112	0.112	0.102	39	0.100	0.096	0.202
10	0.120	0.092	0.118	40	0.100	0.021	0.213
11	0.112	0.092	0.050	41	0.100	0.060	0.112
12	0.099	0.092	0.120	42	0.112	0.050	0.103
13	0.033	0.092	0.080	43	0.030	0.062	0.135
14	0.051	0.005	0.076	44	0.030	0.072	0.145
15	0.100	0.080	0.096	45	0.025	0.080	0.135
16	0.099	0.112	0.070	46	0.065	0.082	0.105
17	0.100	0.050	0.120	47	0.033	0.030	0.003
18	0.055	0.080	0.132	48	0.050	0.050	0.100
19	0.032	0.091	0.052	49	0.120	0.003	0.100
20	0.066	0.096	0.122	50	0.050	0.060	0.090
21	0.025	0.080	0.136	51	0.060	0.012	0.060
22	0.092	0.072	0.100	52	0.070	0.020	0.150
23	0.080	0.099	0.122	53	0.100	0.120	0.123
24	0.142	0.060	0.092	54	0.120	0.112	0.164
25	0.100	0.120	0.100	55	0.042	0.120	0.146
26	0.125	0.011	0.162	56	0.033	0.072	0.140
27	0.030	0.009	0.143	57	0.125	0.211	0.150
28	0.050	0.112	0.112	58	0.080	0.202	0.149
29	0.082	0.100	0.132	59	0.070	0.198	0.100
30	0.142	0.096	0.166	60	0.075	0.119	0.055

Table 21. Sodium content of leaves of coconut palms of Regional Agricultural Research Station, Pilicode, at different leaf positions.

(Sodium % on moisture free basis)

Sl. No.	Leaf position			Sl. No.	Leaf position		
	2nd	10th	14th		2nd	10th	14th
1	0.136	0.186	0.176	31	0.144	0.210	0.348
2	0.108	0.178	0.160	32	0.136	0.244	0.284
3	0.116	0.135	0.160	33	0.078	0.194	0.154
4	0.108	0.168	0.268	34	0.134	0.134	0.158
5	0.116	0.148	0.135	35	0.106	0.184	0.268
6	0.064	0.114	0.148	36	0.114	0.196	0.264
7	0.092	0.168	0.136	37	0.108	0.180	0.272
8	0.086	0.148	0.160	38	0.116	0.172	0.172
9	0.094	0.188	0.148	39	0.094	0.256	0.256
10	0.104	0.194	0.150	40	0.088	0.190	0.264
11	0.134	0.152	0.184	41	0.066	0.200	0.174
12	0.108	0.194	0.264	42	0.088	0.168	0.174
13	0.100	0.152	0.156	43	0.088	0.118	0.160
14	0.126	0.128	0.175	44	0.096	0.188	0.152
15	0.126	0.172	0.268	45	0.080	0.140	0.174
16	0.130	0.246	0.150	46	0.080	0.088	0.138
17	0.094	0.152	0.154	47	0.060	0.136	0.144
18	0.094	0.134	0.146	48	0.102	0.150	0.158
19	0.100	0.130	0.188	49	0.062	0.160	0.180
20	0.100	0.154	0.260	50	0.090	0.156	0.132
21	0.098	0.160	0.172	51	0.082	0.156	0.168
22	0.114	0.192	0.150	52	0.080	0.140	0.174
23	0.100	0.246	0.162	53	0.096	0.194	0.280
24	0.096	0.246	0.180	54	0.106	0.092	0.156
25	0.088	0.192	0.252	55	0.068	0.120	0.164
26	0.088	0.188	0.158	56	0.122	0.158	0.138
27	0.090	0.168	0.150	57	0.106	0.092	0.134
28	0.092	0.220	0.188	58	0.112	0.134	0.200
29	0.064	0.150	0.194	59	0.062	0.190	0.186
30	0.104	0.210	0.152	60	0.088	0.128	0.164

palms at Balaramapuram. The mean values for the content of sodium in the 2nd, 10th and 14th leaves were 0.11, 0.12 and 0.11 per cent respectively. The corresponding values for the 2nd, 10th and 14th leaves of the palms at Mannuthy, as can be noted from Table 20, were 0.08, 0.09 and 0.12 per cent respectively. Similar trend was observed at Pilicode (Table 21) where the mean sodium content for the 2nd, 10th and 14th leaves were 0.10, 0.17 and 0.18 per cent respectively. However, when all the palms at the three different sites were pooled and analysed, the mean values of sodium content were 0.11, 0.13 and 0.12 per cent for the 2nd, 10th and 14th leaves respectively.

When the relationship between the sodium content of the leaf lamina of the 2nd, 10th and 14th leaves with yield was studied by computing simple correlation coefficients, it was found that in no place significant positive correlation was observed. In many instances, for example, the 2nd leaf of the palms at Balaramapuram, negative correlation were obtained with yield. However, when all the palms at the three different sites were pooled and analysed, it was revealed that, the sodium content of the 14th leaf had a significant positive correlation with yield. Data on the above observations are presented in Table 22.

Table 22. Coefficients of correlation (simple linear) between yield (y) and nutrient content of the leaf lamina in relation to leaf position.

Leaf position	Number of pairs (n)		Coefficients of correlation (r)					
			Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sodium
2nd	Balaramapuram	214	0.315**	-0.031	0.319**	-0.166*	-0.103	-0.225**
	Mannuthy	60	0.334**	0.083	0.223	-0.250	0.249	-0.236
	Pilicode	60	0.402**	-0.213	0.842**	-0.595**	-0.096	-0.058
	Pooled	334	0.475**	-0.164**	0.355**	-0.058	0.049	-0.012
10th	Balaramapuram	192	0.611**	0.027	0.191**	-0.060	-0.086	0.007
	Mannuthy	60	0.488**	0.145	0.215	-0.063	-0.021	-0.022
	Pilicode	60	0.369**	-0.103	0.563**	-0.248	-0.294*	-0.167
	Pooled	312	0.518**	0.199**	0.448**	0.067	-0.130*	-0.035
14th	Balaramapuram	163	0.365**	-0.009	-0.172*	0.271**	0.263**	-0.057
	Mannuthy	60	-0.071	0.036	0.270*	-0.176	0.191	0.092
	Pilicode	60	0.366**	0.014	0.185	-0.202	-0.143	0.056
	Pooled	283	0.338**	0.205**	0.223**	0.386**	-0.060	0.215**

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

Table 23. Coefficients of correlation (simple linear) between the leaf number and mineral elements of the 2nd leaf of coconut palms (n = 334).

	Leaf No.	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Nitrogen	0.297**	-	-	-	-	-
Phosphorus	0.223**	0.215**	-	-	-	-
Potassium	0.622**	-0.026	0.049	-	-	-
Calcium	-0.185**	0.128*	0.081	-0.432**	-	-
Magnesium	0.001	0.161**	0.731**	0.146**	0.724**	-
Sodium	-0.021	-0.009	0.183**	-0.026	0.008	0.006

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 24. Coefficients of correlation (simple linear) between the leaf number and the mineral elements of the 10th leaf of coconut palms (n = 312).

	Leaf No.	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Nitrogen	0.251**	-	-	-	-	-
Phosphorus	0.243**	0.109	-	-	-	-
Potassium	0.710**	0.160**	0.190**	-	-	-
Calcium	0.076	-0.013	0.125*	-0.079	-	-
Magnesium	-0.232**	-0.001	-0.016	-0.398**	0.147**	-
Sodium	-0.241**	-0.068	-0.135*	-0.441**	0.038	0.148**

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 25. Coefficients of correlation (simple linear) between the leaf number and mineral elements of the 14th leaf of coconut palms (n = 283).

	Leaf No.	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Nitrogen	0.258**	-	-	-	-	-
Phosphorus	0.322**	0.249**	-	-	-	-
Potassium	0.579**	0.096	0.315**	-	-	-
Calcium	0.292**	0.193**	0.205**	-0.074	-	-
Magnesium	-0.325**	-0.097	-0.128*	-0.521**	-0.019	-
Sodium	0.195**	-0.081	-0.103	-0.107	0.332**	-0.070

* Significant at 5 per cent level

** Significant at 1 per cent level

As seen in Tables 23, 24 and 25, sodium content of the 10th leaf was negatively correlated with the number of leaves whereas in the 14th leaf, the relationship was positive. The sodium content of the 2nd leaf was positively correlated with content of phosphorus. The sodium content always had a negative correlation with the potassium content, especially in the 10th leaf. The sodium content was positively correlated with the calcium content in the 14th leaf, and with the magnesium content in the 10th leaf.

Discussion

DISCUSSION

The present study was undertaken to standardise the leaf tissue to be sampled in order to assess the nutrient status of the coconut palm. Earlier work carried out by Gopi and Jose (1983) indicated the possible leaf position, the nutrient status of which is well correlated with yield. In their study, Gopi and Jose sampled the leaf lamina and the leaflet midrib of all leaf positions and, therefore, they restricted the number of palms to 108. Again, the four leaf samples from a particular leaf position of the four palms of the same treatment were made into a composite sample for chemical analysis. Thus, there were only 27 pairs of observations for the purpose of examining the correlation between yield and the nutrient status in the leaf of a particular leaf position. The present study was, therefore, oriented to assess the validity of the leaf position recommended by Gopi and Jose with a large number of palms representing different tracts of the State. A total of 336 palms were sampled at three leaf positions each, namely, the leaf number 2, 10 and 14. The leaf samples were analysed separately without compositing. The palms of the Coconut Research Station, Balaramapuram belonged to a permanent

NPK trial, details of which have already been furnished, while the palms of Agricultural Research Station, Mannuthy and Regional Agricultural Research Station, Pilicode were from the bulk crop maintained, which received fertilizer application as per the general recommendation of the Kerala Agricultural University.

1. General characteristics of the soil

1.1 Balaramapuram

The soil of the experimental site at the Coconut Research Station, Balaramapuram was deep well drained and sandy loam in texture. As can be seen from the pH of the soil, which varied from 5.4 to 7.1, the soil is moderately acidic in reaction. The content of the total nitrogen in the soil increased with increasing levels of nitrogen application. Application of nitrogen at n_1 level (340 g N/palm/year) resulted in 31 per cent increase in the content of total nitrogen in the soil, over that at n_0 level. This increase is not very appreciable considering the fact that the soils of the n_1 treatment were receiving 340 g N/palm/year for the last 17 years. The probable reason for this low content of nitrogen in the soil receiving an annual application of nitrogen, is the low capacity of the soil to retain nitrogen, due to a low content of organic matter. This is especially true as the soil was not receiving any addition of organic matter for several years. Another reason for the low nitrogen content of the soil may be the increased utilisation of nitrogen by palms which can be seen from a higher content of nitrogen in the leaves of the palms receiving higher nitrogen application. The increased utilisation of nitrogen is further evidenced by an increased yield with an increase in nitrogen application. Application of nitrogen at the n_2 level (680 g N/palm/year) also resulted in an increase in the content of nitrogen in the soil over that at n_1 level. But there was only 12 per cent increase in the content of nitrogen in the soil from n_1 to n_2. This shows that application of nitrogen at higher levels has only less influence in increasing the nitrogen content of the soil. Here also the increased applications resulted in a higher content of the element in the leaf and an increased yield.

Application of phosphorus resulted in a drastic increase in the content of available phosphorus in the soil. Soils receiving no application of phosphorus were having only 3.14 ppm P whereas application of 225 g P_2O_5/palm/year resulted in a retention of 12.77 ppm P in the available form. A further increase in the application to 450 g P_2O_5/palm/year produced a further increase in the available phosphorus content of the soil to 29.53 ppm P. Assuming that the leaching loss of this nutrient from the soil is negligibly small, and considering the fact that increased level of application resulted in only a marginal increase in the content in the leaf, we can conclude that a major portion of the applied phosphorus remains in the soil in the available form. Out of the total amount of phosphorus added to the soil in 17 years at p_1 level, which will work out to 342.21 kg P_2O_5/ha, 13 per cent remained in the available form. On the other hand, 22 per cent of the additional 342.21 kg P_2O_5/ha, added in 17 years at p_2 level was retained in the available form. This is because, the enhancement of phosphorus application from p_1 to p_2 resulted in no increase in yield showing that, phosphorus application at higher levels resulted in a decreased utilisation by the palm.

Application of potassium produced an increase in the content of available potassium in the soil. But the accumulation of potassium in the available form is much lower when compared to the accumulation of phosphorus. This is because of an increased utilisation of potassium by the palm at higher levels of application, as evidenced by an increased content in the leaf and an enhanced yield. This is also because of a large loss of this element through leaching. Thus application of nitrogen and potassium result in only a marginal accumulation in the soil, whereas a major portion of the phosphorus applied remains in available form.

