RELATIONSHIP BETWEEN LEAF NUTRIENTS AND YIELD IN COCONUT

By
MOHANACHANDRAN. S.

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To

Dr. Om Prakash Pachauri.

DECLARATION

I hereby declare that this thesis entitled **"Relationship between leaf nutrients and yield in coconut"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma associateship, fellowship or other similar title to any other University or Society

(MOHANACHANDRAN. S)

Vellayani,
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<u>CERTIFICATE</u>

Certified that this thesis entitled **"Relationship between leaf nutrients and yield in coconut"** is a record of research work done independently by Sri MOHANACHANDRAN S under my guidance and supervision and that it has not previously formed the basis of the award of any degree fellowship or associateship to him.

I further certify that such help or source of information as has been availed of in this thesis is duly acknowledged

(Prof E P KOSHY)
Chairman,
Advisory committee,
Professor & Head (Retd)
Department of Agronomy
College of Agriculture, Vellayani

Vellayam,

APPROVED BY

Chairman

PROF. E. P. KOSHY

Members

P. CHANDRASEKHARAN

DR. R. S. AIYER

DR. P. SARASWATHY

DR. MOHD. YUSUF

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(MOHANACHANDRAN. S.)

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INTRODUCTION

Coconut is the bread winner for the common man in Kerala. Either the palm products or their industrial products and byproducts find utilization in every walk of life. Popularly adored as 'Kalpavriksha' the palm provides food, fuel, fibre, shelter, cosmetics, home decoratives etc. to name a few of the innumerous items. Thus coconut plays a vital role in furthering the economy of Kerala and other the southern States.

With an annual production of 756 crores of nuts, our country is only just behind to Indonesia and Philippines. The share of India in the world's coconut production is 17.3 per cent while the four southern States viz., Kerala, Tamil Nadu, Karnataka and Andhra Pradesh contribute ninety per cent of the total production of the country. Kerala is the prime producer with 46 per cent share as per the 1987-88 estimate of Markose (1989).

Owing to the explosion of population and consequent demand for land, the scope for extending coconut cultivation is limited in India. Therefore, the thrust should be on enhanced productivity leading to higher gross production levels. Nutritional and management aspects often become limiting in realising the full production potential of coconut palms.

Inspite of the higher rank in annual production of nuts compared to other countries, our productivity of palms as well as Copra yield per nut do not provide a happy picture. The number of nuts per tonne of copra were 6800 where as the same for Philippines and Indonesia were only 4500 (Thampan, 1988). Same is the case with productivity. The low consumption of fertilizers and utilization of added fertilizers due to several soil related constraints, lack of optimum management practices and quality seed materials and the serious malady of root (wilt) are some of the factors leading to the reported low productivity in India. While our economy does not allow sumptuous fertilization, there is scope for increasing the fertilizer use efficiency, breeding for higher yield potentials as well as management of diseases and pests and also for evolving judicious nutrient management practices.

Analysis of soils from coconut gardens provides indications of major deficiencies but very often it is misleading. Many nutrients may often be present in the soil and still not available to the palms. So also the soil may appear from the results of chemical analysis to be deficient in a particular essential element, but still the palm may thrive well. Soil analysis thus seems to be of limited value in forecasting nutrient deficiencies in coconut. On the other hand leaf analysis has been recognised as a more reliable method for detecting nutrient deficiencies. This method assumes special significance in perennial crops.

Foliar nutrient level has now been considered as one of the very effective tools to determine the fertilizer requirement of coconut palm. It is possible to measure the degree of nutrient deficiency by leaf analysis and to ascertain the level at which fertilizers should be added to the soil or supplied directly to the plant by foliar sprays.

In Kerala farmers practice a unique system of coconut culture. In most of the cases coconut monoculture is now substituted by multi cropping involving short duration annuals and perennial spices raised as intercrops in coconut gardens. Fertilizer recommendations under such situations are all the more difficult, especially if it is solely based on the soil test values. The canopy competition for light and the variable root absorbing power of crops result in differential utilization of added fertilizer. The translocation of nutrients and their fixation and release in soil largely depend on the extent of depletion by crop uptake. Where a multiplicity of nutrient demands work in unison the delineation of the uptake pattern of individual crop becomes laborious. The only option for assessing the nutritional status of coconut palm under such situations is foliar diagnosis.

Eversince the pioneering work of IRHO in this regard there has been a good lot of investigations and debates on the index tissues and critical levels of nutrients with respect to coconut nutrition. While this approach is not fool proof in the sense that the genetic make up of the plant, the environmental factors and prevailing soil conditions can create variations in the standardised concentrations or reflects for specific situations. Therefore, standardisation of index tissues and critical levels becomes essential for every agro-ecological situations and genetic pool of coconut. However, among the options available, foliar analysis is the most promising and is widely adapted.

The method of leaf analysis for assessing the nutrient needs of the crop rests on the assumption that what ever element is lower than a certain minimum concentration could be raised to optimum level by adding the pertinent fertilizer to the soil. And this works very well for most cases of deficiency.

There has been wide variations in the yield level of palms under identical manuring and environmental conditions grown under same soil type. This variability is an unending puzzle evading solution for the last several years. The present attempt aims at establishing definite correlation between the leaf nutrient levels of coconut palms and the ultimate yield of nuts per tree. Investigations in this line must provide information leading to yield predictions based on foliar diagnosis. This may also help in recommending nutrient supplements for targeted yield level. Very often it is not the precise level of a particular nutrient in the leaf which determines the yield variation. But the nutrient ratios and their interactions which establish a favourable sourse-sink relationship to better yields. Therefore, a wholistic approach in nutritional investigations is essential in the case of coconut. A variation in the levels of a particular nutrient element in the palm tissues can have consequential influence on the contents of certain other elements. This implication has special significance in the case of coconut palm which is unique in the nutritional requirements especially with regard to sodium and chlorine. The special nutrient metabolic features of coconut palm leading to special nutrient requirement have not been probed enough. Therefore, the present investigation is intended to throw light to the extent of influence exhibited by nutrient elements viz., N, P, K, Ca, Mg, S, Na and Cl on the observed yield variations in coconut with the following major objectives:

1. To find out the relative leaf nutrient concentrations in different yield groups of palms under identical fertility conditions

2. Direct and indirect influence of leaf nutrient concentrations on yield.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

While considering the mineral nutrition of coconut, a perennial palm, the residual effects of added nutrients assume much significance than their immediate reflection in the yield of nuts. Coconut is a crop which is grown in Kerala and neighbouring states under a wide varieties of soil and environmental conditions. Standardising the optimum requirements of different nutrients is cumbersome due to the variation in fertilizer use efficiency of different cultivars and the complexity of the nutrient release pattern in different soils. Very often the leaf nutrient composition gives a more dependable assay of the nutritional status of the palm than the soil test values. Scientists, over the years have been exploring the possibility of predicting coconut yield based on leaf composition. However, field experiments for this purpose are difficult to be laid out owing to the perennial nature of the palm. Therefore, research in this line in Kerala are scarce. An attempt has been made to scan the journals and pool the literature available in this regard from Kerala and elsewhere. The review is presented under appropriate headings which suits the present investigation.

2.1 Nutrient removal by coconut palm

Investigation on coconut nutrition during the last century revealed that a growing coconut seedling tends to accumulate a large portion of absorbed nutrients in the developing trunk of the palm which will later be reflected in the ultimate yield. Moreover the sink for different elements in coconut palm varies with growth stage and depends on the existing environment. Eventhough the palm removes much bulk of nutrients from soil solution the same may not be reflected in immediate yield of nuts. Therefore, it is difficult to fix optimum doses for targeted yield in coconut palms. One of the early suggestions for a scientific approach in the mineral nutrition of coconut palm was that of Nathenael (1958). He put forward three approaches to study the coconut nutrition viz. fertilizer experiments, soil analysis and the analysis of coconut water and leaves. Nathenael (1959) suggested a model for assessing the nutrient requirement. According to him F = R-S+L. Where F is the fertilizer nutrient; R is the quantity of the nutrient required by the crop for unrestricted growth; S is the quantity of nutrient supplied by the soil; L is the portion of the fertilizer not utilized by the palm.

Several attempts have been made to quantify the nutrient removal and subsequent accumulation in different

Table 1 Estimated nutrient removal by coconut palms

Sl No	Nutrients N	P	K	Ca	Mg	S	Cl	Basis	Reference
1	20 0	2.5	35 0	NA	NA	NA	NA	[illegible]0 nuts a/ ear	Pillai (19[illegible])
2	64.0	12 7	79 0	NA	NA	NA	NA	Annual removal/year	Jacob and Coyle (19[illegible]
3	92.0	18.1	115.0	NA	NA	NA	NA	6[illegible]0 nuts/ha/year	Cope land (19[illegible]1)
4	74 0	13.2	137.0	12.5	19 4	NA	NA	Annual removal/ha/year	George and Teik (1932
5	91.0	17.6	109.0	NA	NA	NA	NA	Annual removal/ha/year	Eckstein et al. (193[illegible]
6	29.0	3.9	22.0	10.4	13.6	NA	NA	150 palms/ha 25 nuts/tree	Cooke (1950)
7	95.0	48.0	148.0	NA	NA	NA	NA	Annual removal 175 palms/ha	Shethy (1958)
8	56.0	11.9	70.0	33.9	12.5	NA	NA	173 palms ha 40 nuts/tree	Pillai and Davis (196
9	96.0	20.8	120.0	61.8	21.9	NA	NA	1[illegible] palms/ha 40 nuts/tree	Ramadasan and Lal (1[illegible]
10	95 0	9.0	117.0	65.0	NA	NA	NA	1 5 t copra/na	Ouvrier and Ochs (197[illegible]
11	174.0	20.0	249.0	70.0	39 0	NA	NA	6 7 t copra/ha	Ouvrier and Ochs (197[illegible]
12	16.46	2.71	18.76	1.65	1.86	1.48	8.66	Per tonne of copra	Ouvrier (1984)

NA = Not analysed

plant parts resulting a wide range of observations. Table 1 presents the reported figures for the nutrient removal at different yield levels. It may be noted that there is no definite trend in the nutrient removal with respect to yield. The possible reason is variation in agroclimatic condition management practices and genetic potential. Moreover most of the workers had taken into account the harvested nuts only for their evaluation. But in coconut, the leaves, stipules, spathes and spadices also contribute major portion of nutrient removal. A good amount of absorbed nutrients is also retained in the growing stem (Santiago, 1978).

Table 2 Removal of nutrients by different parts of the palm in percentage (Pillai and Devis, 1963)

Parts of the palm	N	P	K	Ca	Mg
Nut	43.0	40.0	63.0	15.3	24.0
Peduncle	4.2	7.0	12.1	3.3	11.4
Spathe	3.5	2.9	2.7	4.5	4.9
Leaf with stipule	41.2	45.1	12.4	73.8	56.5
Stem	8.1	5.0	9.8	3.1	2.2
Total	100.0	100.0	100.0	100.0	100.0

Scientists have attempted to fix sequential importance of major nutrients in coconut nutrition based on the removal of nutrients by the palm and their accumulation in different plant parts. Thus Pillai and Davis (1963) found the relationship as K > N > Ca > Mg > P whereas the findings of Ouvrier and Ochs (1978) was in the order K > Cl > N > Ca > Na > Mg > S > P. Yet another study by Santiago (1978) showed that the uptake of nutrients by a coconut palm is in the order of sequential importance of K > N > Cl > Ca > Mg > P. In an effort to partition the nutrient accumulation in different parts of coconut Pillai and Davis (1963) reported the data presented in Table 2. The quantity of nutrients removed by a single palm (West Coast Tall) yielding an average of 40 nuts and 13 leaves per year, through harvest of nuts or shedding of different plant parts as well as the quantity retained in growing stem works out to be 321 g nitrogen, 69 g phosphorus, 406 g potassium, 196 g calcium and 72 g magnesium as reported by Pillai and Davis (1963).

2.2 Mineral nutrition in coconut

2.2.1 Major nutrients

The above results highlight the paramount importance of potassium in coconut nutrition while the suggestion is for relatively low amounts of phosphorus. For assessing the mineral requirement in oil palm Ollagnier et al. (1970)

described two possible methods. The first method was to study the nutrient element uptake by the palm and the second was based on field experiments coupled with foliar analysis.

In New Guinea, Charles (1968) studied the uptake of nutrients from applied fertilizers by newly planted seedlings. He found out that there was a definite absorption of nutrients as evidenced by foliar analysis, even from the fertilizers applied at the time of planting, but the efficiency of uptake was greater in the subsequent months. Foale (1968) also stressed the importance of fertilization from the nursery stage itself as the nutrient contribution by the endosperm to the growing seedling decreased from fourth month onwards. The nutrient uptake by a newly planted seedling will start from the time of planting and the efficiency of uptake will increase in the subsequent months. This was evidenced by a study conducted in New Guinea by Charles (1968). The response to the absorbed nutrients by a seedling is also high. As studied by Nelliat and Muliyar (1971) application of NPK fertilizers increased all the seedling growth characters. He also observed that early flowering was also induced in fertilized palms. Markose and Nelliat (1975) found an yield increase of 11.7 nuts per palm in single application of fertlizers and 17.8 nuts in split application while the increase was only 3.7 nuts in control over a pre-treatment data. Potassium chloride fertilization can improve the nitrogen status of leaf which was correlated with yield increase. In podsols of North Sumatra, there was no response to phosphorus and little response was obtained to nitrogen application. On the otherhand application of potassium increased growth and yield components (Rosenquist, 1980).

The increase in yield are due to the enhanced nutrient absorption from the added fertilizers and their assimilation for dry matter production. According to Salgado (1946), nitrogen had a beneficial effect on female flower production while on copra content per nut it had an adverse effect as higher number of nuts are required to produce a ton of copra. Nitrogen being a constituent of plant, promotes the development of vegetative parts especially leaves and trunk, and these parts in turn account for the increase in nut production. Studies conducted in Jamaica also showed that nitrogen increased trunk height, female flower production, number of branches and number of nuts (Anon, 1969 and Smith, 1969). The application of nitrogen is reported to have caused copra yield increase by 8 per cent over no fertilizer (Salgado, 1952). It was also confirmed by Pomier and Taffin (1982) that nitrogen application increases production factors, ie., nut per tree and therefore copra per tree.

The studies conducted by Muliyar and Nelliat (1971) reported that the application of nut production by 16.9 per cent but the nut characters viz., weight of whole nut, weight of husked nut and copra weight per nut were adversely affected. Although the yield of nuts were increased by 16.9 per cent copra yield was increased by only 6 per cent. Ollagnier and Mardina Wahyuni (1984) also found that nitrogen has a depressive effect on copra per nut. In a factorial experiment (Anon, 1972) the main effects of N and P and the interaction between N and P and the interaction between N and K were significant on length of leaf and leaflets. However, high nitrogen treatment induced potassium deficiency.

Phosphorus is the element required in least quantity by coconut among the major and minor nutrient elements but the importance of that element cannot be ruled out. Salgado (1946) reported that phosphorus had no effect on copra content. It was also reported by Muliyar and Nelliat (1971) that phosphorus has no effect on nut characters viz., weight of whole nut, weight of husked nut, volume of husked nut and copra weight per nut. On the contrary the work carried out in SriLanka by Halliday and Sylvester (1954) reveals that in poor laterite soils of Veyanagoda and Ahangama with low phosphorus resources, coconut gave spectacular responses to phosphorus application. The increased yield of copra in this case was attributed to increased yield of nuts as well as to higher copra content per nut.

Phosphorus increased girth at collar and the number of fronds produced and the effect was reported to be indirect by enhancing the uptake of K (Mathew and Ramadasan, 1964). According to Mollegard (1971) there was a positive correlation between phosphorus level in the leaves and yield of palms and the coefficient of correlation was higher in the plots which have received potash.

Martin and Prioux (1972) have reported that the application of phosphorus increased nitrogen and magnesium levels in the leaves of oil palm and they have concluded that phosphorus should be the pivot of fertilizer formulae in that crop. In coconut, Ollagnier and Mardina Wahyuni (1984) suggested side effects of phosphorus application as the leaf nitrogen content shows no close link like that which has become classic for oil palm.

So many works have been carried out all over the world regarding the potassium requirement of coconut palm. Potassium is found to have a very important role in regulating water economy, promoting root development, imparting disease resistance and improving the quality of nuts. Consumption of potassium is considered to be high. A deficiency in potassium leads to chlorosis of leaf, scorching and development of poor crown with short fronds. The palms remain stunted with their trunks. Foliar yellowing and tip scorching of leaves are known to be a nutrient deficiency symptom and that can be corrected by potassium manuring. General flaccidity, drying up of tips and necrotic patches on leaflets of older leaves were also observed in young palm which were not supplied with potassium (Salgado, 1953; Menon et al., 1958 and Pillai, 1959). Palms suffering from moderate potassium deficiency respond quickly to applied K while severe and prolonged potassium deficient palms took two to three years to show response (Von Uoxkull, 1971).