Analysis of the soil revealed that with increasing levels of phosphorus application, the exchangeable calcium content of the soil increased. It must be pointed out that, this is not due to an interaction between phosphorus and calcium, but because the phosphatic fertilizer (single superphosphate) used itself contained calcium. On the other hand, with increase in the level of applied potassium, the content of exchangeable magnesium and sodium decreased. Potassium, magnesium and sodium being cations, such an antagonism can be expected as there will be competition for exchange sites between these elements.

1.2 Mannuthy

The experimental site at Mannuthy was having a typical laterite soil. The nitrogen content of the soil was higher than the nitrogen content of the soil at Balaramapuram even with n_2 level of nitrogen application.

The amount of nitrogen applied at Mannuthy was 680 g/palm/year which is the same as the n_2 level of application at Balaramapuram. But, since there was application of organic matter at Mannuthy, the soil was able to retain a higher amount of nitrogen when compared to the soil at Balaramapuram. The available phosphorus content was also higher at Mannuthy eventhough the rate of application was less than the p_1 level of phosphorus application at Balaramapuram. This also may be due to the application of organic matter, which would have supplied some amount of phosphorus to the available fraction in the soil. The available potassium content also was higher at Mannuthy which may be attributed to a decreased loss of this element from the soil in presence of organic matter. On the other hand, the exchangeable calcium, magnesium and sodium contents were lower than their contents in Balaramapuram soil. It is possible that the soil of Balaramapuram being less acidic as compared to Mannuthy soil, is capable of retaining basic cations like calcium, magnesium and sodium in the soil. Also, a relatively high content of potassium in Mannuthy soil would have suppressed the content of other cations due to the probable competition for exchange sites in soil.

1.3 Pilicode

The experimental soil at Pilicode was also lateritic in nature. Here also the total nitrogen, available phosphorus and available potassium contents were higher than at Balaramapuram. The presence of a higher amount of organic matter must have produced an increased accumulation of these elements in the soil, as in the case of the soil at Mannuthy. The exchangeable calcium, magnesium and sodium contents were lower than at Balaramapuram because of high content of available potassium and a more acidic reaction of the soil.

2. Effect of NPK treatment on the number of leaves retained by the experimental palms at Balaramapuram

2.1 Nitrogen

The results indicate that application of nitrogen decreased the number of leaves retained by the palm. Thus, palms receiving no nitrogen application were able to retain a higher number of leaves than palms receiving nitrogen application at n_1 and n_2 levels. This shows that nitrogen is not required for the production and retention of leaves, eventhough the yield was increased at all levels of nitrogen application. The reduction in the number of leaves retained at higher levels of nitrogen application, could only be due to the nitrogen-potassium interaction in the soil. As the result shows, application of nitrogen resulted in a decreased content of available potassium in the soil. The content of available potassium at n_0 and n_1 levels of nitrogen application was 43.01 ppm which decreased to 39.10 ppm at n_2 level. As the content of available potassium in the soil decreased, the uptake of potassium by the palm also decreased as can be seen from a decrease in the content of potassium in the leaf with an increase in nitrogen application. Potassium being an element that is essential for the production and retention of leaves, the decrease in the content of available potassium in the soil and uptake of potassium from the soil with an increase in the application of nitrogen, could have caused a decrease in the number of leaves retained by the palms.

2.2 Phosphorus

The increasing levels of phosphorus application could not bring about any influence on the number of leaves retained by the palms. This may be because, the requirement of phosphorus for the production of leaves may be very low, so that the soil may be able to supply the required quantity even when no phosphorus is added to the soil. Thus, under no conditions, does phosphorus become a limiting factor for leaf production and retention.

2.3 Potassium

Application of potassium produced a drastic increase in the number of leaves retained by the palms. Palms which received no potassium application were able to retain only 11.75 leaves whereas at k_1 level, the number of leaves retained was 20.61, and at k_2 level, it was 22.92. This accounts for 75.40 per cent increase from k_0 to k_1 and 11.00 per cent increase from k_1 to k_2. This shows that the increase in the number of leaves retained by the application of 450 g K_2O/palm/year will be higher than the increase that is obtained for an additional 450 g/palm/year. From this it can be concluded that for the production and retention of a desired number of leaves, a minimum supply of potassium is required. Thus, potassium is the primary and deciding factor determining the production and retention of leaves. This relation is further emphasised by the high, positive and significant correlation existing between the potassium content of leaves and the number of leaves retained by the palms ($r = 0.710^{**}$ for 10th leaf).

2.4 NPK interaction

Results show that, the interaction between the levels of nitrogen and phosphorus was not significant whereas interaction between nitrogen and potassium greatly influenced the number of leaves retained by the palm. When potassium was not applied, application of nitrogen decreased the number of leaves retained. As pointed out earlier, this could be due to a decreased retention of potassium in the soil at higher levels of nitrogen application, and consequent reduced uptake and utilisation of potassium by the palm. Potassium being the most important nutrient involved in the production and retention of leaves, this decreased utilization at higher levels of nitrogen application will definitely hamper the ability of the palm to produce and retain leaves, especially at low levels of potassium supply. The interaction between nitrogen and potassium is further pronounced by the fact that the combined application of nitrogen and potassium is superior to the independent application of the elements. Eventhough potassium application increased the number of leaves retained at all levels of nitrogen application, the effect was more marked at higher levels of nitrogen application. As the result shows, application of 900 g K_2O/palm/year resulted in 52.34 per cent increase in the number of leaves produced at n_0 level, whereas the corresponding value at n_2 level was 136.66 per cent.

The effect of interaction between levels of phosphorus and potassium on the number of leaves retained is similar to the interaction between the levels of nitrogen and potassium. As in the case of nitrogen, application of phosphorus at k_0 level decreased the number of leaves retained by the palm. But, at higher levels of potassium application, addition of phosphorus increased the number of leaves retained by the palm. On the other hand, application of potassium increased the number of leaves retained at all levels of phosphorus application, the influence being the more pronounced at higher levels of phosphorus application. Applications of 900 g K_2O/ palm/year resulted in 58.99 per cent increase in the number of leaves at p_0 level whereas the corresponding value at p_2 level was 125.68 per cent. It appears that the potassium content of the soil is more critical than that of the phosphorus in the expression of leaf number. When the soil contains only a relatively low content of potassium, application of phosphorus could not increase the leaf number whereas applications of potassium alone improved it, and, application of the two elements together drastically increased the leaf number.

3. Effect of NPK treatment on the yield of the experimental palms at Balaramapuram.

The NPK fertilizer experiment at the Coconut Research Station, Balaramapuram was established in order to study the effect of varying levels of nitrogen, phosphorus and potassium on the yield of the palms. Under the present study, the average yield of nuts/palm/year was worked out from the yield of the palms during the last 4 years, viz., 1979 to 1982.

3.1 Nitrogen

Levels of nitrogen had a significant influence on the yield of the palms. The yield steadily increased as the level of nitrogen application was increased from n_0 to n_2. This reveals the importance of nitrogen for coconut. The high utilization of nitrogen by coconut palm is further emphasied by the increased content of this nutrient in the leaves with an increased application.

3.2 Phosphorus

The results indicate that application of phosphorus increases the yield upto 225 g P_2O_5/palm/year. A further increase in the phosphorus application reduces the yield. This shows that the requirement of phosphorus for coconut is far less when compared to the requirement of nitrogen. This low requirement of phosphorus is further evidenced by the considerably low content of this element in the leaves when compared to the content of nitrogen and potassium. Further, the coefficient of correlation between yield and the phosphorus content of the leaves in relatively low showing the absence of a decisive influence of phosphorus on yield. Eventhough the above results help to conclude that the requirement of phosphorus for coconut is low, it does not explain why there is a decrease in yield when the rate of application was increased to 450 g P_2O_5/palm/year. Probably, this might be due to a decreased uptake of potassium from the soil at higher levels of phosphorus application which is reflected in a decrease in the content of potassium in the leaf at higher levels of phosphorus application.

3.3 Potassium

The results show that the influence of potassium on yield of coconut is much greater when compared to the influence of either nitrogen or phosphorus. Application of potassium at k_1 level increased the yield of the palm by 963 per cent over k_0 level, whereas, the increase in yield from n_0 to n_1 was only 107.15 per cent. This points out the importance of application of potassium to the coconut palms, which is not for the production of nuts alone, but for the production and retention of leaves as well. In this respect, it is more important than nitrogen, as nitrogen does not favourably influence the number of leaves retained by the palm at low levels of potassium. As the results show, the increase in yield obtained by enhancing the application rate from k_1 to k_2 is less when compared to the increase in yield obtained when the rate of application was changed from k_0 to k_1. This reveals that at k_0 level, the plant might have been very deficient in potassium, so that an application at that stage might have produced a drastic increase in the yield. On the other hand, at k_1 level, the plant is already receiving some amount of the nutrient so as to fulfil a major portion of its requirement, and an application at this stage might have had only a moderate effect in correcting the deficiency.

3.4 NPK interaction

The interaction between the levels of nitrogen and potassium had a significant influence on yield of the palms. At k_0 level of potassium application, nitrogen had no influence on yield. This shows that at k_0 level, the palm is not in a position to utilize nitrogen since potassium level remained as a limiting factor. Moreover, it is already seen that, application of nitrogen reduces the content of available potassium in the soil. This would mean that, at lower levels of potassium application, addition of nitrogen cannot bring about an increase in yield since the potassium level is critically affected. On the other hand, at k_2 level, nitrogen markedly increased the yield as evidenced from 254.13 per cent increase in the yield when the level of application was increased from $n_0\ k_2$ to $n_2\ k_2$. This also supports the fact that when potassium is limiting, application of nitrogen has no influence on yield, whereas, when potassium is not limiting, availability of nitrogen becomes critical and markedly influences the yield.

Application of potassium on the other hand, increased the yield at all levels of nitrogen. But this effect of potassium was more pronounced at higher levels of nitrogen. At n_0 level, application of potassium at 900 g K_2O/palm/year increased the yield by 293 per cent whereas at n_2 level, this increase was by 1884.88 per cent.

Application of nitrogen increased the yield at all levels of phosphorus, the effect being more pronounced at higher levels of phosphorus. Hence, the effect of nitrogen becomes more pronounced when phosphorus is not limiting. At n_0 level of nitrogen application, addition of phosphorus had no effect on yield. This is because, in absence of the adequate amount of nitrogen, the capacity of the palm to absorb and utilize phosphorus is limiting. This is further evidenced by an increase in yield upto p_2 level of application when the rate of application of nitrogen was at n_2 level. It is interesting to note that, at both n_0 and n_1 level of nitrogen application, addition of phosphorus increased the yield only upto p_1 level whereas application of phosphorus at p_2 level gave the maximum yield when nitrogen was given at n_2 level. It is likely that the effect of nitrogen in the production of dry matter is more decisive than that of phosphorus though the level of phosphorus should not be a limiting factor for the utilization of nitrogen. When nitrogen was given at the highest level, for the production of a proportionally increased yield, a relatively higher amount of phosphorus has to be utilized and that may be the reason for the response of palm to the application of phosphorus upto p_2 level at n_2 level of nitrogen.

When the interaction between the levels of phosphorus and potassium was studied, it was found that at k_0 level, application of phosphorus decreased the yield though that decrease was marginal. This reveals that at k_0 level, the palms are unable to utilize the phosphorus applied, probably due to the effect of potassium as a limiting factor. When potassium was supplied, the palms were able to utilize phosphorus resulting in an increase in yield. At both k_1 and k_2 levels, application of phosphorus increased the yield only upto p_1 level.

4. Effect of NPK treatment on the nutrient contents of the leaves of the experimental palms at Balaramapuram.

4.1 Nitrogen

Result showed that application of nitrogen resulted in an increase in the content of the nutrient in the 2nd, 10th and 14th leaves. As can be expected, application of increased levels of nitrogen produces an increased uptake by the palm and a consequent increase in the content in the leaves, in addition to an enhancement in yield.

4.2 Phosphorus

In general, application of phosphorus resulted in an increase in the content of the same in the leaves at all the three leaf positions. This shows that, when the level of phosphorus applied is increased, the palm takes up more amount of the same nutrient thereby producing a higher content in the leaves. This increase is more marked in the 2nd leaf followed by the 10th and 14th leaves.

4.3 Potassium

Increased application of potassium resulted in an increase in the content of the element in all the three leaf position studied. As in the case of nitrogen, palms receiving a higher amount of available potassium was able to absorb and retain a higher content of the same in all the leaves. This was followed by an increase in the number of leaves produced and an enhanced yield. The increase in the potassium content of the leaf with increase in the application was more pronounced than in the case of phosphorus, showing that, coconut responds to the application of potassium more readily than to the application of phosphorus.