Mathew and Ramadasan (1964) suggested that the application of potassium increased girth at collar. Von Uoxkull (1971) was of the opinion that the beneficial effect of K was due to increased leaf area, improved leaf angle and leaf colour. Better utilization of sun light was resulted by this and ultimately caused increased number of fronds,inflorescence, female flowers, nut set and weight of nuts. Application of potassium resulted in the improvement of all production factors such as fruit setting, number of bunches, number of female flower per bunch, number of nuts, average copra per nut and ultimately the total copra out turn per palm (Fremond, 1964). A positive correlation of leaf potassium content with yield was obtained by Wahid et al., 1974.

Quencez and Taffin (1981) suggested that a good mineral nutrition especially of potassium enables coconuts to get through the dry season easily, leading to a notable yield increase compared to unfertilized trees.

2.2.2 Secondary elements

All the three secondary elements viz., calcium, magnesium and sulphur are known to have prime importance in the metabolic activities of coconut palm eventhough the relative leaf concentration of these elements are reported to be low. Moreover, the influence of secondary elements like calcium and magnesium in improving soil reaction favours coconut nutrition indirectly in the acid soils where the crop is mostly grown. Wilshaw (1941) reported from Malaya that lime application alone gave an increase in yield of nuts as well as weight of copra per nut. The importance of liming in coconut nutrition was stressed also by Krishna Marar (1961). A leaf nutrient concentration of 0.5 to 0.3 percent calcium was found optimum for talls, semitalls as well as dwarfs by Kanapathy (1971).

However, Manciot et al. (1979) could observe little increase in yield by direct application of calcium carbonate for coconut palms. They also observed that in the case of tall coconut palms application of calcium carbonate for four consecutive years had not influenced the foliar level of the nutrients. On the contrary a positive influence of calcium on the general growth and calcium content of coconuts was reported by Dufour et al. (1984).

It is known that calcium is a component of the middle lamella of plant cells and may therefore, have effects on the mechanical strength of tissues (Corley, 1976). Therefore, calcium nutrition is bound to be a limiting factor in the growth and yield of coconut palms.

The importance of magnesium fertilization for coconut from the seedling stage onwards is well recognised as supported by Anonymous (1960) where typical deficiency symptoms have developed in seedlings grown under pot culture devoid of magnesium. Application of this essentia component of chlorophyll along with phosphorus and potassium fertilizers resulted in significant improvement in the vigour of seedlings at nursery stage (Bachy et al. 1962). The application of magnesium to young coconut palms grown in deep infertile black clay soils of Jamaica showed beneficial effects, particularly on frond growth while De Silva et al. (1973) suggested magnesium deficiency as one of the reason for delayed flowering coconut palm. Child (1974) recommended to supplement magnesium at the nursery stage.

All the seedling characters had showed positive correlation with the leaf magnesium content in the results reported by Santiago (1978).

While reporting the data on magnesium content of palms from various fertilizer trials conducted at different parts of the world Manciot et al. (1979 a&b) highlighted that in Ivory Coast magnesium had a highly significant and favourable influence on the yield of nuts as well as copra. Here the number of green leaves in the crown was also influenced by the level of magnesium fertilizers. Another interesting observation by these workers was that prolonged use of potassium fertilizers especially at higher rates may depress foliar magnesium content and induce magnesium deficiency condition in the palm.

However, there are contradicting reports on the effect of this elements in increasing coconut yield. Indirakutty and Pandalai (1968) reported that the magnesium content of coconut leaf did not vary significantly among different yield groups of palms. Further the suggestion of Barrant (1977) was that yield increases due to fertilizer application were not related to any increase or decrease of magnesium content of leaf. Moreover, Ollagnier and Mardina Wahyuni (1984) from a trial with a hybrid PB-121 in Indonesia found that magnesium never influenced the copra per nut.

Ollagnier and Ochs (1972) have reported that sulphur deficiency affects the survival of young plantations. In sulphur deficient young palms growth was stopped, length of rear leaves emitted were less and the leaf splitting was abnormally earlier. The colour of leaves ranged from pale yellow to bright bronze and tips became grey and curled. The deficiency symptoms were corrected by supply of sulphur to the plants.

Sulphur is an essential component of proteins and various co-enzymes and sulphur deficiency will tend to cause the same general disruption of metabolisms as N and P deficiency (Corley, 1976). Sumbak (1976) obtained yield increments of 0.4 to 0.5 tons per hectare by the application of 0.8 kg sulphur per tree per year.

2.2.3 Micro nutrients

Field experiments leading to the quantification of micronutrient requirements of coconut palms are difficult to be laid out and is therefore little. However, long term application of major nutrients as fertilizers will accentuate certain micronutrient imbalances in the plant as well as soil leading to microelements - related constraints in coconut production. Research on trace element nutrition of palms have resulted in projecting the major role played by two micro nutrients in coconut growth and yield. Thus sodium and chlorine assume their significance.

Application of sodium chloride had been a farmers practice in Kerala (India), for a long time now, mainly as a soil ammendment without sufficiently realising the nutritional impact of these elements. In laterite soils addition of common salt in the pits at the time of planting was known to soften the beds and helped early penetration of tender roots (Menon and Pandalai, 1958). Common salt mixed with wood ash applied to the crown of the palm as well as soil is believed to have beneficial effects on the productivity of the palm. Common salt also imparts resistance to leaf blight in coconut palms. Fremond _= . (1964) reported that application of sodium chloride could increase the number of inflorescence, number of female flowers and the number of nuts per palm. The copra content was also increased.

The invigorative effect of sodium chloride in coconut seedlings was reported as early as 1931 by Briones (1931). Addition of common salt at the rate of 0.5 kg per young plant per month on a rocky laterite soil by Salgado (1951) gave a distinct difference in vigour, size and colour compared to untreated plants. Eventhough, the role of sodium is mostly as a substitute for potassium, results of Sankaranarayanan and Varghese (1959) showed that sodium in conjunction with potassium was better in increasing yield than the no sodium treatment. They also found that sodium has no effect on leaf potassium content.

According to Ollagnier and Ochs (1971) there is no direct proof on the effect of sodium in increasing the yield of coconut. But Barrant (1975) was of the opinion that there is beneficial effects of Na and Na-K interaction on the yield of Malayan dwarf palms growing in potassium deficient soils. Manciot et al. (1979) also classified coconut among the plants which give a moderate response to sodium even when there is plenty of potassium.

According to Ollagnier and Ochs (1971), the beneficial effects of sodium chloride in coconut yield might as well be due to the nutritional impact of chlorine. They have also observed that there is positive correlation between chlorine content of leaf and yield of coconuts.

They were among the first to suggest that chlorine be admitted into the rank of essential major nutrient element for coconut palms. Robert Cecil (1975) was also of the same view. The increase in copra yield per tree with increments of potassium chloride application was reported to be due to a close positive relationship between the higher chlorine levels in leaves and copra yield (Magat, et al (1975) He also found that copra yield has a negative relationship with potassium levels in leaves.

The suggestion of Arnon and Whatley (1949) that chlorine as an element indispensable for the satisfactory functioning of photosynthesis was disputed by Eschbach et al (1982) He was of the opinion that, at least in the case of a germinating plant, chlorine has no effect in the photosynthetic activity, night respiration or transpiration.

While Achuthan Nair and Sreedharan (1983) had rated leaf chlorine content to be more effective than potassium content in affecting morphological characters and yield of palms, Ollagnier and Mardina Wahyuni (1984) found that chlorine nutrition results in as much as 40 per cent increase in copra yield per nut.

Of late, the role of chlorine as a nutrient in coconut palm is being related to the stomatal movements of coconut palms. Coconut palms lack starch in their guard cells. Therefore, they depend on chlorine and potassium for the stomatal opening resulting from the variations in cell turgidity (Bracconier and Auzac, 1985; Ollagnier, 1985; Uoxkull, 1985). These findings provide a physiological basis for the observed response of coconut palms to chlorine fertilization. One of the recent reports from Mindanao, Philippines (Magat, et al 1988) proves beyond doubt the significance of chlorine for coconut palms. He observed that sodium chloride application increased nut production, copra weight per nut and copra yield per tree. He was of the opinion that the positive response to KCl application observed in earlier studies is due to the chlorine component of the fertilizer. The optimum rate of sodium chloride suggested by him is 3.8 kg per tree per year.

2.3 Leaf nutrient concentration as a diagnostic tool for nutritional status of coconut palm

Soil analysis have been extensively used as a method of predicting the mineral requirement of crop. However, this technique has its own limitations due to the multiplicity of soil factors that influence the availability of the soil nutrients towards root absorption Very often an assessment of the soil available nutrients do not give an index for their possible uptake pattern of the crop. At present tissue analysis has been widely adopted as a diagnostic tool for predicting the nutrient requirement of the palm, largely due to the pioneering work of IRHO Scientists in West Africa (Anon, 1961). Foliar diagnosis for nutritional assay gained momentum during the late forties of this century. The studies conducted by Manciot et al.(1979a&b) and the results obtained by Magat(1979a&b) have sufficiently illustrated that the leaf analysis is an every time tool for predicting the fertilizer requirement of coconut palm.

2.3.1 Major nutrients

Felizendo et al. (1963) established a positive relation between high contents of nitrogen, phosphorus and potassium in leaves and better yield of nuts. Fremond et al. (1966) suggested critical levels in frond 14 for nitrogen (1.8 to 2.0 per cent), phosphorus (0.12 per cent) and potassium (0.8 to 1.0 per cent) of dry matter. Nethsinghe (1966) indicated that for young palms (4 years old) the optimum foliar content of nitrogen is 2.2 per cent, phosphorus 0.14 per cent and potassium 0.2 per cent of dry matter. Indirakutty and Pandalai (1968) made an attempt to catagorise palms of West Coast Tall into three different yield groups ie., low yielders (below 40 nuts per annum), medium yielders (40 to 80 nuts per annum) and high yielders (more than 80 nuts per annum). The corresponding nitrogen, phosphorus and potassium contents in the leaves are given below.

	N	P	K
Low yielders	1.64	0.12	0.81
Medium yielders	1.76	0.13	1.11
High yielders	1.86	0.14	1.30

The leaf nutrient composition was found to increase with higher yield levels. Cecil (1969) reported that the nitrogen, phosphorus and potassium of frond 14 of healthy palms of high productivity were 1.3, 0.198 and 1.23 per cent respectively. Foliar analysis by Smith (1969) revealed that coconut yield is not a function of individual effect of nutrients but their interactions. He suggested that yield was related to N K ratio and the potassium level in turn should be interpreted in relation to the balance between mono and divalent cations. In Malaya, Kanapathy (1971) suggested tentative optimum levels of 1.8 per cent nitrogen, 0.12 per cent phosphorus and 0.8 to 1.11 per cent potassium for the talls, 1.8 to 2.0 per cent nitrogen, 0.12 per cent phosphorus and 0.8 to 0.9 per cent potassium for semitalls and 1.9 to 2.0 per cent nitrogen, 0.12 per cent phosphorus and 0.75 to 1.0 per cent potassium for dwarfs. Almost similar values were obtained by Von Uoxkull (1971) in palms yielding more than

100 nuts per year. The values reported by him were 1.96 per cent nitrogen, 0.10 per cent phosphorus and 1.26 per cent potassium.

Studying the correlation between yield and nutrient contents of soil and leaf, Wahid et al. (1974) reported that the potassium content of leaf correlated positively with yield. They suggested that the critical level of potassium 0.8 to 1.0 per cent was found to hold good in coconut. Different catagories of coconut palms are grown in several types of soils in Kerala (India). Pillai et al. (1975) reported the mean values of their leaf nutrients as nitrogen 1.82 per cent, phosphorus 0.13 per cent and potassium 1.08 per cent of dry matter. Barrant (1977) obtained values of nitrogen, phosphorus and potassium content of frond 14 ranging from 1.54 to 1.88, 0.1 to 0.16 and 0.63 to 0.93 per cent respectively. He also found that N and K has response to yield significantly to increased application followed by foliar contents.

A sub-optimal concentration of a particular nutrient element in leaf tissues will develop a deficiency symptom characteristic of that element. Manciot et al. (1980) showed that a drop in nitrogen level below 1.13 per cent in the leaf tissue developed deficiency symptom. The critical level suggested by them for nitrogen was 1.5 to 2.0 per cent of frond 14. But Ollagnier and Mardina Wahyuni (1984) recommended a still higher value of nitrogen level in leaves (2.2 per cent). The optimum value recommended for phosphorus by them was 0.12 per cent. Margete et al. (1979) observed that KCl fertilization improved the nitrogen status of leaves which correlated with yield increase. The nitrogen level was raised from 1.78 per cent to a maximum of 2.03 per cent. The phosphorus and potassium contents ranged from 0.140 to 0.156 per cent and 1.270 to 1.463 per cent respectively. The critical level of potassium (in frond 14) suggested by Magat (1979) was 0.8 to 1.0 per cent of dry matter which is same as that suggested by IRHO.

2.3.2 Secondary elements

As in the case of major nutrients, there are wide variations in the suggested optimum or critical levels for secondary elements in the index leaf of coconut palm. The reports from differential climatic and soil situations are bound to show such dissimilarities. The critical level of Ca in leaf suggested by IRHO was 0.5. However, values higher or lower than these levels have been widely reported on healthy palms without any adverse effect on yield or foliar conditions (Fremond, 1964). This suggestion is in agreement with the results obtained by Indirakutty and Pandalai (1968) from three different yield groups of palms which did not vary significantly in the foliar calcium content. The average value obtained was 0.28 per cent on dry matter basis. But Cecil (1969) reported a higher value of 0.48 per cent of Ca in leaves of healthy palms under excellent growth conditions. Most of the results from Jamaica show still higher values of foliar calcium levels ranging from 0.4 to 0.7 per cent and the yield increases due to fertilizer application were not related to any increase or decrease of calcium content of leaf (Barrant, 1977).

Though a higher concentration of calcium does not give a higher yield, the calcium content of the soil will be reflected on the leaf concentration of the palm. This was evidenced by Magat (1979a&b) who obtained results showing that the calcium levels in frond 14 ranges from 0.14 to 0.42 per cent except in one location in his experimental fields, where the parent material is lime stone and the calcium level of palms is 0.68 per cent. The results published by Manciot et al.(1979a&b) was contradictory to this. The works carried out by them in Ivory Coast where calcium carbonate was applied to palms for four consecutive years could not improve the foliar concentration of calcium. They also suggested a calcium level of 0.3 to 0.4 per cent of dry matter in leaf rank 14 as satisfactory.

Felizendo etal (1963) observed that better yields of nuts are associated with low levels of magnesium in leaves. A leaf concentration of 0.25 to 0.3 per cent of magnesium is reported to be sufficient for the coconut palm. But a fall below 0.2 per cent may result in deficiency symptoms (Nethsinghe, 1963). The foliar content of magnesium in healthy palms under excellent growth conditions reported by Cecil (1969) was 0.29 per cent on dry matter basis. A higher level of magnesium in leaves was reported by Barrant (1977) ranging from 0.3 to 0.5 per cent and yield increase due to fertilization were not related to any increase or decrease of magnesium content in leaf. Magat (1979a&b) also found that the foliar content of magnesium varied from 0.16 to 0.48 per cent with an average of 0.29 per cent. Margete et al. (1979) reported from Philippines that the magnesium levels of palm under various levels of potassium chloride fertilization ranged from 0.19 to 0.21 per cent. Palms which contained below 0.2 per cent of magnesium in their leaves showed highly significant response to the application of magnesium and the foliar concentration was also improved (Manciot et al. 1979a&b)

Eventhough sulphur plays a very important role in the biochemical cycles and its deficiency is reported to cause general disruptions in metabolism (Corley, 1976), research leading to quantification of optimum level of this element in coconut leaf are scarce. This nevertheless in no way diminishes the relative significance of the essential component of various amino acids and co-enzymes. Therefore, in the present investigation, an attempt has been made to correlated the leaf S levels to the net yield of palms.

2.3.3 Micronutrients

Among the different micronutrient elements known to be essential for plant growth sodium and chlorine plays major roles in coconut palm where sodium can substitute potassium in several biochemical roles where as chlorine was suggested to be ranked even as a major nutrient by Ollagnier and Ochs (1971).

However, Fremond et al. (1966) suggested a maximum leaf level of 0.4 per cent sodium beyond which adverse effect would be expected. The commonly observed concentration of sodium in the 14th frond coconut palm ranged between 0.21 and 0.46 per cent, Smith (1967); Smith (1968); Pillai et al. (1975) and Barrant (1977). Owing to the reported interactions of sodium and potassium in coconut palms it is difficult to fix critical levels for this micronutrient and hence reports in this aspects are meagre.

Chlorine is an important micro-nutrient exhibiting positive correlation with the yield of nuts. Critical levels of this element in the index leaf was fixed by Taffin and Quincez (1980) as 0.5 to 0.6 per cent of dry matter. In view of the role of this element in imparting disease and drought resistance as well as its strong effect on copra yield Ollagnier et al. (1983) suggested to maintain 0.5 per cent chlorine in the leaf tissues. Uoxkull (1985) suggested a critical leaf concentration of 0.45 to 0.55 per cent chlorine in coconut palms. He suggested also that a reduction in chlorine concentration below 0.35 per cent in dry matter may result in adverse effect.

MATERIALS AND METHODS

MATERIALS AND METHODS

An investigation to establish possible relationships between the leaf nutrient contents in coconut palms on the productivity at different yield levels was carried out as part of the research programme at the College of Agriculture, Vellayani with the following test materials and research.

3.1. Experimental sites

The Instructional Farm of the College of Agriculture, Vellayani, Trivandrum and the laboratories at this institute constituted the sites of the experiment.

3.1.1. Location

Vellayani is situated at 8.5°N lattitude and 76.9° east longitude at an altitude of 29 meters above mean sea level. The area is situated in the hillocks formed by aeolian deposits at a distance of about four kilometers from Arabian sea.

3.1.2. Climate

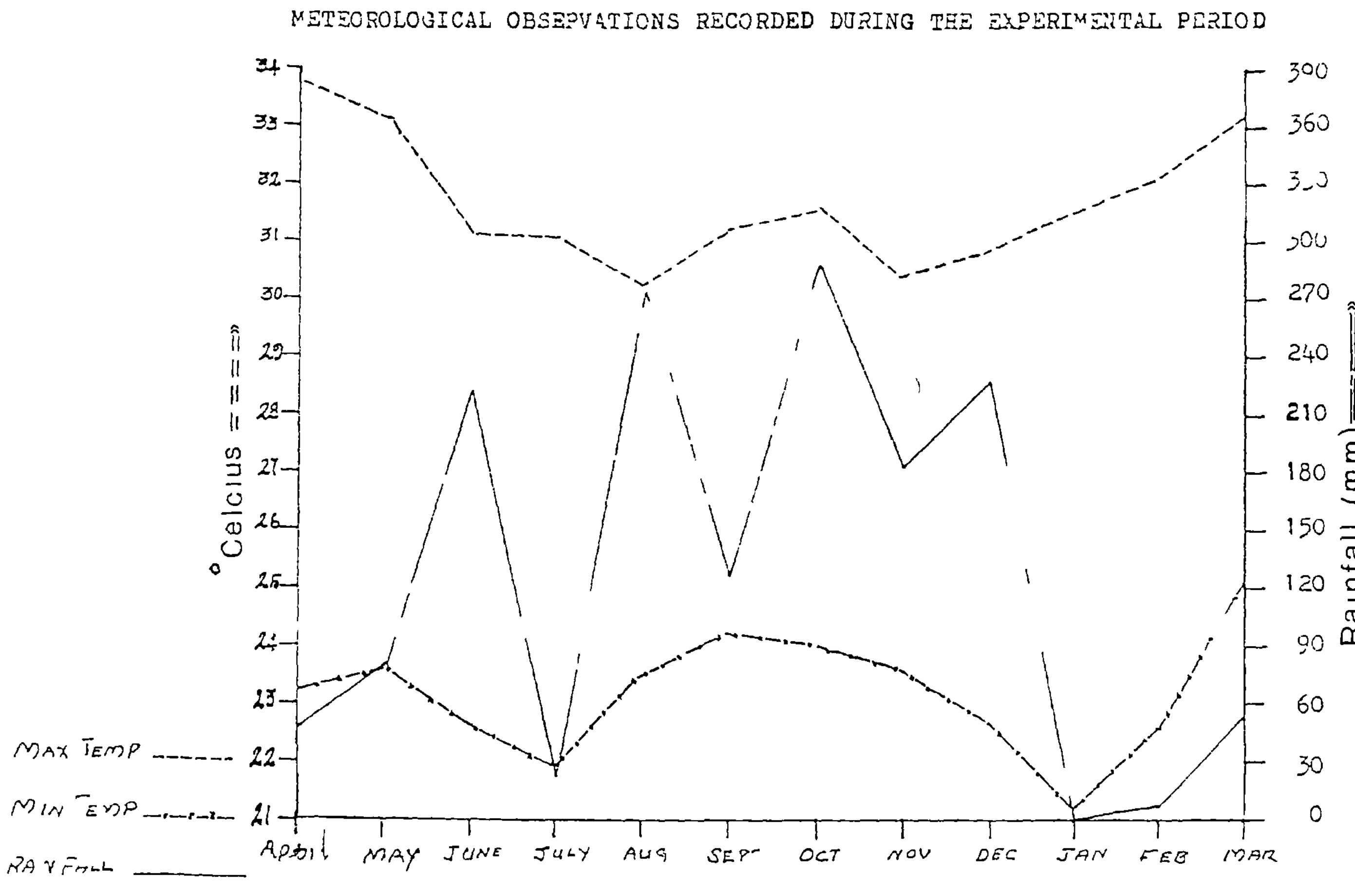
The area from where samples were drawn receives a mean annual rainfall of 1650 mm contributed mainly by the two monsoon seasons viz. South West and North East. The nearness to the sea and the availability of regular rains protects the area from severe drought. The mean temperature ranged from an average minimum of 23.4°C to an average maximum of 37.7°C. The weather conditions prevailed during the period of study are given in Fig.1 and the weather data are presented in Appendix I. In general the climate is conducive for coconut cropping as evidenced by the farmers practices of coconut growing.

3.1.3. Soil

The soil comes under the Vellayani series and is a red sandy loam. It is well drained, fine textured and medium to low in fertility status with respect to major and secondary elements. There is no clear cut profile differentiation and the whole experimental area comes under the same soil series with similar physical and chemical properties. The data on the important physio-chemical properties of the experimental site are given in Appendix II.

3.1.4. Cropping history

The whole area under Vellayani series is predominantly under coconut cultivation. However, almost all small holdings adopt multiple cropping with several types of intercrops. Monoculture plantations are also not uncommon. The samples for the present study were drawn from a monoculture plantation under the Instructional Farm, Vellayani. Eventhough, the soil does not



METEOROLOGICAL OBSERVATIONS RECORDED DURING THE EXPERIMENTAL PERIOD
°Celcius
Rainfall (mm)
MAX TEMP
MIN TEMP
RAINFALL
APRIL
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR

Fig 1

show much variation in physical or fertility status over the years there is conspicuous variation in the yield level of similarly fertilized palms. All the palms under the study received chemical fertilizers as per the package of practices recommendation of the Kerala Agricultural University (0.5 kg N, 0.32 kg P_2O_5 and 1.5 kg K_2O per palm per year in the form of urea, SSP and MOP respectively). The palms were entirely rainfed and fertilizer was applied as two splits just before the two monsoons in June and September.

3.2. Yield grouping and selection of palms

The data on the yields of palms for four years prior to the sample collection were obtained from the Instructional Farm and were utilized for this purpose. From the yield data the palms were grouped into 3 yield levels viz. low yielders (below 40 nuts per palm per year), medium yielders (40 to 80 nuts per palm per year) and high yielders (above 80 nuts per palm per year).

The palms are of west coast tall variety and are forty years old. For the purpose of sample collection 10 palms each from the three yield groups were selected. Thus the total number of palms from which samples were collected was thirty.

3.3. Collection of samples

Standard procedure suggested by Gopi et el. (1982) was followed for leaf sampling. According to them the yield levels are best reflected at the 10th frond as against the 14th leaf suggested by IRHO. Another reason for collecting the 10th leaf was that in most of the cases of low yielders the total number of leaves in the crown is so low that the 14th leaf is often under senescence.

The counting of leaves was done starting from the youngest fully enlarged leaf towards the outer whorls. After locating the index leaf the samples were drawn from the centre of the rachis taking five leaflets each from both sides.

In order to account for the seasonal fluctuations in leaf nutrient concentrations as well as nut yield samples were collected at regular intervals of 45 days synchromising with the harvest time. The final scheme of sample collection is provided below.

I Yield groups - 3

1. Low yielders (below 40 nuts/palm per year)
2. Medium yielders (40 to 80 nuts/palm per year)
3. High yielders (more than 80 nuts/palm per year)

II	Sampling interval	- 45 days
III	Harvest interval	- 45 days
IV	Index leaf	- 10th fully opened leaf from the top of the crown
V	Date of first sampling	- 26th April, 1987.

3.4. Laboratory investigations

The leaf samples collected from the thirty palms were subjected to detailed chemical analysis after processing the sample.

3.4.1. Sample processing

Fifteen centimeter portion of the leaflets was cut from the centre and the mid ribs were removed. The same was then washed in distilled water and dried in shade to remove moisture. The labelled samples in paper bags were kept in hot air oven at 55°C till constant weights were obtained. The samples were powdered in a centrifugal mill before acid digestion.

3.4.2. Estimation of nitrogen

Nitrogen was estimated by micro Kjeldahl method (Jackson, 1967).

3.4.3. Estimation of phosphorus

Phosphorus was estimated colorimetrically by ammonium vanadomolybdate method using a spectronic 2000. (Jackson, 1967).

3.4.4. Estimation of potassium

Potassium content of leaves was determined in the diacid extract by atomic absorption spectrophotometry using a Perkin Elmer Atomic Absorption Spectrophotometer. (Cooksey, M. and Barnett, W. 1979., and Issac, R.A. and Kerber, J.D. 1971).

3.4.5. Estimation of calcium

Calcium content of leaves was determined in the diacid extract by atomic absorption spectrophotometry using a Perkin Elmer Atomic Absorption Spectrophotometer. (Cooksey, M. and Barnett, W. 1979., and Issac, R.A. and Kerber, J.D. 1971).

3.4.6. Estimation of magnesium

Magnesium content of leaves were determined in the diacid extract by atomic absorption spectrophotometry using a Perkin Elmer Atomic Absorption

Spectrophotometer (Cooksey, M. and Barnett, W., 1979, and Issac, R.A. and Kerber, J.D. 1971).

3.4.7. Estimation of sulphur

This was estimated in diacid extract colorimetrically using a Spectronic 2000 (Piper, 1966).

3.4.8. Estimation of sodium

Sodium was estimated in the diacid extract by atomic absorption spectrophotometry using a Perkin Elmer Atomic Absorption Spectrophotometer (Cooksey, M. and Barnett, W. 1979, and Issac, R.A. and Kerber, J.D. 1971).

3.4.9. Estimation of chlorine

The content of chlorine was estimated after ashing the sample with lime by Husband and Goddens method (Piper, 1966).

3.5. Statistical analysis

Analysis of variance studies were conducted to assess the variation in yield and leaf nutrient contents between yield groups and between harvests.

Simple correlations were worked out involving leaf nutrients and yield, in each harvest individually as well as for overall harvests and also for each individual yield groups separately and overall yield groups as given below

1. Correlations for individual harvests
2. Correlations for overall harvests
3. Correlations for individual yield groups
4. Correlations for overall harvests and overall yield groups.

Simple linear and quadratic equations were worked out for each of the 8 leaf nutrients studied to observe its relationship with coconut yield in each group with data of overall harvests.

Multiple regressions were also fitted to study the simultaneous relationship of all the eight leaf nutrients on yield.

To assess the direct and indirect effect of leaf nutrients on the yield of coconut, path analysis was done for overall harvests under yield group separately.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

To study the relationship between eight leaf nutrient contents (N, P, K, Ca, Mg, S, Na and Cl) and coconut yield, analysis of variance, correlation studies, regression analysis and path analysis were conducted and the results are discussed below.

4.1 Variation in yields and nutrient contents between different yield groups and harvests

Analysis of variance studies were conducted to assertain how the yield and leaf nutrient contents varied with yield groups and with harvests and the mean are presented in Table 3 to 10.

4.1.1 Yield

Yield was found to vary significantly with palm types and harvest. High yielders were superior to medium yielders and low yielders. Highest yields were obtained in the third harvest followed by the second and first harvests while the sixth harvest gave the lowest yields in all yield groups. Among the different palm groups and harvests, high yielders of the third harvest gave the highest yield followed by the same plant group in the second harvest and then by the same plant group in the third harvest. The low yielders of the sixth and seventh harvests gave the lowest yields.

The significant differences in yield could be easily explained because the plants were categorised into the three groups only based on the differences in yield. In all palm groups consistently best yields were obtained in the third harvest followed by the second. This is because these harvests are in the season when the best yields of coconut are generally obtained in Kerala due to the influence of favourable agroclimatic conditions.

4.1.2 Content of major nutrients (Table 4 to 6)

Nitrogen, phosphorus and potassium contents in leaf also varied significantly with plant types and harvests and their interactions were also significant.

High yielders generally gave higher values of lead N, P and K contents followed by the medium yielders which in turn were followed by the low yielders. The important roles that N, P and K have to play in nut production have already been explained. Increased female flower production and setting percentage due to the application of major nutrients has already been reported (Pushpangadan, 1985). Another factor that could be observed was that the N, P and K contents in the later harvests were relatively

Table 3 Mean yield of nuts in different harvest per palm

Palm type	Harvest								Mean
	1	2	3	4	5	6	7	8	
Low yield groups	5.10	6.40	6.90	3.90	2.40	0.70	0.70	2.50	3.6
Medium yield groups	10.40	12.50	16.20	9.90	5.40	1.80	3.10	4.20	7.9
High yield groups	18.70	21.90	28.80	16.90	10.10	2.80	6.20	8.20	14.1
Mean	11.40	13.60	17.13	10.23	5.97	1.77	3.33	4.97	

Table 4 Mean foliar nitrogen content in different harvest

Palm type	Harvest								Mean
	1	2	3	4	5	6	7	8	
Low yielding	1.50	1.56	1.65	1.63	1.60	1.63	1.70	1.67	1.612
Medium yielding	1.80	1.85	1.95	1.91	1.90	1.93	2.01	1.97	1.917
High yielding	2.10	2.16	2.25	2.23	2.20	2.23	2.30	2.28	2.219
Mean	1.80	1.86	1.95	1.92	1.90	1.93	2.00	1.97	

Table 5 Mean foliar phosphorus contents in different harvest

Palm type	Harvest								Mean
	1	2	3	4	5	6	7	8	
Low yielding	0.14	0.15	0.15	0.15	0.14	0.15	0.16	0.15	0.148
Medium yielding	0.17	0.18	0.18	0.18	0.15	0.19	0.19	0.19	0.181
High yielding	0.20	0.21	0.21	0.21	0.21	0.21	0.23	0.22	0.214
Mean	0.17	0.18	0.18	0.18	0.18	0.18	0.20	0.19	

Table 6 Mean foliar potassium contents in different harvest

Palm type	Harvest								Mean
	1	2	3	4	5	6	7	8	
Low yielding	0.71	0.82	0.84	0.82	0.86	0.86	0.92	0.86	0.836
Medium yielding	1.01	1.09	1.12	1.11	1.13	1.13	1.14	1.16	1.110
High yielding	1.30	1.39	1.43	1.40	1.43	1.43	1.49	1.44	1.413
Mean	1.01	1.10	1.13	1.11	1.14	1.14	1.18	1.15	

higher (seventh and eighth harvest). The less yield associated with these harvests could have removed less of these nutrients from lead towards nut production in these harvests. The first and second harvests gave the lowest content of these nutrients. The relatively higher yields associated with these harvests, could have removed more of them towards nut production.

4.1.3 Content of secondary nutrients (Table 7 to 9)

Calcium content of leaves was the same in high yielders and low yielders and the lowest content was given by medium yielders. Among the different harvests the first followed by eighth gave higher Ca contents while the third harvest gave the lowest Ca content. The Mg contents did not vary between the yield groups. The second, first and third harvests gave comparetively lower values of Mg content. In the case of S content there was significant variation only between the yield groups with high yielders giving the maximum followed by medium yielders and then by low yielders.

Calcium content did not seem to play a major role in nut production from the correlation studies on the present investigation as well as per observations of earlier studies (Fremond, 1964; Indirakutty and Pandalai, 1968; Barrant, 1977). Hence the variation in

Table 7 Mean foliar calcium contents in different harvest

Palm type	Harvest								Mean
	1	2	3	4	5	6	7	8	
Low yielding	0.58	0.46	0 36	0 42	0.50	0.61	0.40	0.51	0.480
Medium yielding	0 50	0 46	0 38	0 35	0 40	0 55	0.42	0 42	0 436
High yielding	0 57	0.47	0 41	0 43	0.41	0.58	0.58	0 60	0.50[illegible]
Mean	0 55	0 46	0 38	0 40	0 44	0.58	0 47	0.51	

Table 8 Mean foliar magnesium contents in different harvest

Palm type	Harvest								Mean
	1	2	3	4	5	6	7	8	
Low yielding	0 20	0.22	0.21	0 22	0.24	0.23	0 23	0 21	0.219
Medium yielding	0 20	0 16	0 19	0 21	0 21	0.20	0.21	0.24	0 203
High yielding	0 20	0.19	0.21	0 24	0.24	0 24	0.21	0.23	0.218
Mean	0 20	0 19	0 20	0 22	0.23	0.22	0 22	0 23	

Table 9 Mean foliar sulphur contents in different harvest

Palm type	Harvest								Mean
	1	2	3	4	5	6	7	8	
Low yielding	0.15	0.14	0.15	0.14	0.15	0.14	0.14	0.15	0.145
Medium yielding	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.160
High yielding	0.18	0.18	0.18	0.18	0.19	0.18	0.18	0.19	0.184
Mean	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	

Ca contents between yield groups and harvests could be due to some other factors.

The lower values of Mg content associated with the second, first and third harvests could be explained by the larger removal of this nutrient towards nut production which was higher in these harvests. The higher S content in the low yielders may be associated with the yielding capacity of the plants again.