5. Relationship between yield and number of leaves retained by the palms.

Palms selected for the present study varied in the number of leaves retained quite widely. While palms at Balaramapuram were able to retain only 18.29 leaves on an average, palms at Mannuthy retained 32.23 leaves. Palms at Pilicode were intermediary between the above two sites, retaining, on an average, 28.95 leaves. This reveals that, depending upon climatic and other conditions, the capacity of the palm to produce and retain leaves will vary.

When the simple linear correlation coefficients between the number of leaves retained and yield was worked out, it was found that, at all sites the number of leaves retained was positively and significantly correlated with yield. The values of simple linear correlation coefficients were 0.465** at Balaramapuram, 0.635** at Mannuthy, 0.794** at Pilicode and 0.735** when all the palms at the three sites were pooled and analysed. The simple linear regression equation of yield on number of leaves (Fig.5) was $Y = -25.33 + 2.92\ X$. This equation reveals that, the minimum number of leaves required for the very expression of yield is 8.74 and that a unit increase in number of leaves will correspond to a yield increase of 2.92 nuts/palm/year. More the number of leaves, more will be the capacity of the palm to synthesize dry matter which will result in an increased yield. Moreover, since the flower inflorescence is borne in the axils of the leaves, an increase in the number of leaves will result in a corresponding increase in the number of bunches of nuts produced thereby resulting in an increased yield.

The number of leaves retained was significantly and positively correlated with the nitrogen, phosphorus and potassium contents of the 2nd, 10th and 14th leaves.

However, the highest correlation was obtained between the number of leaves and potassium content in all the three leaves. Among the three leaves studied, highest correlation of potassium content with the number of leaves was for the 10th leaf ($r = 0.710^{**}$) followed by the 2nd and 14th leaves ($r = 0.622^{**}$ and 0.579^{**} respectively). The simple linear regression equations of number of leaves on the potassium content of 2nd, 10th and 14th leaves (Fig.2, 3 and 4) respectively are,

$$Y = 6.45 + 8.71\ X \text{ (2nd leaf)}$$

$$Y = 6.43 + 8.72\ X \text{ (10th leaf)}$$

$$Y = 14.79 + 8.51\ X \text{ (14th leaf)}$$

The simple linear regression equation of potassium content of 10th leaf on number of leaves (which had the highest correlation coefficient) reveals that a unit change in the per cent of potassium in this leaf will register an increase in the number of leaves by 8.72.

From the data the optimum number of leaves for maximum yield was worked out as 46.62. Evidently, palms in our condition are retaining considerably less number of leaves when compared to the optimum number. Based on the linear model, the maximum yield can be worked out as 110.80 nuts/palm/year.

Fig. 2. Relationship between K % of 2nd leaf and number of leaves retained by the palm.

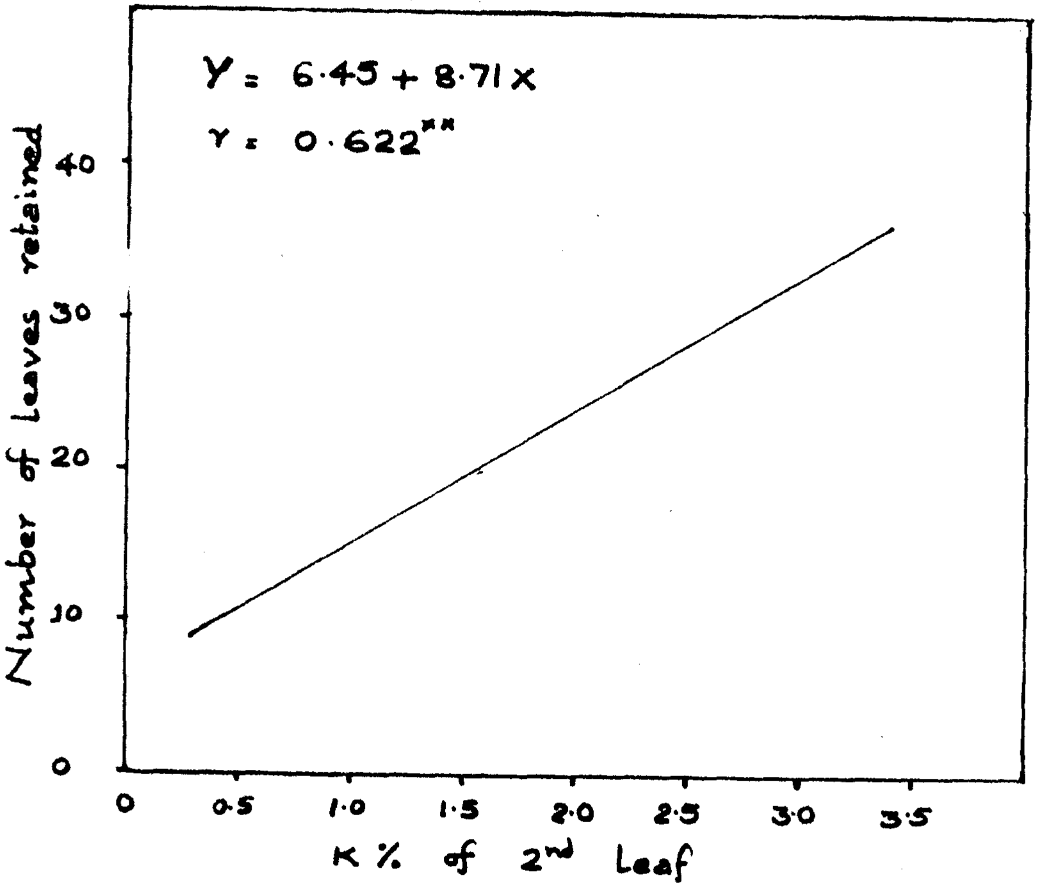


Fig. 3. Relationship between K % of 10th leaf and number of leaves retained by the palm

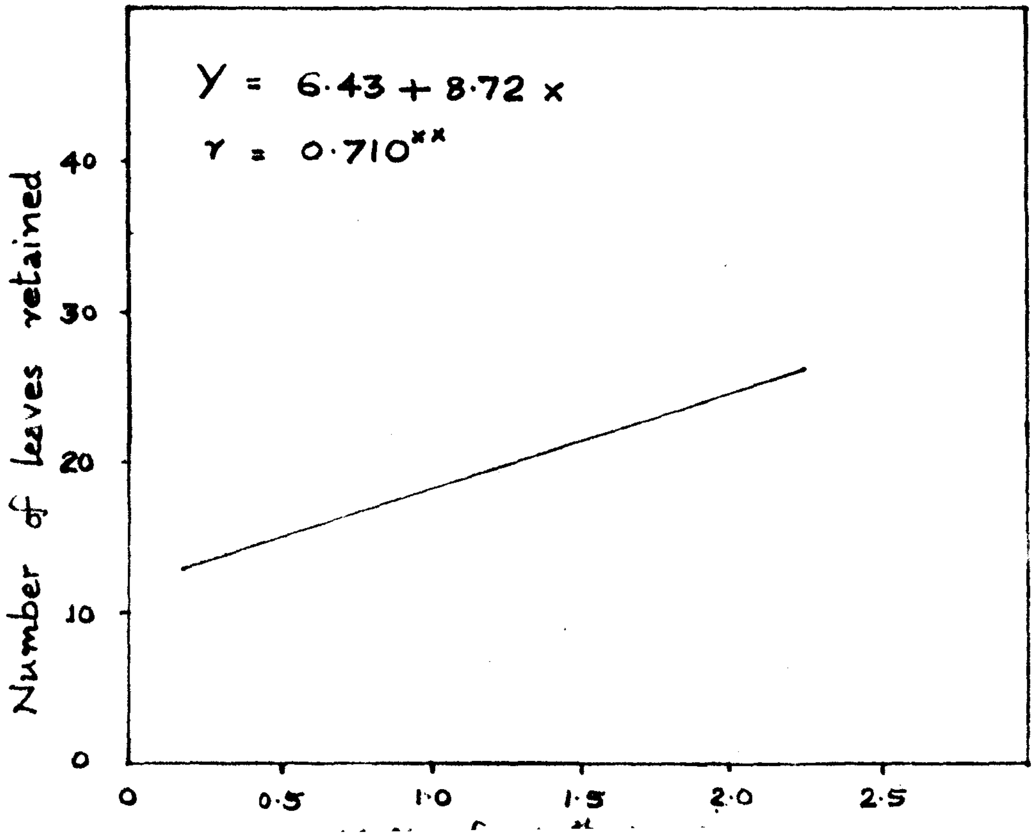


Fig. 4. Relationship between K % of 14th leaf and number of leaves retained by the palm

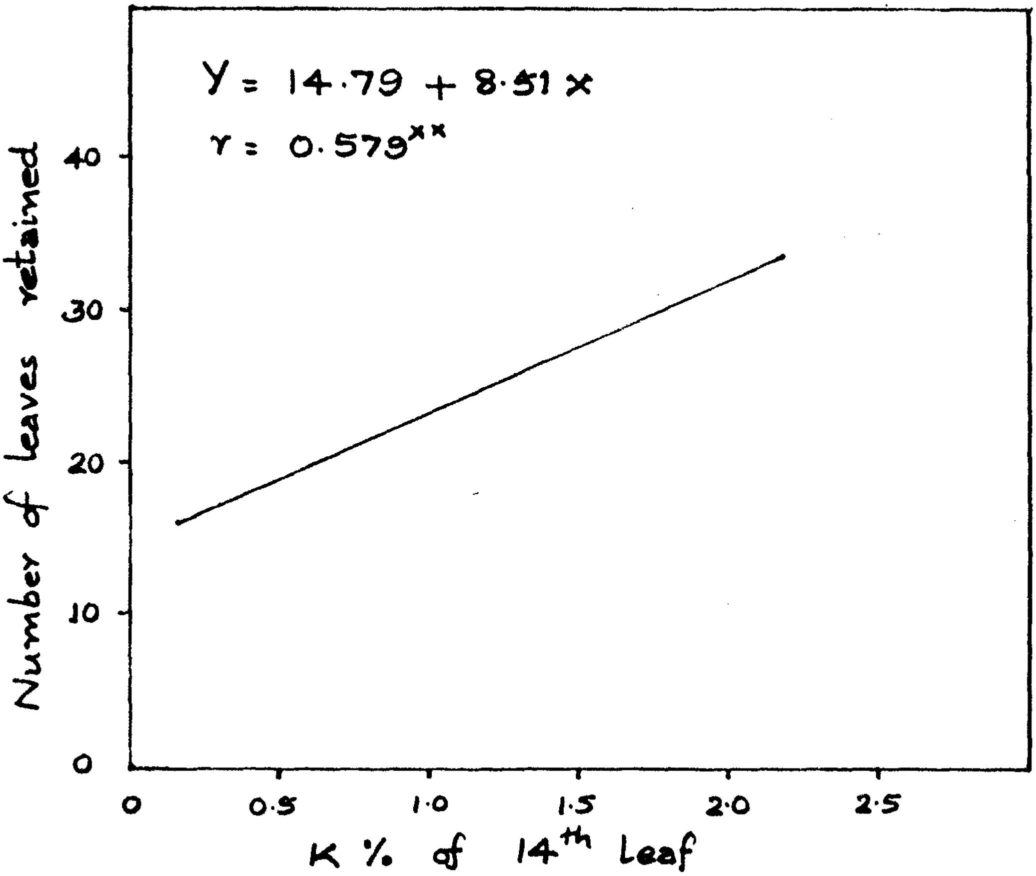
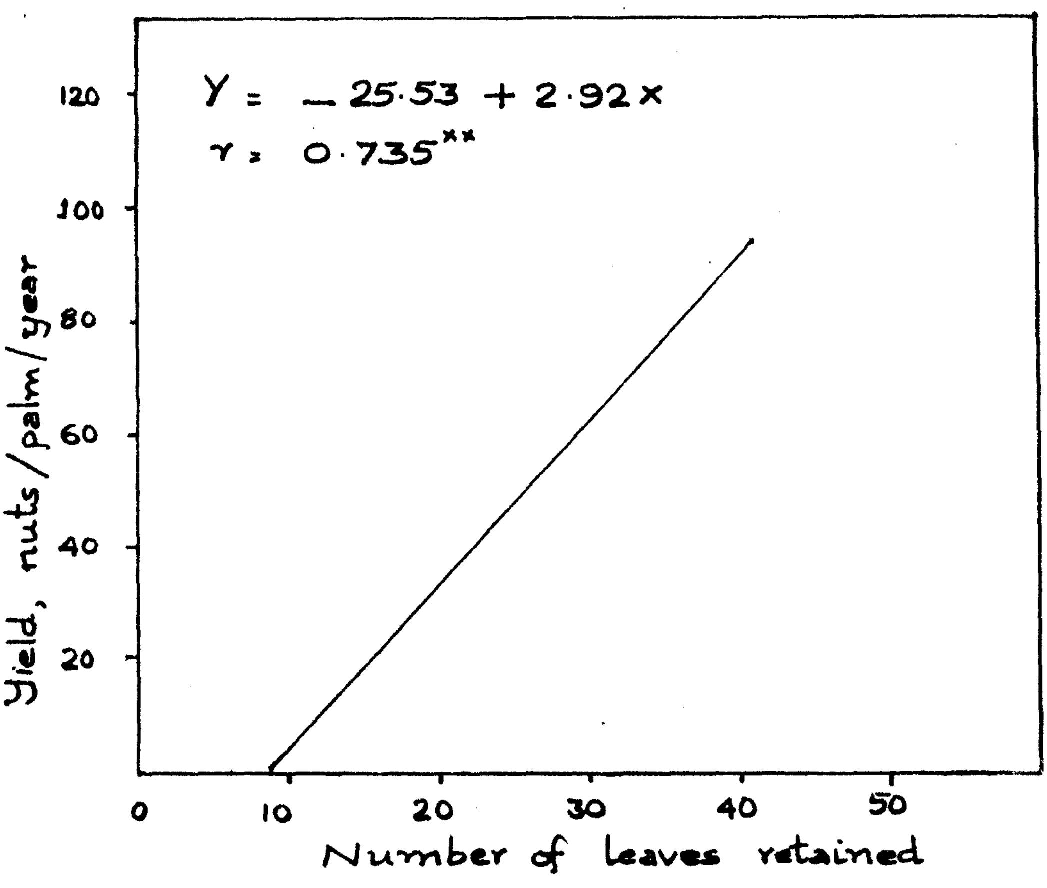


Fig. 5. Relationship between number of leaves retained and yield of the palm



6. Prediction of yield based on the nutrient contents of leaves.

6.1 Nitrogen

Analysis of the content of nitrogen in 2nd, 10th and 14th leaves revealed that the content of nitrogen was highest in the 2nd leaf followed by the 10th and 14th leaves. The result is in conformity with the observations of Ziller and Prevot (1963) and Gopi et al.(1982). The decrease in the content of nitrogen with increase in age of the leaf is because of the translocation of this mobile element from the older leaves to the younger leaves. An analysis of the leaves of the palms at Balaramapuram, where there are different levels of nitrogen application, revealed that there is an increase in the percentage of nitrogen in the leaf at all leaf positions with increasing levels of nitrogen application. This shows that increased application of nitrogen results in an increase in the uptake of this nutrient by the palm, and a corresponding increase in yield.

Simple linear correlation coefficients were calculated in order to study the degree of relationship between the yield of coconut palms and the percentage of nitrogen in the leaf at the three leaf positions. The nitrogen content of the 2nd leaf was significantly correlated with yield at all the three locations under our study. When palms at all the sites were pooled and analysed, there also, the nitrogen content of the 2nd leaf was significantly correlated with yield, the coefficient of correlation being 0.475**. The partial correlation coefficient (eliminating the effects of phosphorus and potassium) in this case was 0.441**. However, the correlation between the nitrogen content of the 10th leaf and yield was higher than the corresponding value for 2nd leaf, in the case of palms at Balaramapuram and Mannuthy. Pooled analysis also showed that yield was correlated with the nitrogen percentage of the 10th leaf more than that of 2nd leaf. The simple and partial linear correlation coefficients in this respect were 0.518** and 0.499** respectively. Nitrogen content of the 14th leaf, on the other hand, showed only a less degree of correlation with yield. In the case of palms at Mannuthy, even a negative correlation was obtained, though not significant. The pooled analysis indicated that the simple and partial linear correlation coefficients between yield and nitrogen content of the 14th leaf were 0.338** and 0.291** respectively. The results, thus are in conformity with the observations of Gopi et al. (1982) who also obtained significant correlation between yield and nitrogen content of 2nd, 10th and 14th leaves. The present study thus confirms the report of Gopi et al. (1982) that the 10th leaf will be the best reflect of the nitrogen status of the palm in relation to yield. Ziller and Prevot (1963), on the other hand, have recommended the 14th leaf for revealing the nitrogen status of the palm. Under the present study also, the nitrogen content of the 14th leaf was significantly correlated with yield. However, the nitrogen contents of the 10th and 2nd leaves are more correlated with yield under our conditions. Ziller and Prevot (1963) have defined the index leaf as the one which has attained full physiological maturity but yet to enter the phase of senescence. In the palms studied by the above scientists this might have been the 14th leaf, as the number of leaves retained by their palms are high, say above 40. On the other hand, palms under our conditions are having only much less number of leaves. For example, the average numbers of leaves retained were 18.29 at Balaramapuram, 28.95 at Pilicode and 32.23 at Mannuthy. There are even palms which have number of leaves as low as 8. Under these circumstances, the 14th leaf, which was described by Ziller and Prevot (1963) as the leaf that has attained full physiological maturity but not entered the phase of senescence, will be a leaf in its early stage of senescence. Perhaps the leaf number 10 can be recognised as the one that will satisfy the attributes of index leaf as suggested by Ziller and Prevot, under our conditions. That must have been why in the present study, the nitrogen content of the 10th leaf was more correlated with yield, than the nitrogen content of 2nd or 14th leaves.

The relationships between the nitrogen content of the leaf lamina of leaf position 2, 10 and 14 and yield have been graphically represented in Fig. 6, 7 and 8. Simple linear regression of yield on the nitrogen content of the 10th leaf was $Y = -33,98 + 44.27\ X$. This reveals that, unit increase in the nitrogen per cent of leaf lamina of leaf number 10 will result in an increase in yield to the tune of 44.27 nuts/palm/year. This also indicates that for the very expression of yield, the minimum percentage of nitrogen to be retained in the 10th leaf will be 0.77.

Assuming the leaf number 10 as the index leaf for predicting the yield based on the nitrogen content, the optimum level of nitrogen for obtaining maximum yield was worked out to be 2.90 per cent. According to Fremond et al. (1966), the optimum level of nitrogen was 1.8 to 2.0 per cent based on the analysis of the 14th leaf. The optimum level suggested by the present study is higher than Fremond's optimum. Evidentally it is because, the