4.1.4 Content of micro nutrients (Table 10 and 11)

Foliar Na content showed variation only with the harvests while Cl content varied with yield groups and harvests. From the correlation studies of the present investigation it was evident that Na contents did not have much correlation with coconut yield. Ollagnier and Ochs (1971) and Pushpangadan (1985) have also observed similar results. There was no difference in Na contents between yield groups also. Moreover, Na seemed to be important only when K became limiting. The different harvests could have resulted in varying Na contents due to differential removal of the nutrient from source to sink by changes in agro-climatic conditions with different harvesting.

Chlorine content was associated with higher yields as evidenced by its significant

Table 10 Mean foliar sodium contents in different harvest

Palm type	Harvest								Mean
	1	2	3	4	5	6	7	8	
Low yielding	0.55	0.42	0.58	0.68	0.45	0.51	0.59	0.61	0.550
Medium yielding	0.50	0.47	0.44	0.60	0.47	0.60	0.62	0.57	0.535
High yielding	0.57	0.52	0.48	0.65	0.52	0.60	0.63	0.65	0.579
Mean	0.54	0.47	0.50	0.64	0.48	0.57	0.61	0.61	

Table 11 Mean foliar chlorine contents in different harvest

Palm type	Harvest								Mean
	1	2	3	4	5	6	7	8	
Low yielding	0.12	0.13	0.13	0.13	0.12	0.13	0.13	0.11	0.123
Medium yielding	0.21	0.22	0.20	0.23	0.21	0.21	0.23	0.20	0.215
High yielding	0.32	0.33	0.31	0.32	0.32	0.33	0.33	0.31	0.320
Mean	0.22	0.23	0.21	0.23	0.22	0.22	0.23	0.21	

correlations in the present investigation. Thus its contents were higher in the high yielders followed by medium yielders and then by low yielders. The difference in agroclimatic conditions and consequent, movement of Cl from source to sink could be the reason for the variation of the content of this nutrient between harvests. Taffin and Quincez (1980), Achuthan Nair and Sreedharan (1983), Ollagnier and Mardina Wahyuni (1984) have all reported evidences in support of the results of the present study.

4.2 Correlation studies

Correlations between leaf nutrient contents and yields were worked out separately in four ways. For each category of palms correlations were worked out for overall yield groups. Again correlations were worked out between harvests and overall yield groups also.

4.2.1 Correlations for individual harvests

4.2.1.1 Low yield group

The results are presented in Table 12 to 19. Yield was significantly and positively correlated with N and K content of the 10th leaf in the second and third harvests and with P and Cl in the first three harvests. There was significant positive correlation between yield and Na content of the leaf in the seventh harvest.

N was positively correlated with P contents in all harvests and with Cl contents excepting seventh harvest. There was significant positive correlation with K except in the first harvest. However, a significant negative correlation was observed between N and Ca contents in the sixth harvest. The phosphorus content of leaf had significant positive correlations with K and Cl levels in all the harvests and a marked positive correlation to Ca in the sixth harvest. The potassium content in the leaf was significantly and positively correlated with Cl contents in all the harvests except first. While sulphur content of leaf was significantly and negatively correlated with N content in the second harvest and Na content in the seventh harvest, Ca content exhibited significant negative correlation with K and Na in the sixth harvest and with Cl in the sixth and seventh harvests. Magnesium content also recorded significant negative correlation with Cl in the seventh harvest. From the above results it is evident that in low yielding palms only N, P, K, Na and Cl contents exhibited significant positive effect at some or other stage on the yield of nuts. While Barrant (1977) and Wahid et al. (1974), have reported significant positive correlation between N and K contents of leaf and yield. Pushpangadan (1985) reported significant positive correlation of yield with P content of leaf.

The nutritional impact of chlorine has been stressed by Ollagnier and Ochs (1971) and Robert and Cecil (1975) and they also observed a positive correlation between chlorine content of leaf and yield of coconut. Sodium content recorded positive correlation with yield only in seventh harvest. This may be because sodium is known to replace K to a certain extent when the later is in short supply, Manciot et al. (1980).

The major nutrients were significantly and positively correlated among themselves in most cases. The enhanced absorption of all these nutrients through the increased uptake of one or the other of them has been reported vary often. (Mathew and Ramadasan, 1964; Mollegard, 1971; Martin and Prioux, 1972; and Markose and Nelliat, 1975). Apart from the major nutrients chlorine alone exhibited significant correlations with one or the other nutrients (especially

Table 12 Correlation matrix - Low yield group - Harvest I

	Yield	N	P	K	Ca	Mg	S	Na
N	0.6106							
P	0.7922**	0.7768**						
K	0.3797	0.5371	0.6712*					
Ca	0.4817	0.0800	0.4935	0.4985				
Mg	0.1750	0.1367	0.1587	-0.0297	-0.0774			
S	-0.2621	-0.1070	0.1514	0.2771	-0.0240	0.1061		
Na	0.0884	-0.0890	0.2875	0.1320	0.4561	0.4012	0.4739	
Cl	0.8168**	0.8216**	0.9121**	0.4523	0.4581	0.1657	-0.1983	0.1402

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

Table 13 Correlation matrix - Low yield group - Harvest II

	Yield	N	P	K	Ca	Mg	S	Na
I	0.6672*							
	0.8174**	0.8449**						
	0.9265**	0.8108**	0.9054**					
a	0.2462	0.4480	0.1977	0.3637				
g	-0.2109	0.0225	0.0454	-0.1949	0.1029			
	-0.2616	-0.7216*	-0.4828	-0.4274	-0.1669	-0.2085		
a	-0.0383	0.0959	0.0746	-0.0317	0.3572	0.1803	0.4177	
l	0.8813**	0.7130*	0.8476**	0.9572**	0.2951	-0.3037	-0.3531	-0.0847

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

Table 5 Correlation matrix - Low yield group - Harvest III

	Yield	N	P	K	Ca	Mg	S	Na
	0.3850**							
	0.8923**	0.9024**						
	0.9119**	0.9661**	0.9464**					
a	-0.1744	-0.1526	-0.2673	-0.1602				
g	-0.5742	-0.3875	-0.3438	-0.3568	0.0916			
	0.0438	0.0854	0.3200	0.0912	-0.4890	0.0845		
a	-0.5256	-0.5538	-0.6108	-0.6156	-0.3030	0.0638	-0.1081	
l	0.3166**	0.9453**	0.8189**	0.8884**	-0.2141	-0.3295	0.0930	-0.5138

Table 15 Correlation matrix - Low yield group - Harvest IV

	Yield	N	P	K	Ca	Mg	S	Na
N	0.0126							
P	-0.0650	0.8985**						
K	-0.0845	0.8962**	0.8261**					
Ca	0.1199	0.1920	0.0323	0.1108				
Mg	0.4691	0.0957	-0.0903	-0.1573	0.3096			
S	-0.1550	-0.0144	-0.0868	-0.1987	0.3654	0.4141		
Na	-0.0806	0.1096	0.0274	0.2721	-0.6049	-0.3028	-0.3146	
Cl	-0.2641	0.8599**	0.8568**	0.9706**	0.1429	-0.2218	-0.1023	0.1717

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

Table 16 Correlation matrix - Low yield group - Harvest V

	Yield	N	P	K	Ca	Mg	S	Na
N	-0.5148							
P	-0.2123	0.9154**						
K	-0.2449	0.8541**	0.9400**					
Ca	0.3314	0.0658	0.1041	0.0468				
Mg	0.4010	-0.5758	-0.3725	-0.0036	-0.2287			
S	-0.4069	0.5049	0.3655	0.5184	0.0078	-0.6134		
Na	0.0722	0.1692	0.2016	0.0264	-0.3250	-0.4030	-0.0037	
Cl	-0.2676	0.8587**	0.9059**	0.8852**	-0.1629	-0.3199	0.5489	0.2702

Table 17 Correlation matrix - Low yield group - Harvest VI

	Yield	N	P	K	Ca	Mg	S	Na
N	0.0897							
P	0.3896	0.8683**						
K	0.2664	0.8884**	0.9323**					
Ca	0.2601	-0.8175**	-0.6707*	-0.7218*				
Mg	-0.0233	-0.0610	0.1199	0.0975	0.1290			
S	-0.0609	0.0682	-0.0503	-0.1588	-0.3406	0.1202		
Na	-0.3692	0.2103	0.1266	0.0600	0.0996	-0.0423	0.2098	
Cl	0.1488	0.8266**	0.6616*	0.8175**	-0.6620*	-0.3171	-0.2772	0.0309

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

Table 18 Correlation matrix - Low yield group - Harvest VII

	Yield	N	P	K	Ca	Mg	S	Na
N	0.5751							
P	0.4749	0.7973**						
K	0.3976	0.6959*	0.9251**					
Ca	-0.0011	-0.2851	-0.3922	-0.4850				
Mg	-0.4981	-0.6222	-0.6294	-0.4667	0.0673			
S	-0.2286	0.0389	-0.1037	-0.2129	-0.2478	-0.1637		
Na	0.7011*	0.5262	0.6012	0.5265	0.1720	-0.3848	-0.7196	
Cl	0.3061	0.5461	0.7906**	0.7845**	-0.6384*	-0.7321*	0.1365	0.2190

* Significant at 5% level ** Significant at 1[illegible]

Table 19 Correlation matrix - Low yield group - Harvest VIII

Yield	N	P	K	Ca	Mg	S	Na
-0.2715							
-0.3578	0.8505**						
-0.1305	0.8347**	0.9458**					
-0.6550	0.7780	-0.0567	-0.1606				
-0.5264	0.0851	0.1731	-0.0238	0.3721			
0.0926	0.4786	0.2000	0.1776	0.5586	0.3250		
-0.2120	-0.0774	0.0800	-0.0529	0.3462	0.2375	0.1490	
-0.3527	0.6896*	0.7887**	0.7321*	-0.1133	0.1117	-0.0936	-0.1986

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

the major nutrients) in most of the harvests.

Yet another worthwhile finding is that significant correlations with yield were generally obtained in the first three harvests for N, P, K and Cl. Perhaps it is the content of the nutrients in the leaf at this juncture that decides the nut production of that year (April 1987 to March 1988) for this category of palms. Time of leaf nutrient testing has a profound influence on the success of tissue analysis being correlated with yield (Tisdale et al., 1985).

4.2.1.2 Medium yield groups

The simple correlation matrices involving yields and leaf nutrient contents are presented in Table 20 to 27. For the medium yielders, nut yield was positively and significantly correlated with N content of leaf in the first and second harvests to P content in the first and third harvests, to K content in the first and fourth harvests, to Mg content in the seventh harvest and to Cl content in the first to the fifth harvests.

Nitrogen content of leaf had a significant positive correlation with P content in all the harvests except the fourth, fifth and eighth and to K and Cl contents in all the harvests except the fourth. With sulphur, N content had a significant positive correlation in the eighth harvest. Phosphorus content had a significant positive correlation to leaf K and Cl contents in all the harvests. In the fifth harvest, P content was negatively correlated with S content. The K levels in the leaf had a significant positive correlation with the Cl content in all the harvests. Among the secondary nutrients, Ca content did no have any significant correlation with any of the characters studied while Mg content of leaf showed a marked positive correlation to Na content in the first harvest. Sulphur content in turn had significant negative correlation with Cl content in fifth harvest.

As in the case of low yielders, in medium yielders also, only N, P, K and Cl in the early harvests continued to play some positive role towards nut production. While sodium was not in the picture Mg content in one harvest (seventh) emerged to give positive correlation with yield. While positive correlation between Cl content and yield was obtained in the first to third harvest, for low yielders positive correlation was obtained for first to fifth harvests for the medium yielders. This very clearly indicates the importance of chlorine. Barrant (1977) observed the significant

Table 20 Correlation matrix - Medium yield group - Harvest I

	Yield	N	P	K	Ca	Mg	S	Na
N	0.9097**							
P	0.9676**	0.8640**						
K	0.9235**	0.8108**	0.8823**					
Ca	-0.4501	-0.4802	-0.3989	-0.5366				
Mg	-0.2326	-0.3937	-0.3357	-0.1847	0.5519			
S	-0.0298	-0.1888	0.1300	-0.0451	0.1384	-0.0033		
Na	0.1397	-0.0707	0.1661	0.1682	0.3985	0.6747*	0.5332	
Cl	0.9372**	0.8921**	0.9393**	0.9112**	-0.5296	-0.4350	-0.1470	-0.0614

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

Table 21 Correlation matrix - Medium yield group - Harvest II

	Yield	N	P	K	Ca	Mg	S	Na
N	0.7314*							
P	0.6095	0.8749**						
K	0.5062	0.6588*	0.7348*					
Ca	0.1317	0.4235	0.3150	-0.0326				
Mg	-0.5397	-0.1350	-0.2384	-0.4731	0.3820			
S	-0.3352	-0.4218	-0.4262	-0.3476	0.0061	0.1311		
Na	0.2871	0.3976	0.2315	-0.1208	0.5812	-0.0532	-0.3805	
Cl	0.7356*	0.9217**	0.9055**	0.6488*	0.2531	-0.1253	-0.5861	0.2768

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

Table 22 Correlation matrix - Medium yield group - Harvest III

	Yield	N	P	K	Ca	Mg	S	Na
N	0.6137							
P	0.7883**	0.8492**						
K	0.5069	0.7974**	0.8577**					
Ca	-0.0254	0.1754	-0.1247	0.0268				
Mg	0.1037	0.4146	0.2906	0.4493	0.5562			
S	-0.3112	0.0727	0.0374	0.2850	-0.1893	-0.1334		
Na	-0.3436	0.1639	0.1003	0.5336	0.2422	0.3890	0.6187	
Cl	0.7185*	0.7682**	0.8762**	0.8330**	0.0291	0.5837	-0.1135	0.1659

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

Table 23 Correlation matrix - Medium yield group - Harvest IV

	Yield	N	P	K	Ca	Mg	S	Na
N	0.2797							
P	0.2718	0.1921						
K	0.8287**	0.2707	0.6778*					
Ca	0.5049	0.4126	0.1605	0.3705				
Mg	0.5438	-0.2908	0.0195	0.4394	0.0422			
S	-0.2735	0.2887	-0.2045	-0.4487	-0.0023	-0.5966		
Na	-0.3495	-0.2474	0.1079	-0.0797	-0.1599	-0.2128	0.0738	
Cl	0.7514*	0.1983	0.7269*	0.9659**	0.1762	0.4986	-0.5221	-0.1051

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

Table 24 Correlation matrix - Medium yield group - Harvest V

	Yield	N	P	K	Ca	Mg	S	Na
N	0.5114							
P	0.5981	0.5826						
K	0.5508	0.7829**	0.7934**					
Ca	-0.1532	0.0358	-0.2596	0.0974				
Mg	0.2378	0.3136	0.1195	0.3166	0.2220			
S	-0.3788	-0.3868	-0.6390*	-0.5803	0.0630	-0.5399		
Na	-0.2162	-0.0442	0.3390	0.0278	0.0097	0.2470	-0.3489	
Cl	0.6784*	0.7435*	0.6491*	0.8366**	0.0272	0.2487	-0.6471	-0.2227

Table 25 Correlation matrix - Medium yield group - Harvest VI

	Yield	N	P	K	Ca	Mg	S	Na
N	0.5888							
P	0.4366	0.8194**						
K	0.6133	0.9169**	0.8828**					
Ca	-0.3768	0.0402	0.0389	-0.1540				
Mg	-0.0947	0.3408	-0.0215	0.2534	0.1532			
S	0.0764	-0.0540	-0.2102	-0.2100	0.0384	0.0422		
Na	-0.0187	0.0806	0.3599	0.0878	0.5451	-0.4352	0.0650	
Cl	0.6067	0.7943**	0.7307**	0.8913**	-0.1323	0.2249	-0.1036	0.3027

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

Table 26 Correlation matrix - Medium yield group - Harvest VII

	Yield	N	P	K	Ca	Mg	S	Na
N	0.0509							
P	-0.0485	0.7919**						
K	-0.0747	0.6941*	0.7471*					
Ca	0.4876	0.0417	-0.1472	0.2017				
Mg	0.7806**	-0.0026	-0.2139	0.1094	0.4968			
S	-0.3505	0.1481	-0.1414	0.1326	-0.0227	-0.1349		
Na	0.0588	0.1282	-0.0855	-0.3028	0.0330	-0.1012	-0.4321	
Cl	-0.0429	0.9278**	0.7970**	0.6476*	-0.3626	-0.0174	0.0432	0.0978

Table 27 Correlation matrix - Medium yield group - Harvest VIII

	Yield	N	P	K	Ca	Mg	S	Na
N	-0.1641							
P	-0.1981	0.5460						
K	-0.1285	0.7673**	0.8782**					
Ca	0.2697	-0.1285	-0.0887	0.0435				
Mg	0.3400	-0.2818	0.0818	-0.1459	-0.2627			
S	-0.1466	0.6818*	0.2929	0.6306	0.2873	-0.3192		
Na	-0.2934	0.8036**	0.8807**	0.9670**	-0.0279	-0.2844	0.5711	-0.1283

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

role the major nutrients had to play on coconut leaf nutrient contents and yield. Manciot et al. (1979) observed that palms which contained below 0.2 per cent of Mg in their leaves showed highly significant response to the application of Mg. Chlorine might have become a significant factor in influencing coconut yield because of the role of this element in imparting disease and drought resistance (Ollagnier et al 1983). It may be borne in mind that just prior to the period of this study there was a drought in this location.