Fig. 6. Relationship between N % of 2nd leaf and yield of the palm

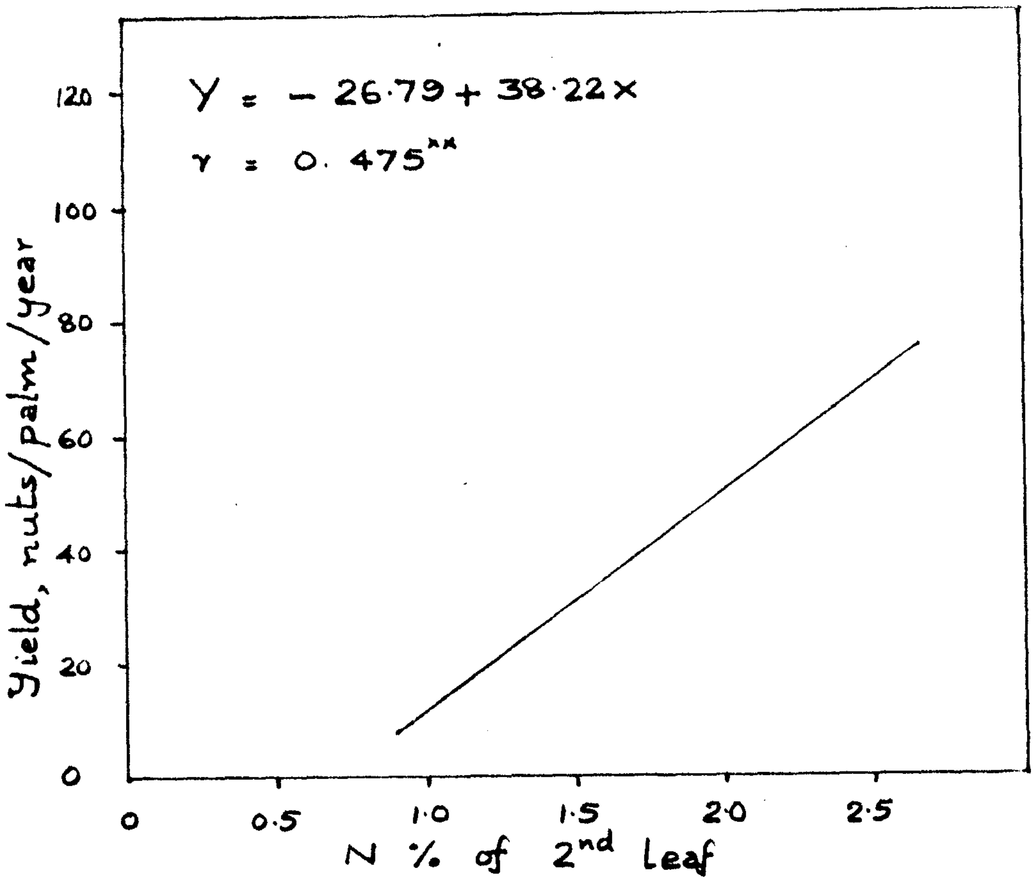


Fig. 7. Relationship between N % of 10th leaf and yield of the palm

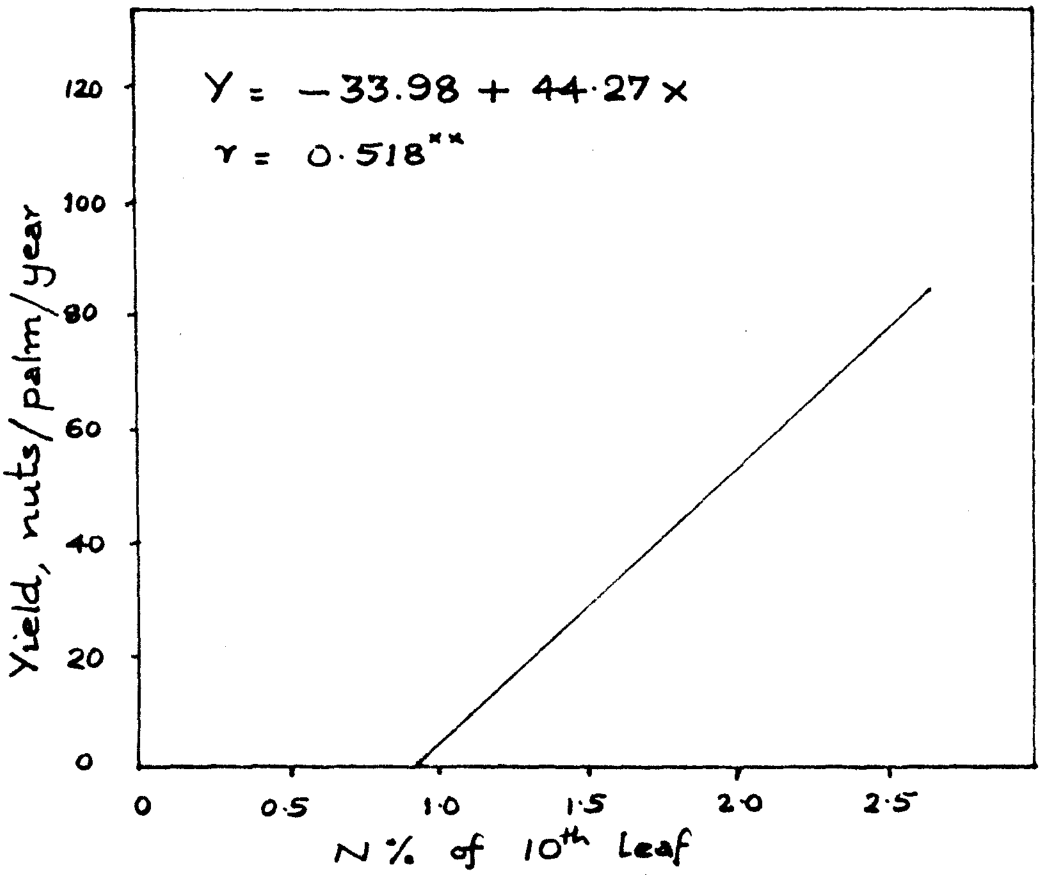


Fig. 8. Relationship between N % of 14th Leaf and yield of the palm

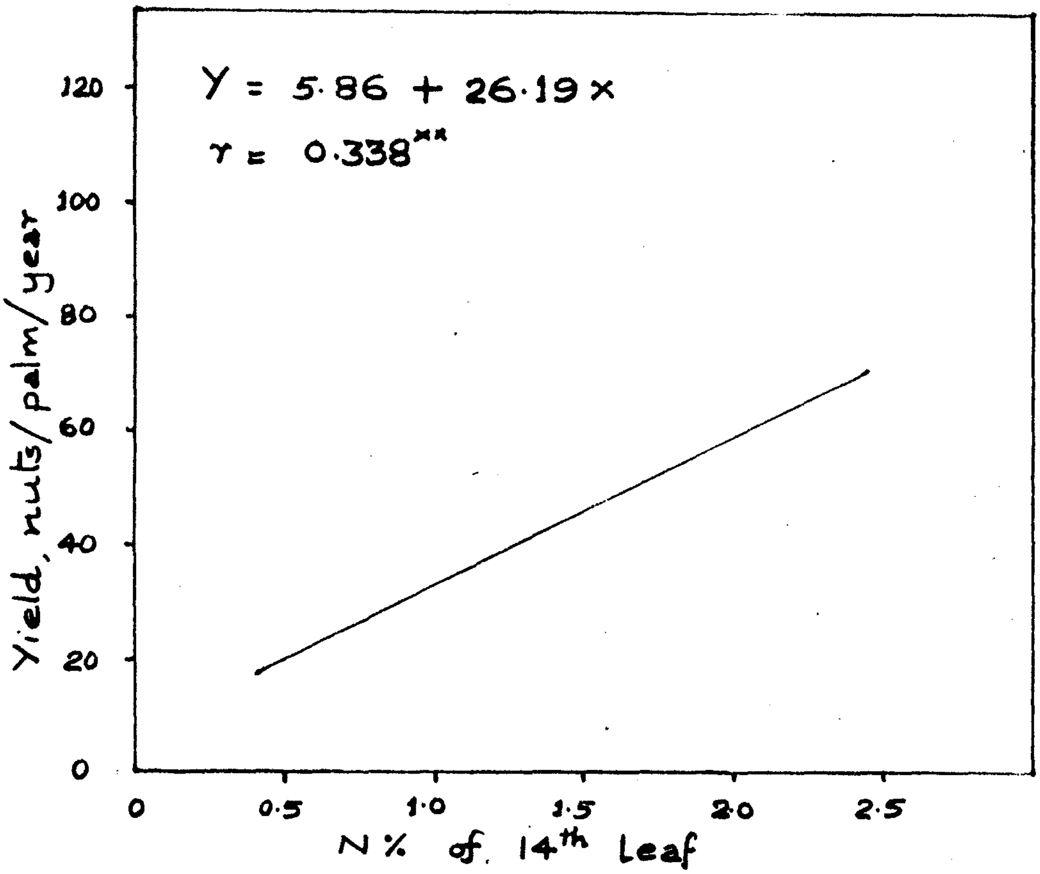
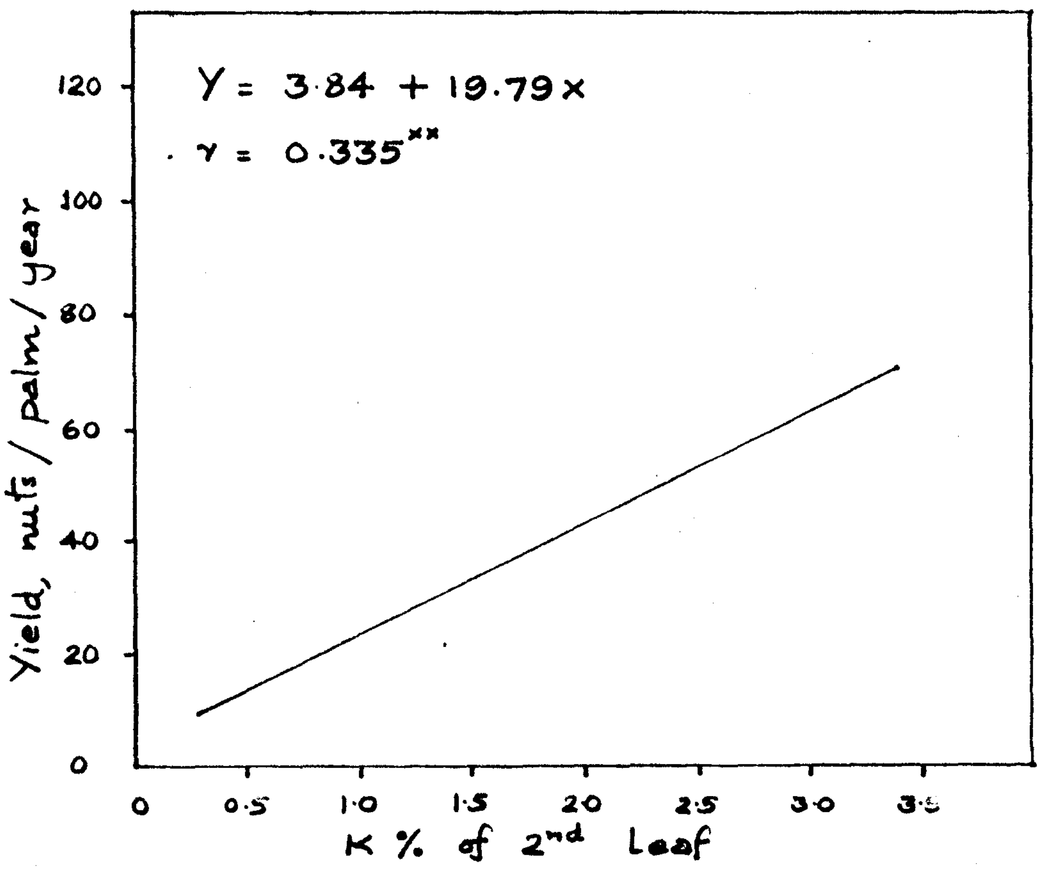


Fig. 9. Relationship between K % of 2nd Leaf and yield of the palm



10th leaf retains a higher content of nitrogen than the 14th leaf.

The nitrogen content was significantly correlated with the number of leaves retained. Since both nitrogen and leaf number are correlated with yield, it is not surprising that they are also correlated with each other. Consequently, the product of nitrogen per cent and leaf number (N% x L) was significantly correlated with yield, the correlation coefficient being 0.697** for the leaf position 10. Similarly, the product of nitrogen per cent and potassium per cent (N% x K%) was correlated with yield significantly (r = 0.277**).

6.2 Phosphorus

Results of the present investigation indicate that the content of phosphorus was highest in the 2nd leaf followed by the 10th and 14th leaves. This observation is similar to the report of Ziller and Prevot (1963) and Gopi and Jose (1983). The content of phosphorus in the leaves is much less when compared to the content of nitrogen and potassium. In general, the content of phosphorus was only 1/10th of the content of nitrogen and 1/8th of the content of potassium in the leaves. This shows that the requirement of phosphorus for coconut is much lower when compared to the requirement of nitrogen and potassium.

The simple linear correlation coefficient worked out between the phosphorus content and yield was significant in all the three leaf positions, the highest correlation being registered by the 14th leaf followed by the 10th leaf. This observation is quite different from the result obtained by Gopi and Jose (1983) who failed to obtain significant correlation between phosphorus content and yield at any leaf positions. However, the partial correlation coefficients were not significant in the present study, showing that the yield is not significantly correlated with the phosphorus content of the leaf. when effects of other nutrients, namely nitrogen and potassium are removed.

6.3 Potassium

Results of the present study reveal that the content of potassium is highest in the 2nd leaf followed by the 10th and 14th leaves. This observation also agrees with the findings of Ziller and Prevot (1963) and Gopi and Jose (1983) who observed a decrease in the content of this element, with increase in age of the leaf. Potassium being a mobile element as nitrogen, there will be translocation of potassium from the older leaves to the younger tissues of the plant thereby resulting in its accumulation in younger leaves. As in the case of nitrogen, application of potassium resulted in an accumulation of this element in the leaves of the experimental palms at Balaramapuram, indicating an increased utilization by the palms. In general, the content of potassium in the leaves was lower when compared to the content of nitrogen.

Simple linear correlation coefficients between the potassium content of the 2nd leaf and yield were significant in the case of palms at Balaramapuram and Mannuthy. The pooled analysis registered a simple correlation coefficient of 0.355** whereas the partial correlation coefficient was 0.417**. Potassium content of the 10th leaf also was significantly correlated with yield in the case of palms at Balaramapuram and Pilicode. The simple and partial correlation coefficients for the pooled data were 0.448** and 0.432** respectively. Potassium content of the 14th leaf failed to show correlation with yield at one per cent level at all the three sites. However, the simple correlation coefficient for the pooled data was 0.223** which was significant at one per cent level. On the other hand, the partial correlation coefficient worked out was not significant. The above results confirm the findings of Gopi and Jose (1983) that the potassium content of 2nd and 10th leaves are significantly correlated with yield. As pointed out by them, the correlation coefficient was highest for the 2nd leaf in the case of palms at Balaramapuram. However, when the pooled data was analysed, the potassium per cent of the 10th leaf was more correlated with yield than that of the 2nd leaf. This is quite understandable as the average number of leaves retained by the palms at Balaramapuram was much lower than the number of leaves retained by the palms at other sites. In general, the potassium content of the 10th leaf will best reflect the potassium status of the palm in relation to yield under our conditions. It should be pointed out that this leaf position was also the best reflect of the nitrogen status of the palm. Thus, the leaf number 10 can be recommended as an index leaf for the simultaneous determination of the nitrogen and potassium status of the palm. Moreover, the phosphorus content of this leaf also was significantly correlated with yield. This finding is not in conformity with the observations of Ziller and Prevot (1963) who recommended the 14th leaf for the determination of nitrogen, phosphorus and potassium. As pointed out earlier, this may be because of the higher number of leaves retained by the palms studied by them when compared to the number of leaves retained by the palms of the present study.

The relationships between the potassium per cent of leaf lamina of leaf positions 2, 10 and 14 and yield are graphically represented in Fig. 9, 10 and 11. The simple linear regression of yield on potassium per cent of 10th leaf was $Y = 7.79 + 27.13\,X$. This would mean that a unit increase in the potassium per cent of the leaf number 10 will result in an increase in yield by 27.13 nuts/palm/year. This indicates that the relative contribution of the potassium per cent of the leaf number 10 to yield is less when compared to the contribution by the nitrogen per cent of the same leaf since the increase in the number of nuts per unit increase in nitrogen per cent is more than the increase in nuts per unit increase in potassium per cent.

The optimum content of potassium in the leaf lamina of the leaf number 10 was found to be 1.80 per cent. According to Fremod _et al_. (1966) the optimum level of potassium was 0.8 to 1.0 per cent whereas Kanapathi (1971) suggested 0.8 to 1.1 per cent as the optimum in the 14th leaf.

Fig. 10. Relationship between K % of 10th Leaf and yield of the palm

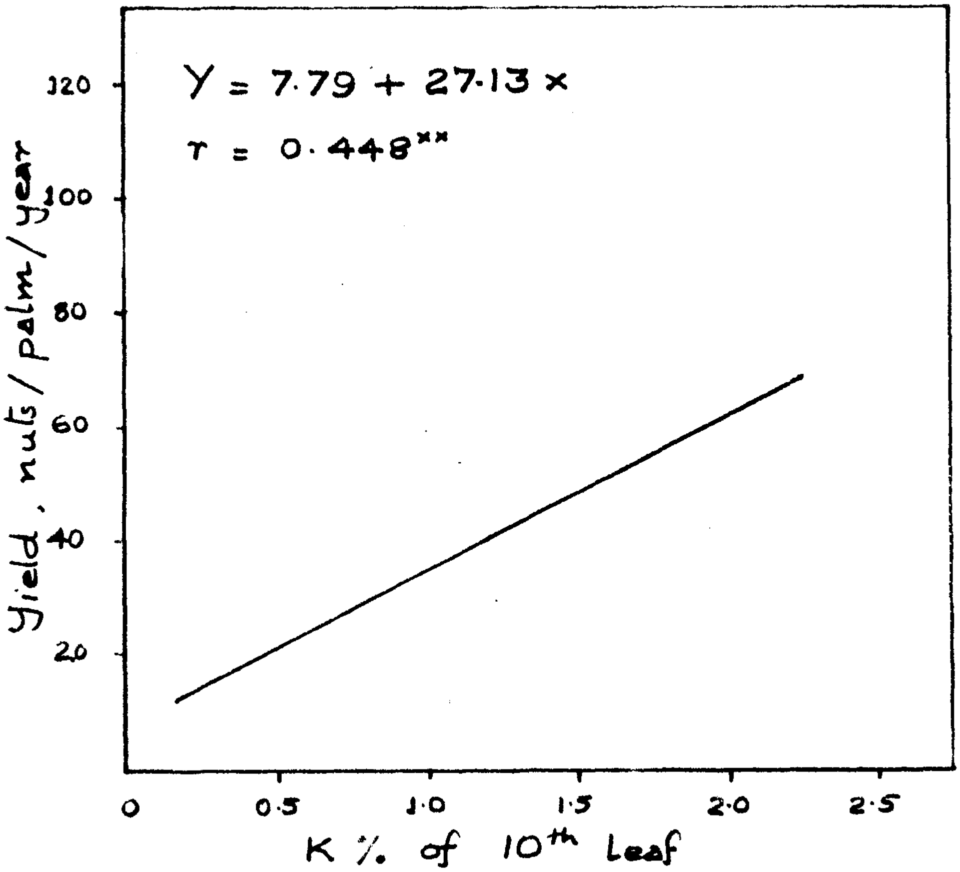
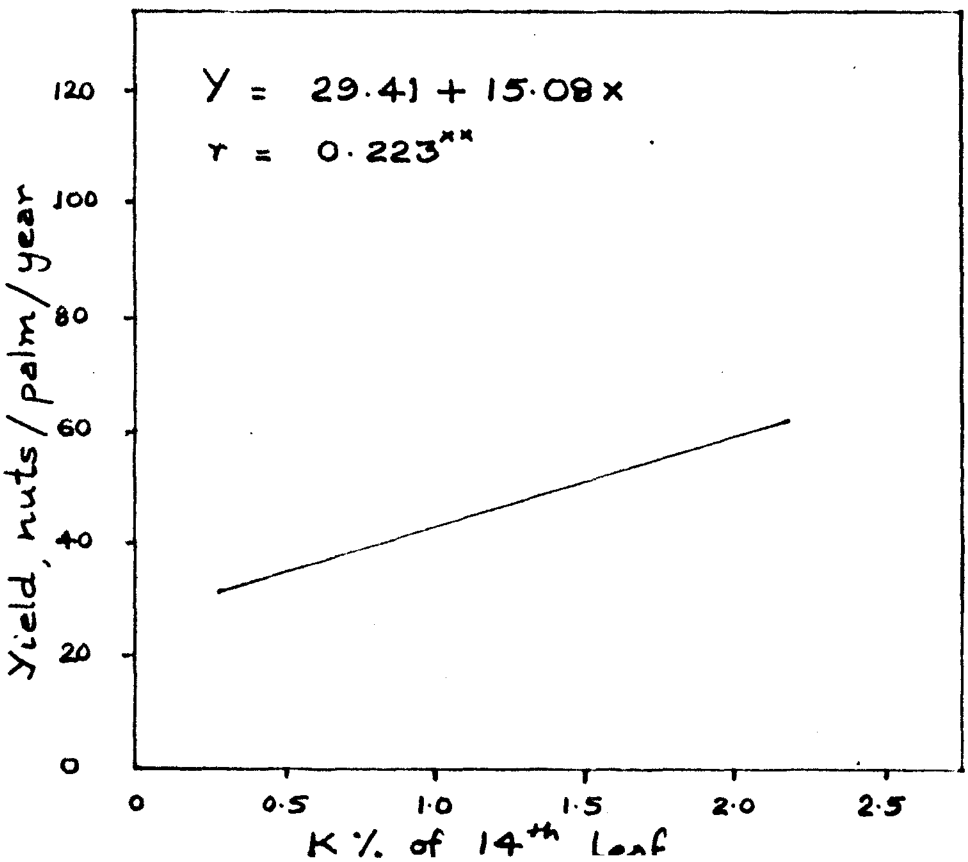


Fig. 11. Relationship between K % of 14th leaf and yield of the palm



As pointed out earlier, the potassium contents of all the three leaf positions were significantly correlated with leaf number, the highest correlation being registered by the 10th leaf. There was antagonism noticed between potassium and other cations, namely, calcium, magnesium and sodium. Potassium content was negatively correlated with calcium and sodium contents at all the three leaf positions, and with the magnesium content at the leaf positions of 10 and 14. Such antagonism of potassium with other cations has been noticed by Prevot and Ollagnier (1961), Ziller and Prevot (1963), Coomans (1974) and Loganathan and Balakrishnamurthi (1981). According to Prevot and Ollagnier (1961) such antagonism between potassium and other cations occurs only when the content of potassium is more than 0.5 per cent. When potassium content is less than 0.5 per cent, potassium showed synergism with other cations. In the present study, the relationship was antagonistic probably because the content of potassium was more than 0.5 per cent in general.

6.4 Calcium

Data relating to the content of calcium in the three leaf positions revealed that, contrary to nitrogen, phosphorus and potassium, the content of calcium increases with increasing age of the leaf. This trend was obtained in all the three sites studied. Calcium being an element that is relatively immobile when compared to nitrogen and potassium, the content will be highest in the oldest leaf where an accumulation of calcium will occur. Moreover, the antagonistic relationship between potassium and calcium acts as a cause for this increase in the content of calcium with increase in age of the leaf as there is a corresponding decrease in the content of potassium. Eventhough it is not possible to reveal the exact trend in the variation of calcium with age of the leaf making use of only three leaves as in the present study, the result definitely points out to the probable accumulation of calcium in the 14th leaf when compared to the 2nd and 10th leaves. The low content of calcium in the leaves helps to conclude that the requirement of this element is much less when compared to the requirement of nitrogen and potassium. The mean content worked out when all the leaves at all the sites were pooled was 0.41 per cent which is approximately 1/4th of the content of nitrogen and 2/7th of the content of potassium. However, the content of calcium is greater than the content of phosphorus by a factor of 2.4.

Simple linear correlation coefficients between calcium content and yield were negative in all the sites, in the case of 2nd and 10th leaves. These correlation coefficients were not significant at one per cent level. This shows that, neither the 2nd leaf nor the 10th leaf can reflect the calcium status of the palm in relation to yield. The same was the observation in the case of 14th leaf also, for palms at Mannuthy and Pilicode. However, positive significant correlation was obtained between the calcium content of the 14th leaf and yield in the case of palms at Balaramapuram and also when palms at all the sites were pooled and analysed (0.271** and 0.386** respectively). The palms at Mannuthy and Pilicode retained relatively higher content of calcium in the 14th leaf (0.61 and 0.63 per cent respectively) as compared to the palms at Balaramapuram (0.42 per cent). The critical limit of calcium in leaf for optimum yield as standardised by IRHO is only 0.50 per cent. Therefore it is possible that the calcium content of the palms at Mannuthy and Pilicode could not critically influence the yield while that of the palms at Balaramapuram critically influenced the yield.

When the correlation coefficient between the calcium content and the number of leaves retained was studied, it was revealed that the correlation coefficient was significant and positive only for the leaf position 14. Since significant correlations were obtained between leaf number and yield as well as between calcium content of 14th leaf and yield, it is quite likely that leaf number is correlated to the calcium content of the 14th leaf.

6.5 Magnesium

The magnesium content, in general, is highest in the 10th leaf followed by the 14th leaf. Magnesium being a relatively mobile element in the plant and also a component of the chlorophyll it is likely to be high in young and physiologically mature leaf. The first few leaves of the coconut palm retain only low content of chlorophyll and that may be the reason for the low content of magnesium in the leaf lamina of 2nd leaf.

As in the case of calcium, the magnesium content was significantly and positively correlated with yield only in the 14th leaf at Balaramapuram. At no other site, and in the case of no other leaf position, significant correlation was noticed for the magnesium content with yield. Hence, it can be concluded that the leaf positions 2, 10 and 14 cannot reflect the magnesium status of the palm in relation to yield.

6.6 Sodium

A pooled analysis of all the palms at the three sites revealed that the content of sodium was highest in the 10th leaf followed by the 14th leaf. As suggested by Prevot and Ollagnier (1961) the high content of sodium in the 10th and 14th leaves may be due to a decreased content of potassium in these leaves. Ziller and Prevot (1963) also reported such antagonism between potassium and sodium. The relationship is further emphasised by the negative correlation obtained between the leaf number and the sodium per cent of the 2nd and 10th leaves. Moreover, sodium per cent was having a negative correlation with potassium content in all the leaf positions.

An analysis of the palms at all the three sites to study the relationship between the sodium content of the 2nd, 10th and 14th leaves with yield revealed that the simple correlation coefficient was significant only in the case of the 14th leaf. Hence, among the three leaves studied, the leaf number 14 will best reflect the sodium status of the palm in relation to yield.

7. Development of yield prediction models

The major objective of foliar diagnosis is to estimate the nutrient status of the palm in relation to its capacity to produce nuts. An idea of the content of the nutrients in the index leaf will help to predict the yielding potentiality of the palm and the possible yield that could be achieved at a given time. For this, standardisation of the index leaf is necessary. A trial in this line was conducted by constructing different yield prediction models for the 2nd, 10th and 14th leaves.

The regression models constructed for the 2nd, 10th and 14th leaves using the per cent of nitrogen, phosphorus, potassium, calcium, magnesium and sodium and the leaf number (L) are given below.

Regression model 1 (Leaf number 2)

$$Y = -86.798 + 32.523\,N + 17.913\,P + 4.381\,K + 5.540\,Ca - 2.226\,Mg + 94.734\,Na + 2.171\,L$$

$$R^2 = 0.580^{**}$$

Regression model 2 (Leaf number 10)

$$Y = -36.244 + 17.293\,N - 33.827\,P - 9.672\,K - 7.986\,Ca + 4.024\,Mg + 0.338\,Na + 3.141\,L$$

$$R^2 = 0.612^{**}$$

Regression model 3 (Leaf number 14)

$$Y = -69.937 + 14.456\,N - 15.716\,P - 1.004\,K + 36.895\,Ca + 31.753\,Mg + 35.242\,Na + 2.522\,L$$

$$R^2 = 0.459^{**}$$

Among the three regression models given above, the regression model for the leaf number 10 has the highest R^2 value. By this equation, yield can be predicted with 61.2 per cent accuracy. The next best model will be the one constructed for the leaf position 2 where the yield predicted is correlated with the experimental yield with an R^2 value of 0.58. The leaf number 14 comes only last, where the prediction of yield will have an accuracy of only 45.9 per cent.

The contents of calcium, magnesium and sodium were not significantly correlated with yield in any leaf positions at all sites. Hence it was thought to eliminate these three variables and to construct regression models using nitrogen, phosphorus, potassium and leaf number. The regression equations thus constructed are given below.

Regression model 4 (Leaf number 2)

$$Y = -68.036 + 32.191\,N + 13.292\,P + 1.097\,K + 2.306\,L$$

$$R^2 = 0.560^{**}$$

Regression model 5 (Leaf number 10)

$$Y = -55.984 + 25.925\,N - 28.055\,P - 3.513\,K + 2.749\,L$$

$$R^2 = 0.629^{**}$$

Regression model 6 (Leaf number 14)

$$Y = -35.837 + 14.406\ N + 2.726\ P - 11.670\ K + 2.992\ L$$

$$R^2 = 0.414^{**}$$

The above three equations also reveal the superiority of the regression model constructed for the leaf number 10 over the other two leaves. The yield can be predicted with an accuracy of 62.9 per cent based on the regression model of leaf number 10 whereas the accuracy of prediction for the 2nd and 14th leaf models are only 56 per cent and 41.4 per cent respectively. It must be pointed out that the leaf number 10 was superior to the other leaves in predicting yield when all the variables were considered together (Regression model 2). Moreover, this leaf has the added advantage of being the best reflect of the nitrogen and potassium status of the palm in relation to yield, at the same time maintaining significant correlation with respect to phosphorus content and yield. Considering all these, it is concluded that leaf number 10 will be the best leaf to be selected as the index leaf for foliar diagnosis in coconut under Kerala conditions. The leaf number 14 as suggested by Ziller and Prevot (1963) can also be used though with less accuracy as the nutrient contents of this leaf had a positive correlation with yield. However, the leaf number 2 will be better than the leaf number 14 in this respect, as pointed out by Gopi and Jose (1983). The apparent anomaly in this respect between the works conducted here and at IRHO may be due to the difference in the number of leaves retained by the palms at these two different regions. As pointed out earlier, the 14th leaf under the conditions of this study is not the leaf "that has completed its physiological maturity but not entered the phase of senescence", but is the one which is in its early stage of senescence. In many cases there are even palms with number of leaves as low as 8. As pointed out by Gopi and Jose (1983), the leaf number 2 will be better than the 14th leaf. However, the work of Gopi and Jose (1983) was confined to the palms located at Balaramapuram where the average number of leaves retained by the palms is less than the number of leaves retained by palms in other parts of the State such as Mannuthy and Pilicode. Hence the recommendation of 2nd leaf as the index leaf cannot be generalised throughout the State as the experimental palms at Balaramapuram do not ideally represent the palms of the cultivator's field. On the other hand, the present study was conducted at three locations that are widely apart, and the results obtained can be taken as a general observation for the entire State. As stated earlier based on the present study the leaf number 10 is suggested as the index leaf for the foliar diagnosis in coconut under Kerala conditions.