Among the different nutrients it was again noted that only N, P, K and Cl contents of the leaf were mutually correlated positively and significantly in most of the cases. The other nutrients showed significant correlations only in isolated cases. Perhaps only N, P, K and Cl had influenced the uptake of one or another through their individual influences.

4.2.1.3 High yield groups

The correlations involving yields and leaf nutrient contents of high yielding coconut palms are presented in Table 28 to 35. Significant positive correlation with yield was shown only by K, Mg and Cl contents in the third harvest, by Cl in the fourth harvest and by P content in the seventh harvest. In the seventh harvest it was significantly and negatively correlated with Mg levels.

Among the different leaf nutrients studied, N was significantly and positively correlated with Cl content in all eight harvests, with K in all harvests except the fourth and to Mg in the second, sixth and eighth harvests. N content was also significantly and positively correlated with S in the first harvest. The leaf P content had significant positive correlation with Mg content in the eighth harvest and a significant negative correlation with K content in the second harvest and Ca content in the fourth harvest. The foliar K content was positively correlated with Mg levels in the second and fourth harvest, with Na in the sixth harvest and with Cl in all the harvests except the second. Leaf Ca content was positively correlated with Mg content in the fifth harvest. Magnesium content in the leaf was significantly and positively correlated with sodium contents in the third and seventh harvests and to Cl content in the third and sixth harvests. Sulphur content of leaves had a significant negative correlation with sodium levels in the fourth harvest.

Table 28 Correlation matrix - High yield group - Harvest I

	Yield	N	P	K	Ca	Mg	S	Na
N	0.0878							
P	-0.1213	0.3226						
K	0.5691	0.6908*	-0.0220					
Ca	0.2970	-0.0456	0.0285	0.1228				
Mg	0.5597	0.1665	0.2165	0.2352	0.0807			
S	0.1654	0.8001**	0.4323	0.3887	-0.2821	0.2288		
Na	0.6198	0.3744	-0.2713	0.6188	0.3480	0.5826	0.1529	
Cl	0.4690	0.1708*	0.9940	0.9545**	0.3033	0.1494	0.3400	0.6101

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

Table 29 Correlation matrix - High yield group - Harvest II

	Yield	N	P	K	Ca	Mg	S	Na
N	0.1739							
P	-0.0715	-0.1593						
K	0.2495	0.6839*	-0.6419*					
Ca	0.0899	0.4136	0.0427	0.2229				
Mg	-0.2178	0.7067*	-0.2365	0.6712*	0.2995			
S	0.3828	0.2357	-0.0077	0.0417	0.2771	0.0361		
Na	-0.2237	0.4910	-0.2763	0.6610*	0.1539	0.6110	-0.5045	
Cl	0.1453	0.7870**	-0.0132	0.5031	0.3993	0.4580	0.4718	0.2791

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

Table 30 Correlation matrix - High yield group - Harvest III

	Yield	N	P	K	Ca	Mg	S	Na
N	0.4115							
P	-0.1320	0.4165						
K	0.6902*	0.7791**	0.1587					
Ca	-0.1331	-0.1934	0.0490	-0.1355				
Mg	0.7698**	0.3613	0.1484	0.7511*	-0.0165			
S	-0.4591	-0.5568	0.3519	-0.6066	-0.0921	-0.1686		
Na	0.4997	0.2748	0.2230	0.5182	-0.2143	0.8567**	0.1027	
Cl	0.7425*	0.7580*	0.1858	0.9057**	-0.1029	0.6753*	-0.5430	0.4373

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

Table 31 Correlation matrix - High yield group - Harvest IV

	Yield	N	P	K	Ca	Mg	S	Na
N	0.2310							
P	-0.0414	-0.0135						
K	0.5239	0.5655	0.0473					
Ca	0.2658	-0.1962	-0.7108*	-0.2615				
Mg	0.1908	0.2708	0.3420	0.2310	-0.3547			
S	0.0347	0.6193	0.0431	0.3860	-0.0900	0.2200		
Na	0.0220	-0.2865	-0.1144	-0.1886	0.0632	0.2209	-0.8139**	
Cl	0.6323*	0.6798*	-0.1166	0.8806**	-0.1156	0.4111	0.4760	-0.2092

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

Table 32 Correlation matrix - High yield group - Harvest V

	Yield	N	P	K	Ca	Mg	S	Na
N	0.3488							
P	-0.1897	-0.1062						
K	0.4923	0.7703**	0.1104					
Ca	0.0727	0.0321	0.1212	-0.2222				
Mg	0.4814	0.3151	0.2272	0.1959	0.7303*			
S	-0.4642	-0.0727	-0.3525	-0.4958	0.0965	-0.3213		
Na	0.4013	0.0317	-0.5980	0.0717	0.1868	-0.1259	0.0214	
Cl	0.4404	0.6675*	0.2237	0.9201**	-0.1274	0.3931	-0.5972	-0.1595

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

Table 33 Correlation matrix - High yield group - Harvest VI

	Yield	N	P	K	Ca	Mg	S	Na
N	0.1058							
P	0.1186	-0 3345						
K	-0 0756	0.7664**	-0 6028					
Ca	0.0934	0 1832	-0 3282	0 4128				
Mg	0.1261	0.8973**	-0.2449	0 6187	0 2147			
S	-0.2742	-0.1407	0 1197	-0.2189	-0 2286	-0.0774		
Na	0 1829	0.5785	-0 1284	0 6470*	-0 1155	0 2773	-0 2254	
Cl	-0.0367	0.7978**	-0.5297	0.9577**	0.5602	0.6497*	-0.3140	0 5155

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

Table 34 Correlation matrix - High yield group - Harvest VII

	Yield	N	P	K	Ca	Mg	S	Na
N	0.2631							
P	0 6851*	0.4711						
K	0.2976	0.8392**	0.5622					
Ca	-0.1789	-0 5259	0.0628	-0.1799				
Mg	-0.7155**	0 0279	-0.3864	0.2230	0.2394			
S	0.0441	-0.0017	0.3902	-0 1173	-0.0116	-0.3906		
Na	-0.5544	0.1240	-0.2655	0.3767	0.1700	0.7598	-0.0885	
Cl	0 4089	0.7469*	0.4762	0.9038**	-0.1372	-0.0218	-0 1487	0.2124

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

Table 35 Correlation matrix - High yield group - Harvest VIII

	Yield	N	P	K	Ca	Mg	S	Na
N	-0.1190							
P	-0.0565	0.1615						
K	-0.1159	0.8223**	0.1701					
Ca	0.3732	0.4723	-0.0673	0.4545				
Mg	0.1448	-0.3148	0.7303*	-0.2035	-0.1926			
S	0.3033	0.3418	-0.0361	0.1983	0.5520	-0.4250		
Na	0.0916	-0.3970	0.0726	-0.2297	-0.1920	0.4934	-0.2719	
Cl	-0.0085	0.6893*	0.2337	0.8847**	0.4461	-0.0032	0.0719	-0.3557

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

It could be seen that as plants progressed from low and medium yield groups to high yielders the significant positive correlation seen between the leaf contents of major nutrients and yield seemed to become less prominent as K and P gave significant positive correlation only in one instance each. Chlorine was the nutrient which gave positive correlation with yield in maximum harvests for the high yielding palms. Perhaps at high yield levels, since the content of major nutrients were also high, generally they did not play a prominent role towards yield increase. While it was nutrients like Cl which was limiting and could positively correlate with yield. Taffin and Quincez (1980), Ollagnier et al (1983) and Uoxkull (1985) have all noted the importance of chlorine nutrition for coconut palms.

4.2.1.4 Overall yield groups

The simple correlations worked out for all the yield groups together for the individual eight harvests are presented in Table 36 to 43. Coconut yield was significantly and positively correlated with N, P, K, S and Cl contents in all the eight harvests. Yield showed significant positive correlation with Ca content in the seventh and eighth harvest and a negative correlation in the fifth harvest.

Among the different nutrients studies, N levels of leaf showed a significant positive correlation with P, K, S and Cl in all harvests. While N showed a significant positive correlation with Ca in the seventh harvest, there was significant negative correlation in the fifth harvest. Phosphorus content of leaves was significantly and positively correlated to K, S and Cl contents in all the harvests while it showed a negative significant correlation with Ca content in the fifth harvest. Foliar K content was significantly and positively correlated to S and Cl contents in all the harvests. As in the case of N, foliar K content also showed a significant positive correlation with Ca in the seventh harvest and negative correlation in the fifth harvest. Calcium content of leaves was found to have a notable positive correlation with Cl contents in the seventh harvest and with S content in the seventh and eighth harvests. It also had a significant positive correlation with Na in the first and second harvests and a negative correlation with Cl content in the fifth harvest. Foliar content of Mg was significantly and positively correlated with Na content in the first and third harvests. Sulphur content of leaves was positively and significantly correlated with Cl content of leaves in all harvests while the leaf content of Na was positively correlated with Cl in the second harvest.

37 Correlation matrix - Overall yield groups all plants - Harvest II

	Yield	N	P	K	Ca	Mg	S	Na
N	0.9777**							
P	0.9752**	0.9861**						
K	0.9766**	0.9995**	0.9834**					
Ca	0.0563	0.0456	0.0654	0.0312				
Mg	-0.2949	-0.2946	-0.3082	-0.2992	0.2073			
S	0.8701**	0.8822**	0.8488**	0.8844**	0.0524	-0.2743		
Na	0.3147	0.3464	0.3290	0.3387	0.3629*	0.0884	0.1704	
Cl	0.9730**	0.9801**	0.9826**	0.9761**	0.0968	-0.2894	0.8591**	0.3632*

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

Table 38 Correlation matrix - Overall yield groups all plants - Harvest III

	Yield	N	P	K	Ca	Mg	S	Na
N	0.9858**							
P	0.9855**	0.9927**						
K	0.9867**	0.9988**	0.9907**					
Ca	0.3370	0.3524	0.3417	0.3559				
Mg	-0.0001	-0.0401	-0.0387	-0.0295	0.1302			
S	0.8586**	0.8799**	0.8950**	0.8873**	0.2402	-0.0472		
Na	-0.3058	-0.3246	-0.3352	-0.3069	-0.2232	0.4503*	-0.2104	
Cl	0.9890**	0.9818**	0.9843**	0.9801**	0.3332	0.0483	0.8435**	-0.2956

A very interesting fact that could be observed by the analysis of the pooled data on yield groups was that the results exhibited more consistency and the values of correlation coefficients obtained were very often as high as 0.9 and above, wherever significant positive correlations were obtained. This may be because when the analysis was carried out for the different yield groups individually, the influence of genetic characters would have dominated resulting in partially masking the effect of nutrients to some extent. On pooling the low yielding, medium yielding and high yielding plant types together the influence of genetic characters would have been diluted there by giving a clearer picture of the effect of nutrients.

The most consistent results were obtained for N, P, K, S and Cl. Not only were they found to influence coconut yield positively in all the harvests, but they themselves were found to be significantly and positively correlated mutually in all the harvests. Nitrogen being a constituent of plant, promoted the development of vegetative parts especially leaves and trunk and these parts also in turn accounted for the increase in nut production (Anon, 1969 and Smith, 1969). Felizendo et al. (1963) have established a positive relation between high contents of nitrogen, phosphorus and potassium in leaves and better

Table 36 Correlation matrix - Overall yield groups all plants - Harvest I

	Yield	N	P	K	Ca	Mg	S	Na
N	0.8918**							
P	0.9792**	0.9886**						
K	0.9823**	0.9991**	0.9867**					
Ca	0.0184	-0.0552	-0.0390	-0.0483				
Mg	-0.0205	-0.0483	-0.0468	-0.0479	0.2263			
S	0.9449**	0.9563**	0.9523**	0.9564**	-0.0151	-0.0201		
Na	0.1031	0.0459	0.0558	0.0509	0.4306*	0.5252**	0.1708	
Cl	0.9849**	0.9822**	0.9825**	0.9795**	-0.0192	-0.0612	0.9335**	0.0964

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

yield of nuts. Markose and Nelliat (1975) have observed that potassium chloride fertilization can improve the nitrogen status of leaf which was correlated with yield increases. According to Salgado (1946), nitrogen had a beneficial effect on female flower production. Accroding to Mollegard (1971) there was a positive correlation between phosphorus level in the leaves and yield of palms and the coefficient of higher in the plots which received potash. A positive correlation of leaf potassium content with yield was obtained by Wahid et al. (1974). Sulphur is an essential component of proteins and various coenzymes and as such sulphur has a role to play in the N and P metabolism as observed by Corley (1976). Ollagnier and Ochs (1971) have observed that there is a positive correlation between chlorine content of leaf and yield of coconuts. Of late, the role of chlorine as a nutrient in coconut palm is being related to the stomatal movements of coconut palms. Coconut palms lack starch in their guard cells. Therefore, they depend on chlorine and potassium for the stomatal opening resulting from the variations in cell turgidity (Braconnier and Auzac, 1985; Ollagnier, 1985 and Uoxkull, 1985). These findings provide a physiological basis for the importent role that chlorine played in the present study. A recent report on the effect of chlorine by Magat (1988) also substantiate our finding.

37 Correlation matrix - Overall yield groups all plants - Harvest II

	Yield	N	P	K	Ca	Mg	S	Na
N	0.9777**							
P	0.9752**	0.9861**						
K	0.9766**	0.9995**	0.9834**					
Ca	0.0563	0.0456	0.0654	0.0312				
Mg	-0.2949	-0.2946	-0.3082	-0.2992	0.2073			
S	0.8701**	0.8822**	0.8488**	0.8844**	0.0524	-0.2743		
Na	0.3147	0.3464	0.3290	0.3387	0.3629*	0.0884	0.1704	
Cl	0.9730**	0.9801**	0.9826**	0.9761**	0.0968	-0.2894	0.8591**	0.3632*

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

Table 38 Correlation matrix - Overall yield groups all plants - Harvest III

	Yield	N	P	K	Ca	Mg	S	Na
N	0.9858**							
P	0.9855**	0.9927**						
K	0.9867**	0.9988**	0.9907**					
Ca	0.3370	0.3524	0.3417	0.3559				
Mg	-0.0001	-0.0401	-0.0387	-0.0295	0.1302			
S	0.8586**	0.8799**	0.8950**	0.8873**	0.2402	-0.0472		
Na	-0.3058	-0.3246	-0.3352	-0.3069	-0.2232	0.4503*	-0.2104	
Cl	0.9890**	0.9818**	0.9843**	0.9801**	0.3332	0.0483	0.8435**	-0.2956

Table 39 Correlation matrix - Overall yield groups and all plants - Harvest IV

	Yield	N	P	K	Ca	Mg	S	Na
N	0.9538**							
P	0.9408**	0.9866**						
K	0.9543**	0.9967**	0.9885**					
Ca	0.1315	0.0778	0.0261	0.0512				
Mg	0.2854	0.1744	0.1894	0.1828	0.1281			
S	0.8458**	0.9050**	0.8782**	0.8936**	0.1618	0.1815		
Na	-0.1170	-0.1059	-0.1039	-0.1032	0.0076	-0.0167	-0.2499	
Cl	0.9662**	0.9820**	0.9797**	0.9842**	0.0444	0.2310	0.8791**	-0.1264

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

Table 40 Correlation matrix - Overall yield groups and all plants - Harvest V

	Yield	N	P	K	Ca	Mg	S	Na
N	0.9366**							
P	0.9228**	0.9892**						
K	0.9423**	0.9983**	0.9895**					
Ca	-0.3688*	-0.4521*	-0.4352*	-0.4396*				
Mg	0.2024	0.0473	0.0557	0.0687	0.3544			
S	0.8510**	0.9242**	0.9146**	0.9321**	-0.3303	0.0130		
Na	0.3080	0.2509	0.2355	0.2516	-0.0814	-0.0444	0.2190	
Cl	0.9428**	0.9876**	0.9857**	0.9865**	-0.4492*	0.0841	0.8975**	0.2295

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

41 Correlation matrix - Overall yield groups and all plants - Harvest VI

	Yield	N	P	K	Ca	Mg	S	Na
N	0.7969**							
P	0.8086**	0.9880**						
K	0.7919**	0.9986**	0.9845**					
Ca	-0.2155	-0.1503	-0.1955	-0.1370				
Mg	0.0738	0.1034	0.0579	0.1071	0.2126			
S	0.6688**	0.8987**	0.8865**	0.9024**	-0.1768	0.1053		
Na	0.1565	0.2644	0.2768	0.2521	0.1586	0.0779	0.2022	
Cl	0.7901**	0.9770**	0.9570**	0.9779**	-0.1118	0.1762	0.8620**	0.2923

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

Table 42 Correlation matrix - Overall yield groups and all plants - Harvest VII

	Yield	N	P	K	Ca	Mg	S	Na
N	0.9434**							
P	0.9510**	0.9900**						
K	0.9438**	0.9880**	0.9920**					
Ca	0.6935**	0 6793**	0.6979**	0.7287**				
Mg	-0.3161	-0.3205	-0.3441	-0.2852	-0.0163			
S	0.8499**	0.9209**	0.9166**	0.9214**	0.6421*	-0.3551		
Na	0.1388	0.1328	0.1366	0.1140	0.1475	-0.0540	-0.0571	
Cl	0.9377**	0.9861**	0.9855**	0.9763**	0.6413**	-0.3374	0.9016**	0.1424

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

Table 43 Correlation matrix - Overall yield groups and all plants - Harvest VIII

	Yield	N	P	K	Ca	Mg	S	Na
N	0.9094**							
P	0.8897**	0.9918**						
K	0.9059**	0.9980**	0.9913**					
Ca	0.4014*	0.2800	0.2455	0.2594				
Mg	0.1536	0.2025	0.2697	0.2209	-0.0901			
S	0.8596**	0.8825**	0.8615**	0.8678**	0.4881**	0.0194		
Na	0.1611	0.1250	0.1218	0.1179	0.2225	0.2215	0.0959	
Cl	0.8919**	0.9844**	0.9821**	0.9782**	0.3159	0.1854	0.8767	0.0928

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

4.2.2 Correlations for overall harvests

4.2.2.1 Individual yield groups

Correlations were worked out between yields and eight nutrients studied by pooling all the harvests for individual yield groups separately and the results are presented in Table 44 to 46. Yield was found to be significantly and negatively correlated to leaf N, P, K and Ca content for all the yield groups. It had a significant negative correlation with Na in medium and high yielding palms and with Mg in medium yielders.

Considering the correlation between various nutrients it was observed that N content was significantly and positively correlated with P and K contents of leaf in all yield groups and to Na content in low yielding palms. Nitrogen content was negatively correlated with Ca contents in low yield groups phosphorus content of leaf in all yield groups had a significant positive correlation with K contents and with chlorine levels in low and medium yielding palms. Phosphorus also had a significant positive correlation with Ca levels in high yielding palms and with Na content in medium yielding palms. Potassium status of leaf was significantly and positively correlated with Ca content in medium yielders and negatively correlated with it in low yielding palms. A significant positive correlation was observed between Ca status and Na content of leaf in medium yielders and with Mg level in high yielders. Magnesium content in leaves had a significant positive correlation with Na and Cl in high yielding palms. Magnesium levels had a significant negative correlation with S level of leaves in medium yielding plants.

From the above results it becomes evident that when analysis is done over all harvests for individual yield groups separately, because of dominant influence of genetic characters the correlations may get distorted. For example, there was not a single case of significant negative correlation between yield and any plant nutrients in any harvest when analysed separately. But on pooling the harvests together for each individual yield groups, perhaps genetic influences or other distoring effects could have produced the negative significant correlation between yield and N, P and K contents of leaves.

Yet another reason may be that pooling of all harvests together for individual yield groups could also produce a distorted picture. From the results it could be seen that N, P and K contents were mostly correlated with yield only in the early periods for low yielders and medium yielders and towards later harvests the magnitude of correlation decreased and even became negative though not significant. The same could be said of N and K in the case of high yielders where

Table 44 Correlation matrix - Low yield group - Overall harvests

	Yield	N	P	K	Ca	Mg	S	Na
N	-0.4403**							
P	-0.3340**	0.6097**						
K	-0.5343**	0.8853**	0.6398**					
Ca	-0.2407*	-0.3545**	-0.1457	-0.2782*				
Mg	-0.1895	0.0539	0.0477	0.1645	0.0710			
S	-0.0295	0.0192	-0.1742	-0.0297	-0.0252	-0.0053		
Na	-0.0793	0.2548*	0.0911	0.0284	-0.0536	-0.0604	0.0292	
Cl	-0.0021	0.1749	0.6635**	0.1803	-0.0581	-0.1294	-0.1694	-0.0264

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

Table 45 Correlation matrix - Medium yield group - Overal harvests

	Yield	N	P	K	Ca	Mg	S	Na
N	-0.3710**							
P	-0.4668**	0.6998**						
K	-0 4175**	0.8536**	0.6216**					
Ca	-0.2183	-0.2143	0.0574	-0.2218*				
Mg	-0.2301*	0.1897	0.0787	0.2065	0.0882			
S	0.0443	-0.1068	-0.0744	-0.1443	0.1216	-0.2397*		
Na	-0.3293**	0.2174	0.3287**	0.1630	0.2407*	0.1560	-0.1020	
Cl	0.0798	0.1315	0.4349**	0.0708	-0.1230	0.0288	-0.1383	0.1402

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

Table 46 Correlation matrix - High yield group - Overall harvests

	Yield	N	P	K	Ca	Mg	S	Na
N	-0.3804**							
P	-0.4675**	0.6466**						
K	-0.4705**	0.9125**	0.6547**					
Ca	-0.4118**	0.1012	0.2924**	0.0259				
Mg	-0.1930	0.2006	-0.0017	0.1884	0.0280			
S	-0.0310	-0.0270	-0.0132	-0.0627	0.0800	-0.0784		
Na	0.2594*	0.2119	0.1058	-0.1382	0.2082	0.4292**	0.2174	
Cl	-0.1330	0.1180	0.0912	0.1446	0.2016	0.3088**	-0.0294	0.2003

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

positive correlations in the early stages tended to become negative towards the later period may be because a higher removal of nutrients from the leaf towards nut production resulting from an increased production of nuts in these plants and the decrease became manifested towards the fag end of the harvests. This again stresses the importance of sampling time in plant analysis for determining effects on yield.

4.2.2 Overall yield groups

Simple correlations worked out pooling all the eight harvests and all yield groups together are presented in Table 47.

Coconut yield was significantly and positively correlated with N, P, K, S and Cl contents of the 10th leaf and was found to be significantly and negatively correlated with Ca and Mg status.

Considering the correlations among the leaf nutrients themselves it could be seen that the N content in the 10th leaf of all palms had a significant positive correlation with P, K, S, Na and Cl levels of leaf. Phosphorus levels of the 10th leaf had a significant positive correlation with K, S, Na and Cl while K content in turn was also positively and significantly correlated with S, Na and Cl levels of leaves. Calcium content of the 10th frond had also a significant positive correlation to S and Na contents while magnesium levels in leaf was observed to have a marked positive correlation to Na. Foliar sulphur content showed significant positive correlation to Cl content of leaves. The role of N, P, K, and Cl have already been discussed earlier. This might be because the increased uptake of one nutrient promotes the uptake of the other nutrients as well. Pushpangadan (1985) reported the importance of K on production of female flowers and significant interaction effect of NK and PK. An apparent increase in setting percentage was also observed for N and K.

From the sections 4.1 and 4.2 it has come out that it is N, P, K, Cl and to some extent sulphur which are the most important nutrients that play a major role towards nut production in coconut. The major nutrients and chlorine also seemed to influence one another positively. Thus these were the nutrients that emerged as most important for coconut yield and nutrition.

Table 47 Correlation matrix - Overall harvests, all yield groups and all plants

	Yield	N	P	K	Ca	Mg	S	Na
N	0.5126**							
P	0.4730**	0.9722**						
K	0.5193**	0.9925**	0.9726**					
Ca	-0.1629*	0.0485	0.1116	0.0602				
Mg	-0.1445*	0.0261	0.0019	0.0314	0.0988			
S	0.5442**	0.8696**	0.8535**	0.8779**	0.1314*	-0.0329		
Na	-0.1188	0.1376*	0.1299*	0.1053	0.1457*	0.1840**	0.0407	
Cl	0.5775**	0.9491**	0.9518**	0.9568**	0.0991	0.0168	0.8719**	0.1101

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

4.3 Regression Analysis

Simple linear equations and quadratic equations were fitted to study the relationship the individual leaf nutrient contents had with yield in the case of low, medium and high yield groups. It was observed that the quadratic response functions gave higher R^2 values than that of linear equation in every case and thus the results are interpreted based on the former.

For the three major nutrients, N, P & K alone, the R^2 values were found to be significant at 0.01 level for all the three yield groups studied. Among the secondary nutrients, while the response function fitted for sulphur was significant at 0.01 level and calcium was significant at 0.05 level for low yield groups, for medium yield groups, Mg gave significant R^2 values at 0.01 level. Sodium gave significant quadratic response at 0.01 and 0.05 levels respectively for the medium and high yielding palm types respectively. Using only the equations that gave significant R^2 values, different nutrient contents in the leaf for maximum yields were worked out and are presented in Table 51.

From the above results it is evident that yield is influenced in all types of palms by all the three major nutrient contents in the leaf. The large requirement of these nutrients by the plants is a well

Table 48

Summary results of Regression Analysis of low yielding palms

Nutrients	Estimated quadratic equation	F Value
N	$Y = -98.80707 + 145.4668\ N - 50.72071\ N^2$	9.85 **
P	$Y = -90.62138 + 1354.367\ P - 4835.5\ P^2$	6.22 **
K	$Y = -109.9205 + 307.3799 * K - 204.3052 * K^2$	28.63 **

* Significant at 5% level

Table Value

$F_{2,77}$ = 3.11 (5%)

" = 4.88 (1%)

ESTIMATED QUADRATIC RESPONSE FUNCTION OF NITROGEN FOR LOW YIELD GROUP

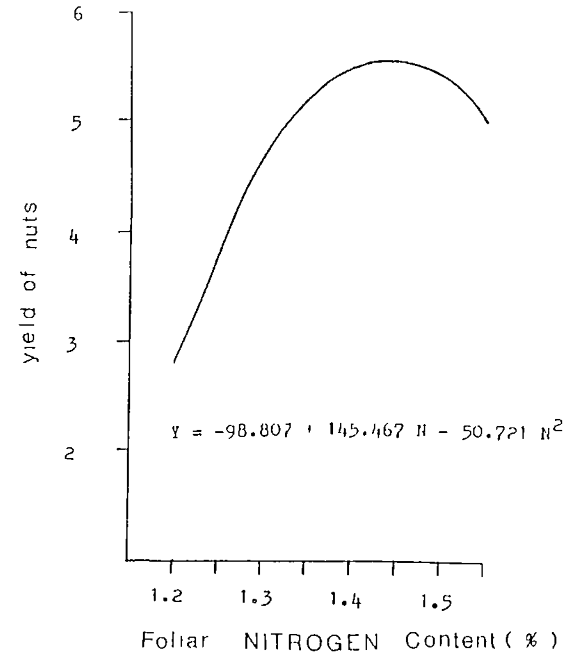


Fig 2

ESTIMATED QUADRATIC RESPONSE FUNCTION OF PHOSPHORUS FOR LOW YIELD GROUP

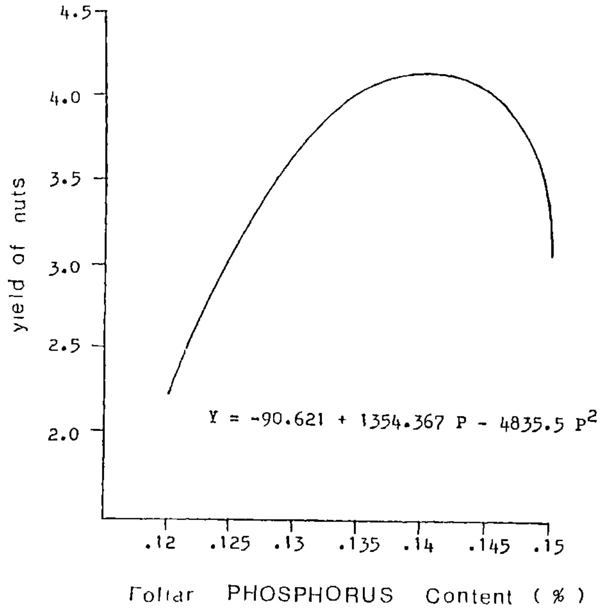


Fig 3

ESTIMATED QUADRATIC RESPONSE FUNCTION OF POTASSIUM FOR LOW YIELD GROUP

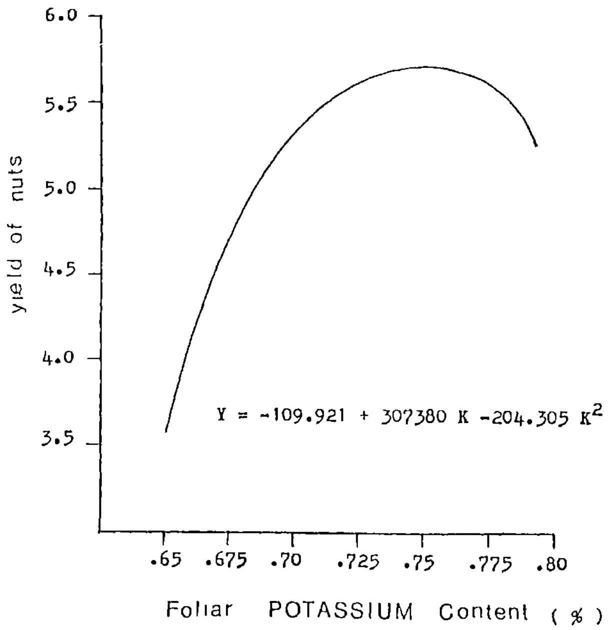


Fig 4

established fact and hence such influence is easily accounted. In the case of secondary nutrients the influence seemed to vary with palm types when sulphur and calcium gave equations with good fit for low yield groups, it was magnesium that gave a good response function for medium yield groups, while those of the secondary nutrients gave good fitted response functions for high yielders. The relative contents of these nutrients with respect to other leaf nutrient contents which may perhaps be the decisive factor were, varying witn the genetic make up of the plants under different yield categories.

A very interesting fact that could be observed was that only the leaf content of sodium gave response functions with good fit, and that too, only for medium and high yielders. Perhaps only with higher productions the role of Na becomes significant as at relatively lower yields, perhaps the leaf nutrient requirement is easily satisfied.

Only in the case of the major nutrients, N, P and K, leaf nutrient content for maximum yield could be arrived at for all the three plant types. The figure clearly shows how the leaf nutrient content of N and K responsible for maximum yields very

Table 49

Summary results of Regression Analysis of

medium yielding palms

Nutrients	Estimated quadratic equation	F Value
N	$Y = -241.9081 + 290.7188\ N - 83.57422\ N^2$	6.46 **
P	$Y = -431.9755 + 5155.063\ P - 15030.5^{*}\ P^2$	13.41 **
K	$Y = -1369.05 + 2610.11^{*}\ K - 1231.867^{*}\ K^2$	25.67 **
Na	$Y = 7{,}8437 + 12.97141\ Na - 22.43527\ Na^2$	5.25 **

* Significant at 5% level

Table Value

$F_{2,\ 77} = 3.11$ (5%)

" $= 4.88$ (1%)