Considering the leaf number 10 as the index leaf, a multiple regression model was worked out from the values of nitrogen, phosphorus and potassium contents of the leaf lamina and the number of leaves retained. In addition to nitrogen-phosphorus, phosphorus-potassium and nitrogen-potassium interactions, the interactions between leaf number and nitrogen, and leaf number and potassium were also included. This was done because the total content of nitrogen and potassium in the leaf will be a function of the total drymatter which is mainly represented by the number of leaves, so that the product of nitrogen per cent and leaf number, and potassium per cent and leaf number will given a value something similar to the uptake of these nutrients. However the phosphorus - leaf number interaction was eliminated since the product of phosphorus per cent and leaf number was not significantly correlated with yield. The regression model thus worked out is given below.

Regression model 7 (leaf number 10)

$$Y = -92.924 + 44.682\,N - 0.0004\,P + 49.397\,K + 6.292\,L - 6.970\,N \times P + 30.729\,N \times K - 2.218\,L \times N + 17.449\,P \times K - 0.205\,L \times K$$

$$R^2 = 0.853^{**}$$

Utilizing this model, the yield can be predicted with an accuracy of 85.3 per cent. The high R^2 value thus obtained justify the selection of the 10th leaf as the index leaf. The quadratic form of the above regression model was also constructed.

Regression model 8 (leaf number 10)

$$
\begin{aligned}
Y = \; & - 34.619 + 29.594\ N - 33.827\ P + 51.279\ K \\
& + 6.547\ L + 23.646\ N^2 - 0.932\ N \times P + 10.044\ N \times K \\
& - 2.493\ L \times N + 20.294\ P \times K - 54.768\ K^2 + 0.379\ L \times K
\end{aligned}
$$

$$R^2 = 0.862^{**}$$

The variable P^2 was eliminated from the model as it had only low correlation with yield. The predicted yield and the experimental yield were highly correlated here also ($R^2 = 0.862^{**}$). This means that, the present model helps to predict the yield with an accuracy of 86.2 per cent. But it should be remembered that, the regression model 7 will help to predict yield with an accuracy of 85.3 per cent. In this respect the quadratic model has got only a marginal advantage over its simple linear form. Hence the regression model 7 is as good as the regression model 8 in predicting yield and therefore can be easily employed due to its simplicity.

Summary

SUMMARY

Coconut palms of a NPK fertilizer trial maintained at the Coconut Research Station, Balaramapuram were selected for the present study along with bulk palms from two other sites, namely the Agricultural Research Station, Mannuthy, and the Regional Agricultural Research Station, Pilicode. Samples of leaf lamina were drawn from three leaf positions, namely the leaf No.2, 10 and 14 separately from all the selected palms. Chemical analysis of the leaf and soil samples were done in order to find out the content of nitrogen, phosphorus, potassium, calcium, magnesium and sodium. The nutrient contents of the three leaf positions were correlated with yield in order to standardise the tissue, the nutrient contents of which will best reflect the yield of the palms. Regression models were also worked out in order to predict the yield based on tissue analysis. Attempts were also made to establish critical levels of the nutrients to be maintained in the index leaf for optimum yield. The important findings are summarised below:

1) Application of nitrogen and potassium resulted in only a marginal increase in the contents of these nutrients in the available form in the soil. On the

other hand a major portion of the applied phosphorus remained in the soil in the available form.

2) Application of nitrogen decreased the number of leaves retained by the palms whereas the application of phosphorus had no effect on the number of leaves retained.

3) Application of potassium drastically increased the number of leaves retained by the palms. Also, the potassium content of the leaf samples was significantly correlated with the number of leaves retained ($r = 0.710^{**}$ for 10th leaf).

4) Application of nitrogen in absence of potassium decreased the number of leaves retained whereas application of potassium increased the number of leaves retained at all levels of nitrogen application.

5) Application of nitrogen and potassium steadily increased the yield whereas application of phosphorus increased the yield only upto a rate of application of 225 g P_2O_5/palm/year.

6) Application of nitrogen increased the yield only at k_2 level of potassium application whereas application of potassium increased the yield at all levels of nitrogen application.

7) Application of nitrogen increased the yield at all levels of phosphorus. On the other hand, application of phosphorus steadily increased yield only at n_2 level of nitrogen application.

8) Application of phosphorus increased the yield only at k_2 level of potassium application.

9) Application of nitrogen, phosphorus and potassium increased the content of these nutrients in the 2nd, 10th and 14th leaves.

10) The number of leaves retained was highly correlated with yield, the regression of yield on number of leaves being $Y = -25.33 + 2.92\ X$ ($r = 0.735^{**}$) where Y is the yield in nuts/palm/year and X is the number of leaves.

11) The minimum number of leaves to be retained for the very expression of yield was 8.74. The optimum number of leaves for maximum yield was 46.62.

12) The contents of nitrogen, phosphorus and potassium were highest in the 2nd leaf, followed by the 10th and 14th leaves. On the other hand the content of calcium was highest in the 14th leaf whereas the contents of magnesium and sodium were highest in the 10th leaf.

13) Yield of the palm was significantly correlated with the nitrogen per cent of the leaf lamina for leaf positions 2, 10 and 14. The highest coefficient of partial correlation of 0.499** was registered for the leaf position 10, followed by 0.441** for the leaf position 2. The regression of yield on the nitrogen per cent of the 10th leaf was $Y = -33.98 + 44.27 X$ ($r = 0.518$**) where Y is the yield (nuts/palm/year) and X is the nitrogen percentage.

14) The optimum per cent of nitrogen in the leaf lamina of the 10th leaf for obtaining maximum yield was found to be 2.90.

15) The partial correlation coefficient between the phosphorus content of leaf and yield was not significant in the case of 2nd, 10th and 14th leaves.

16) The coefficients of partial correlation between yield and potassium per cent of leaf lamina of leaf positions 2 and 10 were significant, the highest value of 0.432** being recorded by the 10th leaf followed by 0.417** by the 2nd leaf.

17) The simple linear regression equation of yield on potassium per cent of the 10th leaf was worked

out to be $Y = 7.79 + 27.13 X$ ($r = 0.448^{**}$) where Y is the yield in nuts/palm/year and X is the potassium percentage.

18) The optimum content of potassium in the 10th leaf for maximum yield was 1.80 per cent.

19) Potassium showed an antagonistic relationship with calcium, magnesium and sodium as revealed by negative correlation between potassium content and the contents of these cations in the 2nd and 10th leaves.

20) The contents of calcium, magnesium and sodium in the leaf lamina showed significant correlation with yield only in the case of the leaf position 14.

21) The best yield prediction model constructed with the number of leaves retained (L) and the per cent of nitrogen, phosphorus, potassium, calcium, magnesium and sodium was for the leaf position 10 ($R^2 = 0.612^{**}$).

22) When the number of leaves retained and the nitrogen, phosphorus and potassium per cent of the leaf were considered, there also, the best yield prediction model was obtained for the leaf position 10, where the yield can be predicted with an accuracy of 62.9 per cent.

23) Utilising the 10th leaf, the yield can be predicted with an accuracy of 85.3 per cent by using the regression model $Y = -92.924 + 44.682\ N - 0.0004\ P + 49.397\ K + 6.292\ L - 6.970\ NxP + 30.729\ NxK - 2.218\ LxN + 17.449\ PxK - 0.205\ LxK$.

24) The yield can also be predicted with an accuracy of 86.2 per cent based on the regression model constructed for the leaf number 10.

$$Y = -34.619 + 29.594\ N - 33.827\ P + 51.279\ K + 6.547\ L + 23.646\ N^2 - 0.932\ NxP + 10.044\ NxK - 2.493\ LxN + 20.294\ PxK - 54.768\ K^2 + 0.379\ LxK$$

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* Originals not seen

Appendices

Appendix I. General characteristics of soil (Balaramapuram)

Sl. No.	Treatment n p k	pH in water (1:2.5)	Total N%	Available ppm. P	Available ppm. K	Exchangeable, me/100 g. Ca	Exchangeable, me/100 g. Mg	Exchangeable, me/100 g. Na
1	0 0 0	6.1	0.056	2.53	27.37	1.19	0.63	0.06
2	0 0 1	6.8	0.112	3.18	70.38	0.77	0.77	0.08
3	0 0 2	6.2	0.084	6.85	58.65	0.84	0.56	0.09
4	0 1 0	7.0	0.084	12.85	19.55	0.98	0.42	0.08
5	0 1 1	7.1	0.084	11.63	46.92	1.61	0.21	0.07
6	0 1 2	5.9	0.140	11.42	54.74	1.12	0.49	0.07
7	0 2 0	5.8	0.056	23.19	19,55	1.26	0.56	0.08
8	0 2 1	6.0	0.140	19.40	46.92	1.47	0.42	0.06
9	0 2 2	6.4	0.056	35.20	54.74	1.95	0.56	0.08
10	1 0 0	6.1	0.168	2.35	19.55	0.91	0.49	0.06
11	1 0 1	6.5	0.112	1.80	46.92	0.84	0.14	0.05
12	1 0 2	7.0	0.084	1.90	58.62	0.70	0.35	0.11
13	1 1 0	5.6	0.168	14.01	15.64	1.75	0.49	0.06
14	1 1 1	6.1	0.084	9.83	43.01	0.84	0.49	0.07
15	1 1 2	6.2	0.112	12.09	27.37	0.98	0.63	0.06
16	1 2 0	6.7	0.112	12.33	50.83	1.05	0.77	0.13
17	1 2 1	7.0	0.112	27.08	58.65	1.26	0.49	0.07
18	1 2 2	6.0	0.112	36.38	58.65	1.33	0.28	0.08
19	2 0 0	5.9	0.140	2.53	15.64	0.49	0.56	0.05
20	2 0 1	6.0	0.112	3.00	43.01	0.49	0.42	0.06
21	2 0 2	6.7	0.140	2.28	62.56	0.70	0.56	0.06
22	2 1 0	6.4	0.140	11.91	19.55	0.91	0.70	0.05
23	2 1 1	5.8	0.140	18.09	50.83	0.91	0.49	0.08
24	2 1 2	5.5	0.140	5.75	39.10	1.05	0.14	0.07
25	2 2 0	5.4	0.140	35.28	19.55	1.54	0.91	0.06
26	2 2 1	6.4	0.168	39.36	46.92	1.33	0.91	0.10
27	2 2 2	6.6	0.168	20.72	54.74	1.26	0.14	0.09

Appendix II. General characteristics of soil (Mannuthy)

Sl. No.	pH in water (1:2.5)	Total n%	Available ppm		Exchangeable me/100 g		
			P	K	Ca	Mg	Na
1	4.7	0.112	30.67	74.66	0.77	0.42	0.08
2	4.9	0.168	39.10	160.56	0.84	0.21	0.08
3	5.2	0.140	30.67	75.33	0.70	0.49	0.07
4	5.3	0.211	41.76	74.29	0.84	0.42	0.06
5	5.3	0.211	36.66	151.33	0.49	0.49	0.06
6	6.1	0.168	36.66	160.65	0.49	0.14	0.07
7	6.3	0.211	30.67	151.15	0.70	0.35	0.07
8	4.8	0.168	31.23	145.00	0.91	0.49	0.05
9	6.1	0.168	32.66	145.00	0.91	0.28	0.06
10	6.1	0.112	31.23	151.33	0.25	0.50	0.08
11	6.3	0.112	30.67	160.56	0.49	0.05	0.06
12	6.3	0.140	41.76	123.12	0.70	0.42	0.09
13	6.1	0.140	41.76	112.01	0.33	0.49	0.03
14	6.3	0.140	41.76	100.79	0.34	0.14	0.05
15	5.3	0.211	36.66	108.66	0.70	0.14	0.05
16	5.7	0.211	36.66	151.33	0.70	0.13	0.07
17	6.1	0.140	39.10	80.81	0.25	0.22	0.04
18	5.3	0.211	36.66	74.29	0.28	0.35	0.08
19	6.1	0.168	30.67	168.13	0.26	0.42	0.09
20	6.6	0.211	36.66	108.66	0.38	0.49	0.03
21	6.9	0.211	31.23	120.65	0.53	0.49	0.03
22	5.5	0.211	39.10	111.15	0.54	0.35	0.07
23	5.2	0.211	39.10	120.65	0.56	0.28	0.08
24	5.3	0.168	39.10	120.65	0.50	0.05	0.06
25	5.2	0.168	41.76	168.13	0.54	0.49	0.04
26	5.2	0.112	39.10	145.34	0.75	0.14	0.05
27	5.2	0.211	41.76	145.34	0.40	0.22	0.05
28	5.2	0.211	41.76	100.79	0.34	0.42	0.08
29	5.1	0.140	41.76	140.65	0.70	0.42	0.08
30	5.3	0.112	30.67	135.75	0.84	0.14	0.07

(Contd.)

Appendix II (Contd.)

Sl. No.	pH in water (1:2.5)	Total N%	Available ppm.		Exchangeable, me/100 g.		
			P	K	Ca	Mg	Na
31	4.7	0.112	31.23	108.66	0.49	0.05	0.06
32	4.7	0.211	36.66	74.46	0.93	0.35	0.07
33	4.8	0.211	32.66	74.66	0.91	0.49	0.05
34	5.9	0.140	31.23	75.33	0.25	0.35	0.08
35	4.8	0.140	39.10	151.33	0.70	0.13	0.09
36	4.9	0.168	39.10	160.65	0.34	0.14	0.05
37	5.6	0.140	39.10	151.15	0.70	0.42	0.07
38	5.7	0.211	41.76	120.65	0.28	0.50	0.08
39	6.3	0.112	41.76	74.29	0.38	0.49	0.03
40	5.5	0.211	39.10	108.66	0.54	0.14	0.07
41	5.5	0.211	36.66	111.15	0.56	0.42	0.06
42	5.5	0.168	30.67	120.65	0.54	0.21	0.05
43	5.5	0.168	41.76	111.15	0.40	0.42	0.07
44	5.6	0.168	41.76	120.65	0.77	0.42	0.08
45	5.7	0.112	36.66	120.65	0.70	0.35	0.06
46	5.4	0.140	33.27	168.13	0.49	0.50	0.07
47	5.2	0.168	31.23	145.34	0.70	0.49	0.08
48	5.1	0.168	35.28	160.56	0.91	0.13	0.03
49	5.0	0.211	35.28	100.79	0.49	0.42	0.07
50	5.0	0.211	39.36	112.01	0.33	0.35	0.09
51	5.1	0.211	35.28	151.33	0.70	0.49	0.07
52	5.5	0.140	39.36	160.65	0.25	0.42	0.03
53	6.0	0.168	39.10	151.15	0.26	0.22	0.04
54	5.8	0.168	36.38	74.46	0.54	0.05	0.07
55	5.9	0.168	35.28	160.65	0.56	0.49	0.04
56	5.2	0.140	36.38	108.66	0.54	0.35	0.04
57	5.0	0.211	35.20	75.33	0.40	0.14	0.07
58	5.2	0.211	41.76	108.66	0.75	0.42	0.07
59	5.1	0.112	41.76	108.66	0.56	0.28	0.07
60	5.1	0.168	35.20	140.45	0.38	0.14	0.06

Appendix III. General characteristics of soil (Pilicode)

Sl. No.	pH in water (1:2.5)	Total N%	Available ppm.		Exchangeable me/100 g		
			P	K	Ca	Mg	Na
1	4.3	0.125	36.12	520.50	2.32	0.03	0.15
2	6.6	0.168	56.55	331.50	2.25	0.04	0.29
3	6.0	0.240	44.32	562.50	1.66	0.06	0.20
4	5.8	0.212	36.12	570.12	2.49	0.03	0.29
5	6.3	0.180	50.01	565.50	2.49	0.03	0.20
6	5.4	0.266	56.55	542.50	2.22	0.04	0.22
7	5.3	0.168	32.88	565.50	2.66	0.06	0.33
8	6.6	0.125	34.59	520.50	2.32	0.09	0.15
9	5.8	0.180	36.12	531.50	2.49	0.03	0.24
10	6.0	0.212	44.32	562.50	2.22	0.07	0.20
11	6.6	0.168	34.59	470.50	2.49	0.03	0.29
12	6.6	0.180	59.74	531.50	2.25	0.09	0.22
13	5.4	0.240	56.55	456.00	2.32	0.06	0.37
14	4.3	0.125	36.12	565.50	2.49	0.09	0.33
15	4.3	0.125	56.55	570.12	2.66	0.07	0.15
16	6.3	0.180	32.88	565.50	2.49	0.05	0.24
17	5.8	0.125	34.59	470.50	2.01	0.03	0.20
18	6.4	0.212	36.12	331.50	2.32	0.06	0.22
19	6.6	0.180	44.32	456.00	2.49	0.05	0.15
20	6.6	0.180	32.88	518.70	2.25	0.06	0.15
21	6.0	0.168	59.74	456.00	2.49	0.03	0.37
22	4.3	0.266	32.88	565.50	2.01	0.09	0.29
23	5.4	0.180	59.74	491.20	2.32	0.09	0.37
24	6.6	0.180	32.88	331.50	1.66	0.08	0.22
25	5.8	0.125	56.55	542.50	2.49	0.06	0.15
26	5.3	0.212	36.12	570.12	2.32	0.09	0.27
27	5.8	0.180	44.32	491.20	2.25	0.08	0.29
28	6.6	0.168	34.59	456.00	2.49	0.06	0.15
29	6.6	0.180	32.88	570.12	2.32	0.03	0.15
30	4.3	0.125	59.74	531.50	2.66	0.03	0.27

(Contd.)

Appendix III (Contd.)

Sl. No.	pH in water (1:2.5)	Total N%	Available, ppm.		Exchangeable, me/100 g		
			P	K	Ca	Mg	Na
31	5.3	0.180	50.01	518.70	2.01	0.08	0.20
32	5.8	0.168	59.74	331.50	2.49	0.03	0.29
33	6.6	0.180	50.01	560.10	2.32	0.03	0.29
34	6.0	0.125	44.32	442.60	1.98	0.03	0.15
35	6.6	0.125	32.88	565.50	2.25	0.06	0.11
36	5.8	0.212	34.59	565.50	2.01	0.09	0.15
37	6.6	0.125	42.66	540.50	1.66	0.03	0.20
38	6.6	0.212	50.01	456.00	2.32	0.06	0.12
39	4.3	0.180	32.88	518.70	2.49	0.03	0.15
40	5.3	0.168	34.59	542.50	1.95	0.06	0.29
41	4.3	0.212	59.74	565.50	2.25	0.09	0.11
42	6.3	0.266	50.01	565.50	2.49	0.09	0.22
43	4.7	0.125	34.59	560.10	1.32	0.09	0.15
44	6.0	0.212	44.32	531.50	2.66	0.03	0.11
45	5.8	0.180	34.59	522.40	2.49	0.08	0.22
46	6.6	0.180	56.55	518.70	2.25	0.06	0.29
47	6.4	0.168	44.32	540.50	2.01	0.06	0.11
48	6.6	0.180	44.32	542.60	2.32	0.05	0.15
49	6.6	0.180	34.59	531.50	2.49	0.09	0.24
50	6.4	0.212	56.55	542.50	1.98	0.09	0.22
51	5.8	0.212	32.88	522.20	2.66	0.03	0.15
52	6.6	0.180	32.88	518.70	2.01	0.08	0.15
53	4.7	0.180	59.74	560.10	2.32	0.08	0.49
54	6.4	0.168	59.74	565.50	1.98	0.06	0.20
55	4.7	0.125	50.01	565.50	2.49	0.03	0.15
56	5.3	0.212	42.66	531.50	2.25	0.03	0.20
57	6.6	0.266	50.01	542.60	2.32	0.08	0.15
58	6.4	0.180	44.32	565.50	2.66	0.09	0.22
59	4.7	0.180	34.59	542.50	2.22	0.09	0.15
60	4.3	0.125	59.74	531.50	2.49	0.03	0.49

Appendix IV. Effect of NPK treatments on the number of leaves retained by the experimental palms at Balaramapuram (ANOVA)

	SS	df	MS	F
Total	1557.443	53	-	-
Block	33.035	5	6.607	3.488*
N	66.035	2	32.518	17.167**
P	3.914	2	1.957	1.033
N x P	11.103	4	2.776	1.466
K	1250.827	2	625.413	330.182**
N x K	53.835	4	13.459	7.106**
P x K	65.173	4	16.293	8.602**
NPK	1.567	2	0.783	0.414
NP^2K	21.630	2	10.815	5.710*
NPK^2	8.343	2	4.172	2.202
NP^2K^2	1.310	2	0.655	0.346
Error	41.671	22	1.894	-

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix V. Effect of NPK treatments on the yield of experimental palms at Balaramapuram (ANOVA)

	SS	df	MS	F
Total	32908.085	53	-	-
Block	796.282	5	153.856	1.870
N	6979.331	2	3489.665	42.402**
P	1058.963	2	529.481	6.434**
N x P	1187.056	4	296.764	3.606*
K	15064.082	2	7532.041	91.520**
N x K	3946.496	4	986.624	11.988**
P x K	1093.447	4	273.362	3,322*
NP^2K	326.059	2	163.030	1.981
NPK^2	467.846	2	233.923	2.842
NP^2K^2	77.488	2	38.744	0.471
Error	1810.582	22	82.299	-

* Significant at 5 per cent level

** Significant at 1 per cent level

YIELD PREDICTION IN COCONUT BASED ON FOLIAR N, P AND K VALUES

By

N. KRISHNA KUMAR

ABSTRACT OF THESIS

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ABSTRACT

A study was undertaken to standardise the foliar diagnostic technique in coconut palm and to work out regression models for predicting the yield based on foliar nutrient contents. Palms were selected from three different zones of Kerala State, namely the Coconut Research Station, Balaramapuram, the Agricultural Research Station, Mannuthy and the Regional Agricultural Research Station, Pilicode. Leaf samples drawn from the leaf positions 2, 10 and 14 separately from each palm were analysed for nitrogen, phosphorus, potassium, calcium, magnesium and sodium. Attempts were made to standardise the leaf position, the nutrient status of which will best reflect the yield and to establish the critical levels of the nutrients in the index leaf. Regression models were also worked out to predict the yield based on tissue nutrient contents and the number of leaves retained by the palm.

Observations revealed that application of nitrogen, phosphorus and potassium resulted in an increase in the content of these nutrients in the 2nd, 10th and 14th leaves.

The number of leaves retained by the palm was mainly a function of potassium applied. The leaf number was highly correlated with the potassium per cent of the

leaf lamina of the three leaf positions the highest correlation of 0.710** was registered for the leaf position 10. The number of leaves retained was also significantly correlated with yield (r = 0.735**). The optimum number of leaves to be retained for maximum production was worked out to be 46.62.

Yield of the palms was significantly correlated with the nitrogen per cent of leaf lamina of 2nd, 10th and 14th leaves, the highest coefficient of partial correlation being registered by the 10th leaf (r = 0.499**). The partial correlation coefficients between yield and the phosphorus per cent of leaf lamina of the three leaf positions were not significant. The coefficient of partial correlation between yield and potassium per cent of leaf lamina of leaf position 2 and 10 were significant, the highest value of 0.432** being recorded by the 10th leaf. On the other hand, the contents of calcium, magnesium and sodium in the leaf lamina showed significant correlation with yield only in the case of the leaf position 14. The optimum contents of nitrogen and potassium in the 10th leaf for maximum yield was 2.9 and 1.8 per cent respectively.

Yield prediction models worked out using the percentage of nitrogen, phosphorus, potassium, calcium, magnesium and sodium, and the leaf number indicated that the model worked out for the 10th leaf had the maximum accuracy of prediction. Models worked out eliminating calcium, magnesium and sodium also confirmed the supremacy of the 10th leaf for the prediction of yield. Thus the leaf lamina of the leaf position 10 can be recommended as the best tissue for foliar diagnosis in coconut. Yield can be predicted with an accuracy of 85.3 per cent by the regression model,

$$Y = -92.924 + 44.682\ N - 0.0004\ P + 49.397\ K + 6.292\ L - 6.970\ NxP + 30.729\ NxK - 2.218\ LxN + 17.449\ PxK - 0.205\ LxK$$

utilising nitrogen (N), phosphorus (P) and potassium (K) contents of the leaf lamina of 10th leaf and the number of leaves retained. Yield can also be predicted with an accuracy of 86.2 per cent based on the following regression model worked out for the leaf position 10.

$$Y = -34.619 + 29.594\ N - 33.827\ P + 51.279\ K + 6.547\ L + 23.646\ N^2 - 0.932\ NxP + 10.044\ NxK - 2.493\ LxN + 20.294\ PxK - 54.768\ K^2 + 0.379\ LxK.$$