ESTIMATED QUADRATIC RESPONSE FUNCTION OF NITROGEN FOR MEDIUM YIELD GROUP

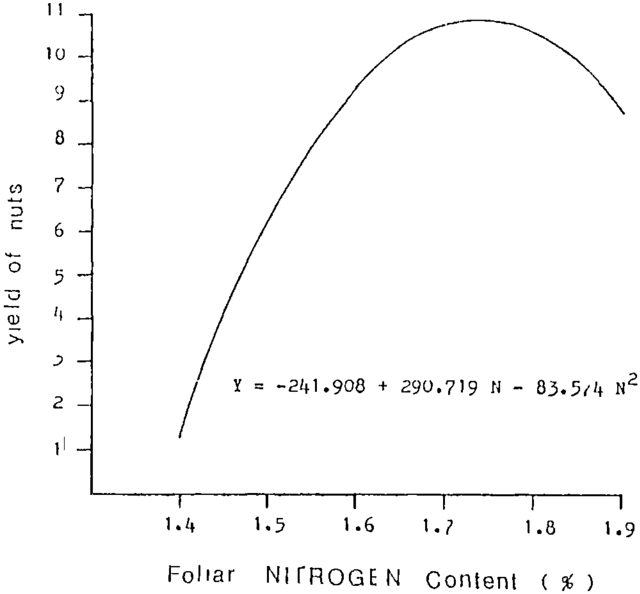


Fig 5

ESTIMATED QUADRATIC RESPONSE FUNCTION OF PHOSPHORUS FOR MEDIUM YIELD GROUP

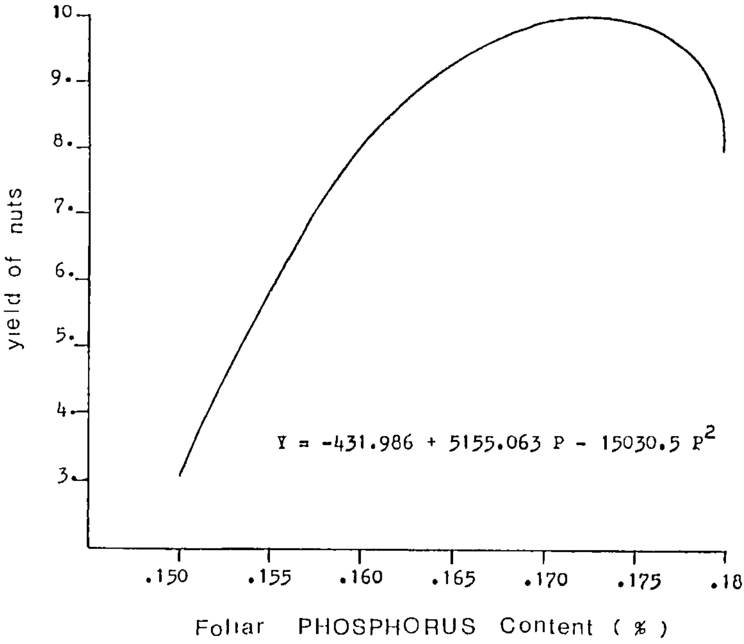


Fig 6

ESTIMATED QUADRATIC RESPONSE FUNCTION OF POTASSIUM FOR MEDIUM YIELD GROUP

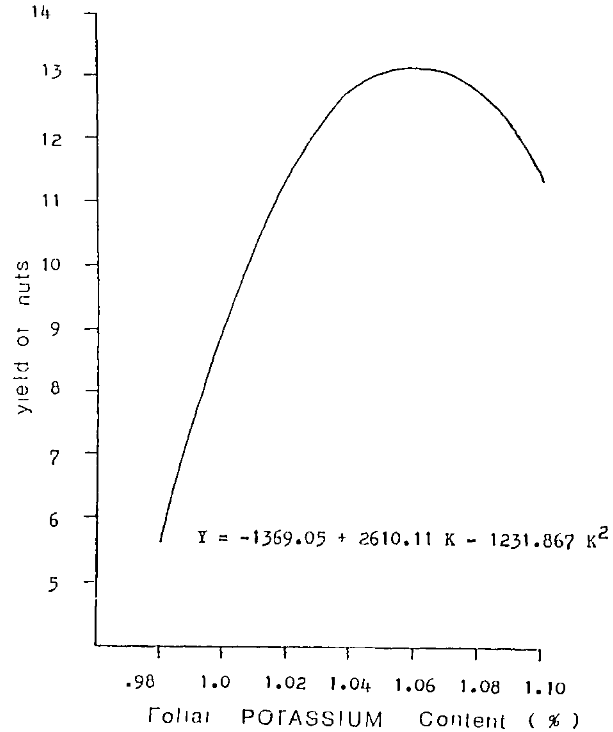


Fig 7

obviously increased from the low yielders to the medium yielders and from them to high yielders. Thus increasing yielding ability also very largely depends upon higher contents of these nutrients in the leaf to meet the requirements for top yields. A comparison of the contents of the major nutrients in the leaf in each category of palms for maximum yields again show that N content was the highest in all palm types followed by K and then by P following the pattern obtained by Indirakutty and Pandalai (1968), Abraham (1978), Pushpangadan (1985). The N and P contents in the leaf (1.91% and 0.12% respectively) for maximum yield for high yielders were very much the same as the ciritical levels of these nutrients as suggested by Fremond et al. (1966) who stated that critical levels in frond 14 for nitrogen was 1.8 to 2.0 per cent and phosphorus was 0.12%. However, the potassium value obtained in this study for maximum yield in high yielding plant type was 1.33% which was higher than the critical value suggested by the above authors (0.8 to 1.0%). Variation in the frond selected or the age of the palms may be the reasons why the nutrient contents for maximum yields were near to the suggested ciritical levels.

Table 50

Summary results of Regression Analysis of high yielding palms

Nutrients	Estimated quadratic equation	F Value
N	$Y = -300.599 + 338.367\ N - 88.5\ N^2$	6.80 **
P	$Y = 0.6662703 + 515.375\ P - 2109.25\ P^2$	10.82 **
K	$Y = -1065.909 + 1638.5 * K - 617.8516 * K^2$	15.92 **
S	$Y = 17.2881 + 367.457\ S - 1065.914\ S^2$	0.05

* Significant at 5% level

Table value

$F_{2, 77}$ = 3.11 (5%)

" = 4.88 (1%)

ESTIMATED QUADRATIC RESPONSE FUNCTION OF NITROGEN FOR HIGH YIELD GROUP

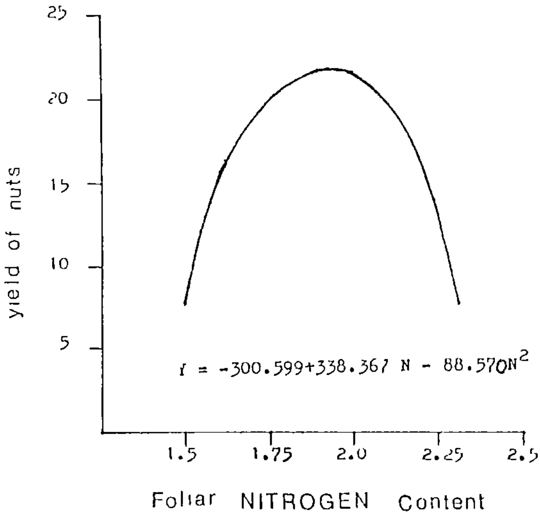


Fig 8

ESTIMATED QUADRATIC RESPONSE FUNCTION OF PHOSPHORUS FOR HIGH YIELD GROUP

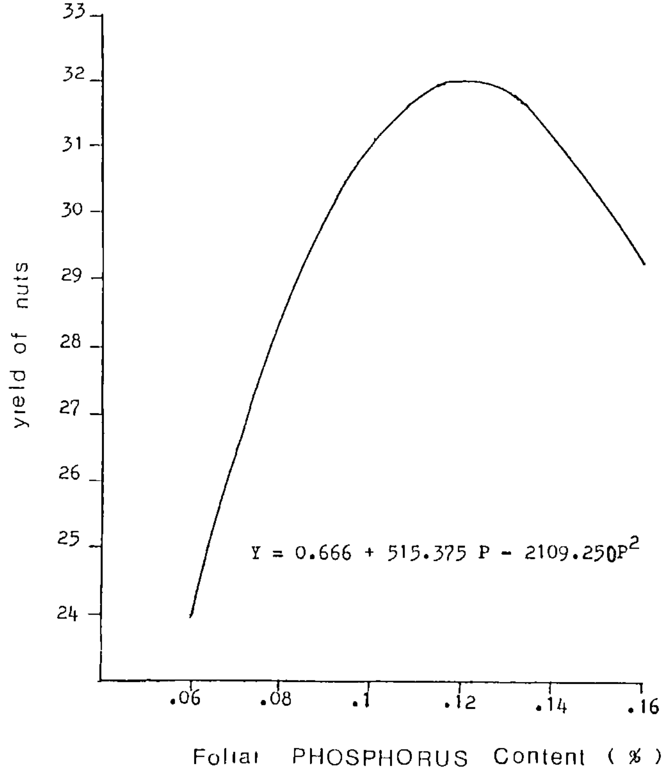


Fig 9

ESTIMATED QUADRATIC RESPONSE FUNCTION OF POTASSIUM FOR HIGH YIELD GROUP

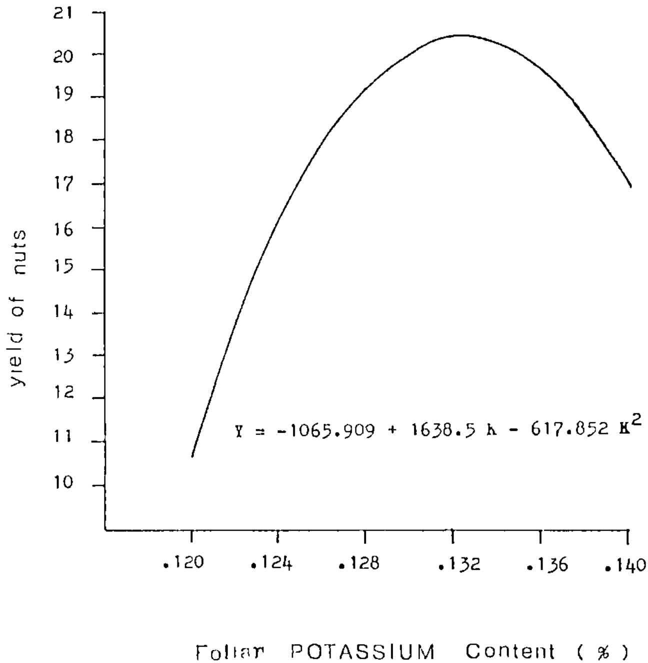


Fig 10

Indirakutty and Pandalai (1968) has reported that leaf N contents were 1.64%, 1.76% and 1.86%, leaf P contents were 0.12%, 0.13% and 0.14% and leaf K contents were 0.81%, 1.11% and 1.30% for low yielders, medium yielders and high yielders respectively indicating an increase in all the three major nutrient contents in the leaf with increase in yielding ability. This is very much in agreement with the results of the present study except in the case of P which showed a slight decrease from medium yielders to high yielders.

Foliar analysis by Smith (1969) had revealed that coconut yield is not a function of individual effect of nutrients but their interactions. Hence the ratios involving major nutrients in the leaf for maximum yields in the different categories of coconut palms were worked out and are presented in Table 52. The N : P ratio increased very slightly from low yielders to medium yielders but the increase was much higher from medium yielders to high yielders. This might be because of the slight fall in P content coupled with the increase in N content from the medium yielders to high yielders. Consideraing the N : K ratio it is very abvious that there was a steady decrease from low yielders to medium yielders and from then to the high yielders. Thus increased yields seemed to be associated with higher

Table 51 Leaf nutrient contents for maximum yields

Leaf nutrient	Low yielding palms	Medium yielding palms	High yielding palms
N	1.433998	1.739285	1.911679
P	0.1400442	0.1714867	0.122170
K	0.7522567	1.059412	1.325966
Ca	0.6012837	-	-
Mg	-	0.2271092	-
S	0.1447736	-	-
Na	-	0.2890851	0.08487589
Cl	-	-	-

levels of K contents in relation to the N contents in the leaf. Since N and K contents increased from low yielders to medium yielders and from them to high yielder the accompanying fall in N : K ratio can only be accounted for by a greater rate of increase in K contents compared to N contents. The similar downward trend shown by P : K ratios also underline this point. Increased yields due to increased trunk height, female flower production, number of bunches and number of nuts have been reported by many authors (Anon, 1969; Smith, 1969; Pomier and Taffin, 1982 and Pushpangadan, 1985). The low profile of phosphorus is also observed by many authors (Salgado, 1946; Pushpangadan, 1985).

The major role that potassium seemed to play can be explained by the fact that this nutrient is important for regulating water economy, promoting root development and imparting disease resistance. Increased leaf area, improved leaf angle and leaf colour, better utilization of sunlight, increased number of fronds, inflorescence, female flowers, nut set and ultimately yield due to potassium have been reported by Von Uoxkull (1971). Queneez and Taffin (1981) have suggested that a good mineral nutrition, especially of potassium, enables coconuts to get through the dry season easily, leading to a notable yield increase.

Table 52 Nutrient ratios and yielding capacity

Nutrient ratio	Low yielding palm type	Medium yielding palm type	High yielding palm type
N:P	10.21	10.24	15.92
N:K	1.91	1.64	1.44
P:K	0.19	0.16	0.09

A significant negative correlation between foliar N : K ratio and yield has also been observed in coconut by Abraham (1978).

4.3.1 Multiple regression

The multiple linear regression of yield on leaf nutrients was investigated. The fitted regression equation are given in table 53 . All the fitted regressions were found to be significant. Among the partial regression coefficients, the regression of yield on K and Ca were found to be significant in low yielders, P and Cl in medium yielders, N and Ca in high yielders. When regression was fitted in over all types of palms P, Ca, Mg, S and Na were found to have significant influence on yield. The SE of the regression co-efficient are given in appendix. 47% of variation in yield was explained by the fitted regressions in low and high yielders, 41% in medium yielders and 49% when all the palms were taken together.

4.4 Direct and indirect effect of foliar nutrient content on yield

The cause and effect relationship of foliar nutrients on yield was explained by path analysis. Consideraing yield (effect) as a function of various causal factors (foliar nutrients) the direct and indirect contribution of these foliar nutrients to the

Table 53 - Summary results of Multiple Regression Analysis

Palm Type			
Low	Y = 34.64 + 1.24 N - 28.51 P - 26.66 K** - 8.90 Ca** - 2.60 Mg -23.16 S - 1.28 Na + 19.24 Cl.	F = 7.90**	R^2 = 47%
Medium	Y = 63.66 + 17.19 N - 329.06 P ** - 31.49 K - 5.63 Ca - 17.16 Mg - 5.41 S - 5.52 Na + 72.05 Cl **	F = 6.13**	R^2 = 41%
High	Y = 93.80 + 85.45 N **- 142.19 P - 149.66 K* - 27.81 Ca * - 19.07 Mg - 70.25 S - 10.17 Na + 29.49 Cl	F = 7.91 **	R^2 = 47%
Over all Palm types	Y = 14.93 + 11.16 N - 238.52 ** P - 8.16 K - 11.62 Ca ** - 20.07 Mg *+ 91.99 *S - 5.80 * Na + 102.92 Cl	F = 27.55	R^2 = 49%

* Significant at 5% level

** Significant at 1% level

$F_{8, 71} = 7.90$

effect is given in Table 54 to 56.

4.4.1 Low yield groups (Table 54 and Fig.11)

Significant negative correlation was observed between nitrogen and yield (-0.4403) while its direct effect was positive but less. Indirect effects of N via. Ca and Cl were positive while through others were negative. The negative significant correlation is mainly influenced by the indirect effect of nitrogen through K (-0.56184).

Both the direct effect of P and its correlation with yield was negative (-0.3340) but the direct effect contributed only about 28% of this correlation. The indirect effects of P via., K, Mg and Na were negative and through N, Ca, S and Cl were positive. A major share of this correlation is accounted by the indirect effect of P via., K (-0.40604).

Significant negative correlation was observed between K and yield (-0;5343) and the direct effect of K was also negative and high (0.63464). The positive indirect effect of K via., Ca (0.11539) is mainly responsible for a slight reduction in the magnitude of this correlation. Though the direct effect of Ca (-0.41445) and its correlation with yield was negative

Table 54 Direct and indirect effects of foliar nutrient contents on yield in Low yield palms

X_1 (N)	X_2 (P)	X_3 (K)	X_4 (Ca)	X_5 (Mg)	X_6 (S)	X_7 (Na)	X_8 (Cl)	r
0.03264	-0.05647	-0.56184	0.14692	-0.00224	-0.00099	-0.02064	0.02233	-0;440
0.01990	-0.09263	-0.40604	0.06039	-0.00199	0.00902	-0.00738	0.08473	-0.3340
0.02889	-0.05926	-0.63464	0.11530	-0.00686	0.00154	-0.00230	0.02302	-0.534
-0.01157	0.01350	0.17656	-0.41445	-0.00296	0.00130	0.00434	-0.00742	-0.240
0.00176	-0.00442	-0.10452	-0.02943	-0.04163	0.00027	0.00489	-0.01652	-0.1896
0.00063	0.01614	0.01885	0.01044	0.00022	-0.05178	-0.00237	-0.02163	-0.0295
0.00832	-0.00844	-0.01802	0.02221	0.00251	-0.00151	-0.08100	-0.00337	-0.079
0.00571	-0.06146	-0.11442	0.02408	0.00539	0.00877	0.00214	0.12770	-0.002

(Residual effect 0 72733)

DIRECT AND INDIRECT EFFECTS

LOW YIELD GROUP

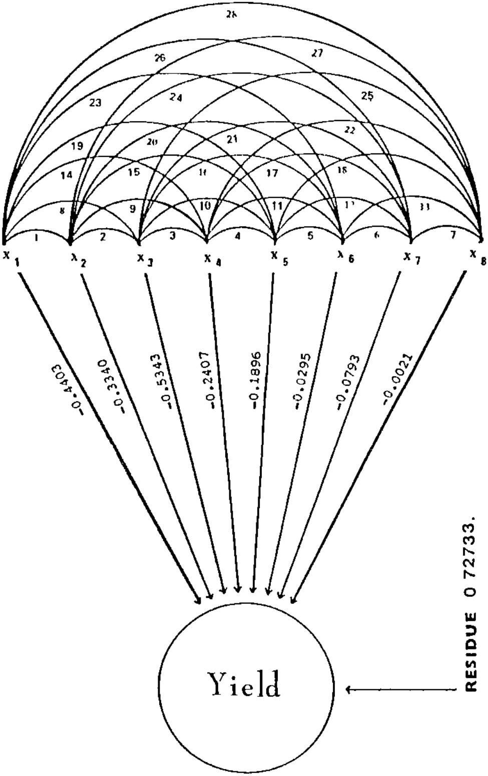


Fig : 11

(-0.2407) the magnitude of its direct effect is higher than that of its correlation. The positive indirect effect of Ca especially via., K (0.17656) dominated Ca in influencing the yield directly.

The correlations of Mg, S, Na and Cl with yield were negative and not significant. The effect of S, Na and Cl with yield were negligible. However, the direct effect of Cl was positive (0.12770). The value of residue factor (0.72733) reveals that 27% of the variation in yield was influenced by these eight leaf nutrients in low yielding coconut palms.

4.4.2 Medium yield groups (Table 55 and Fig.12)

Significant negative correlations were observed for N, P, K, Mg and Na with yield. Though the correlation betwen N and yield (-0.3710) was negative the direct effect of N was positive. The indirect effects of N through P, K, Mg and Na were negative and through Ca, S and Cl were positive. The negative indirect effects of N via., P and K was mainly responsible for the negative correlations of N with yield.

Both direct effect of P (-0.51206) and its correlation (-0.4668) with yield was negative. The indirect effect of P through N, S and Cl were positive

Table 55 Direct and indirect effects of foliar nutrient contents on yield in Medium yield palms

X_1 (N)	X_2 (P)	X_3 (K)	X_4 (Ca)	X_5 (Mg)	X_6 (S)	X_7 (Na)	X_8 (Cl)	r
0.22824	-0.35834	-0.24356	0.02447	-0.02847	0.00070	-0.03408	0.03998	-0.3710
0.15972	-0.51206	-0.17736	-0.00655	-0.01181	0.00049	-0.06145	0.13222	-0.4668
0.19483	-0.31829	-0.28533	0.02532	-0.03099	0.00095	-0.02552	0.02152	-0.4175
-0.04891	-0.02939	0.06329	-0.11417	-0.01323	-0.00080	-0.03768	-0.03739	-0.2183
0.04330	-0.04030	-0.05892	-0.01007	-0.15006	0.00158	-0.02442	0.00879	-0.2301
-0.02438	0.03810	0.04117	-0.01388	0.03597	-0.00660	-0.01597	-0.04205	0.0443
0.04962	-0.16831	-0.04651	-0.02748	-0.02341	0.00067	-0.15654	0.04265	-0.3293
0.03001	-0.22269	-0.02020	0.01404	-0.00434	0.00091	-0.02196	0.30402	0.0798

while through others were negative. The positive indirect influence of P especially through N and Cl resulted in a reduction in the magnitude of correlation.

The direct effect of K was negative (-0.31829) and its correlation with yield was also negative and significant (-0.4175). Maximum positive indirect effect of K was via., N (0.19483) and negative indirect effect was via. P (-0.31829). The major factor influencing K indirectly was P. The contribution of other factors were negligible.

The correlation of Ca with yield was not significant (-0.2183), its direct effect was also less (0.06329).

The direct effect (-0.15006) and correlation of Mg with yield (-0.2301) were negative. The indirect effects of Mg via., N, Ca, S and Cl were positive and with others were negative. The negative indirect effects contributed towards its correlation with yield.

The correlation and the direct effect of S on yield were negligible. The factor Na contributed about 48 per cent of its correlation with yield. Its negative influence via. P contributed much to this correlation.

DIRECT AND INDIRECT EFFECTS

MEDIUM YIELD GROUP

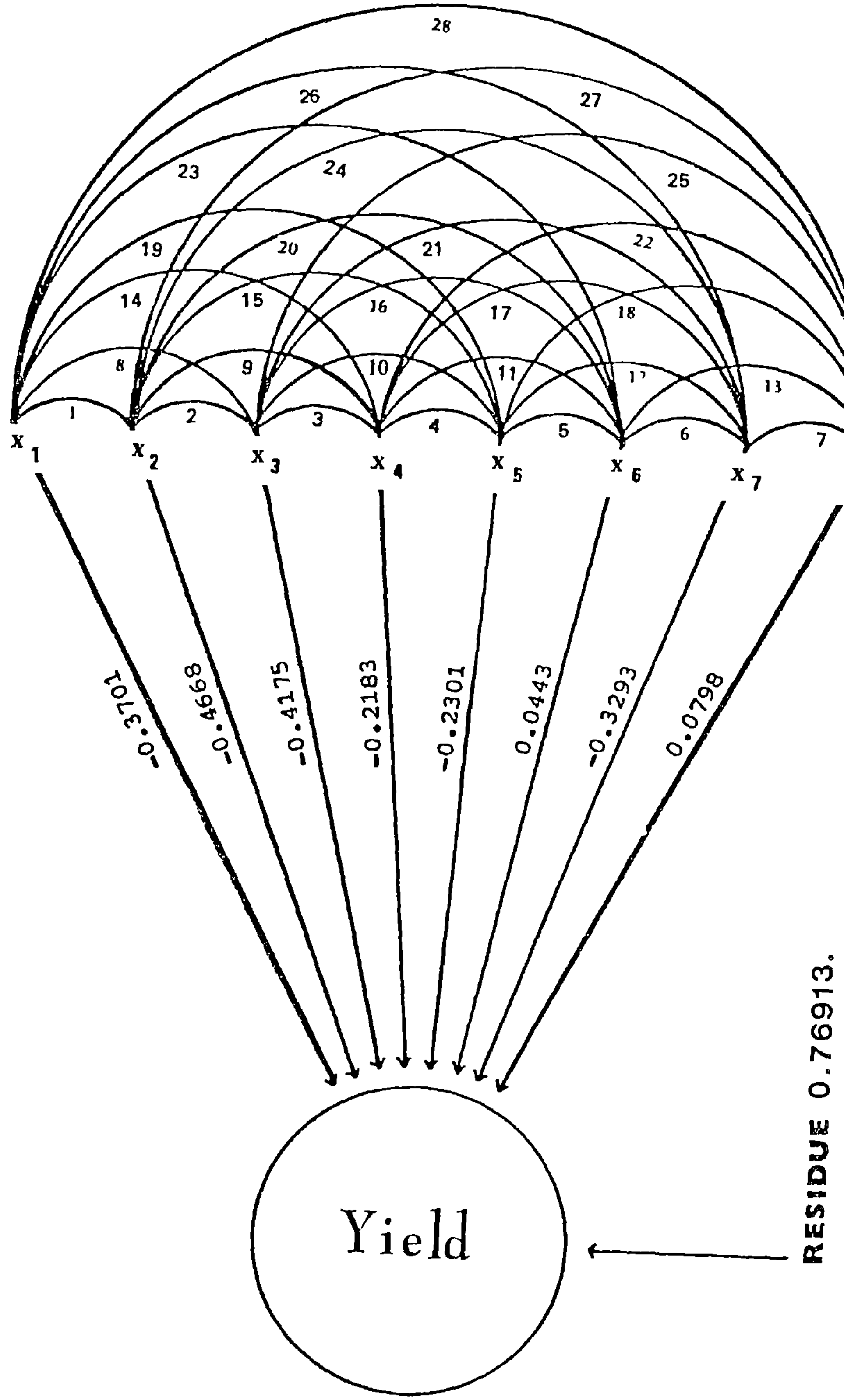


Fig : 12

Though the correlation of Cl with yield was negligible its direct effect was 0.30402. The negative indirect effect of Cl, especially via. P lead to a reduction in the magnitude of correlation. As the eight nutrients considered for the study contributed to 23 per cent of the variation in yield of medium yielding palm (Residue 0.7691).

4.4.3 High yield groups (Table 56 and Fig.13)

The leaf nutrient contents of N, P, K, Ca and Na were found to have significant negative correlation with yield while the remaining nutrients considered for this study were not correlated with yield of nuts in high yielding palms. The direct effect of N was high (0.61600) while its correlation with yield was negative and

The correlation of Cl with yield was negative and not significant (-0.1330) but its direct effect was positive and small (0.07445).

Twenty seven per cent of the variation in yield may be explained through the leaf nutrients considered in the case of high yielders (Residue = 0.7313). It is

Table 50 Direct and indirect effects of foliar nutrient contents on yield in High yield palms

X_1 (N)	X_2 (P)	X_3 (K)	X_4 (Ca)	X_5 (Mg)	X_6 (S)	X_7 (Na)	X_8 (Cl)	r
0.61600	-0.10627	-0.81073	-0.03902	-0.02112	0.00049	-0.02854	0.00879	-0.3804
0.39830	-0.16435	-0.58168	-0.11273	0.00018	0.00024	-0.01425	0.00679	-0.4675
0.56210	-0.10760	-0.88847	-0.00999	-0.01983	0.00114	-0.01861	0.01077	-0.4705
0.06234	-0.04806	-0.02301	-0.38554	-0.00295	-0.00145	-0.02814	0.01601	-0.4118
0.12367	0.00028	-0.16739	-0.01080	-0.10527	0.00143	-0.05781	0.02299	-0.1930
-0.01663	0.00217	0.05571	-0.03084	0.00825	-0.01818	-0.02928	-0.00219	-0.0310
0.13053	-0.01739	-0.12279	-0.08054	-0.04518	-0.00395	-0.13469	0.01491	0.2591
0.07269	-0.01499	-0.12847	-0.07773	-0.03251	0.00053	-0.02698	0.07445	-0.1330

DIRECT AND INDIRECT EFFECTS
HIGH YIELD GROUP

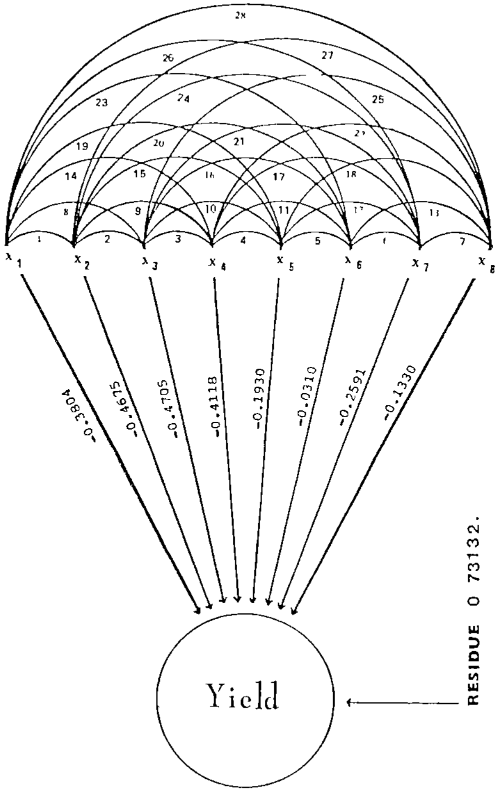


Fig 13

evident from the above results that the different nutrients differed in their roles for nut production with the different yield categories of palms especially in the indirect effects and for secondary and micro-nutrients. Some of the above results are in agreement with that obtained by Manciot et al. (1980) and Pushpangadan (1985).

SUMMARY AND CONCLUSION

Nutritional investigations through chemical analysis of index leaves of coconut palms was attempted at the College of Agriculture, Vellayani, utilizing the coconut leaf samples collected from the Instructional Farm, Vellayani. The data generated were subjected to various statistical treatments so as to arrive at concrete conclusions on the effect of different leaf nutrients on the ultimate yield of coconut palm. Elemental analysis with respect to N, P, K, Ca, Mg, S, Na and Cl were carried out in the 10th leaf of coconut palms of different yield groups at regular intervals of 45 days for one year from April 1987. The statistical analysis comprised simple correlation studies, analysis of variance, path analysis and regression analysis.

Simple correlation studies between the concentrations of eight plant nutrients and the nut yield at individual harvests revealed that the major plant nutrients viz., N, P and K could influence the nut yield to a significant extent irrespective of the yield level of the palm. The reported benefit of sodium application seemed to be due to its substitutive effect to potassium. Meanwhile the importance of chlorine nutrition for coconut palms emerged positively from the results. This trace elements not only has a direct impact on the yield but also has significant interactions with the major nutfients. The correlations were significant at relatively lower yield levels which became less prominent as the yield increased.

A correlation between the overall data for nut yield from different yield groups and the nutrient contents revealed a clear picture on the effect of nutrients, eliminating the effect of genetic variations. In this case N, P, K, S and Cl were found to influence the yield directly as well as through their interactions. On the contrary, when the data for different harvests of individual yield groups were pooled and tested the genetic variations masked the effect of nutrients on yield.

Simple correlations worked out after pooling all the eight harvests and all the palm types revealed that the coconut yield was significantly and positively correlated with N, P, K and Cl contents of the 10th leaf, where as the secondary nutrients viz., Ca and Mg had a negative impact on yield. The effects of Na and S were not consistent and therefore definite conclusions could not be drawn.

Results of analysis of variance studies showed that there was significant variation between the nut yield at different harvests. Highest yields were obtained in the third harvest closely followed by second and first. It may be noted that the leaf nutrient - yield correlations were much pronounced in the first to fifth harvests. Therefore, the optimum sampling time of foliar diagnosis is suggested between April and July, since the content of nutrients in the leaf at this stage was found to influence the yield over the complete year.

In the case of major nutrients viz., N, P and K a higher leaf concentration do not imply better yields immediately as evidenced by their low contents during the first and third harvests and higher concentrations at seventh and eighth harvests. The variation in Ca, Mg and S contents at the different sampling times and different yield groups did not show any definite trend since the effect of these nutrients on the yield of nuts is relatively insignificant. However, better yields were associated with high sulphur content in the leaves whereas the calcium content was same in high as well as low yielders. Magnesium content did not vary between the yield groups.

In the case of other nutrients Na content did not vary between yield groups while Cl showed a remarkable association with yield levels. The Cl content also varied significantly between the different sampling times.

The prominent nutrient elements which play decisive roles in coconut production were found to be N, P, K, Cl and to some extent S whereas the role of Na is considerable only in cases of K deficiency.

In order to give a concrete scientific footing for the above findings path analysis of the data was carried out which revealed the direct as well as indirect effect of different nutrients on the yield of coconut palms. The eight nutrients considered for the study were found responsible for 27% of the variation in yield of low yielding palms while the corresponding figures were 23% and 27% respectively for medium and high yielders. The role played by individual nutrients towards nut production varied with yield level.

Regression analysis yielded the conclusion that individual leaf nutrient contents had a quadratic relationship with the yield of coconut palms. This relationship was more pronounced in the case of N, P and K at all yield levels. Other nutrients under investigation showed variations at different yield levels. It is suggested that elements which are taken up by the palm in bulk quantities have a direct influence on yield in the quadratic nature of response while the other essential elements were significant only at relative concentrations for maintaining optimum nutrient ratios for maximum metabolic activities.

The N, P and K contents in 10th leaf for maximum yield as evolved from this study are 1.91 per cent, 0.12 per cent, and 1.33 per cent respectively for high yielding palms. Increasing yield capacity seemed to involve improving the levels of the nutrients in the leaf while the contents of secondary nutrients and trace elements have to be judiciously managed to satisfy optimum nutrient ratios.

Potassium emerged to be the single major nutrient determining most of the yield variations in coconut as evidenced by the lower N : K ratios at higher yield levels. Multiple regression analysis resulted in the observation that the coconut yield is not a function of individual effects of nutrients but is determined by simultaneous interactions of all the nutrients.

Some of the salient findings summarised above were of heuristic nature and therefore, the following suggestions are presented for future research.

1. The source-sink relationships of nutrient element have to be established in coconut palms at various agro-climatic and genetic differences, through bio-chemical analysis of compounds which take part in metabolic activity than the elemental analysis of leaves.

2. The interactions of nutrient elements have to be brought out by computing nutrient ratios and working out their effects on ultimate yield.

3. While investigating the effect of nutrients on nut yield of coconut it is important that the yield of copra and oil as well as the quality of oil have to be considered since these may be influenced greatly by the level of nutrition.

4. The specific roles played by elements like sodium and chlorine seem to be varied at different yield levels. Therefore, there is need to delineate their roles from other nutritional, genetic and environmental variations.

5. Experiments in the present line of work have to be carried out at different age groups of palms so as to evolve manurial recommendations at different stages of growth of this perennial palm.

6. Standardisation of index tissues and critical levels for different nutrients at different growth stages and habitats must be undertaken.

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APPENDICES

Appendix - I

Meteorological observations recorded during the experimental period.

Month	Max.Temp. °Celcius.	Min.Temp. °Celcius.	Rain Fall. mm.
April	33.98.	23.27.	48.0
May	33.24.	23.64.	83.0
June	31.18.	22.62.	223.1
July	31.04.	21.90.	20.4
August	30.38.	23.50.	272.6
September	31.28.	24.27.	125.7
October	31.55.	24.00.	286.0
November	30.46.	23.57.	182.3
December	30.86.	22.74.	233.2
January	31.52.	20.97.	Nil
February	32.19.	22.57.	6.6
March	33.21.	25.07.	55.3

Appendix - II

Physical and chemical properties of soil in the experimental site

Mechanical composition:			
Coarse Sand	-(%)-	13.7.	(International pipett method)
Fine Sand	-(%)-	33.4.	" "
Silt	-(%)-	28.0.	" "
Clay	-(%)-	24.7.	" "
Textural class	:	Loam	
p^H	:	7.2	
Organic Carbon	:	0.49%	Jackson (1967)
Available phosphorus	:	92 ppm	"
Exchangeable Potassium	:	81 ppm	"
Magnesium	:	0.7 (me/100g)	"
Calcium	:	1.3 (")	"
Sulphur	:	152 ppm	"
Sodium	:	462 ppm	"
Chlorine	:	180 ppm	"

APPENDIX III

Standard error of partial regression co-efficient

Partial regression coefficient	Low	Medium	High
N	19.39	13.77	29.85
P	11.16	21.79	107.98
K	28.55	17.43	37.52
Ca	5.80	9.77	7.25
Mg	3.60	5.30	19 55
S	0.08	0.20	75.14
Na	0.63	10.84	6.40
Cl	0.00	0.64	36.92

RELATIONSHIP BETWEEN LEAF NUTRIENTS AND YIELD IN COCONUT

By
MOHANACHANDRAN. S.

ABSTRACT OF A THESIS
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COLLEGE OF AGRICULTURE
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An investigation on the nutritional status of coconut palms as reflected in the 10th fronds and its relation with the yield of palms was carried out at the College of Agriculture, Vellayani during 1987 from samples drawn from palms of three yield groups (low, medium and high yielders). Chemical analysis of leaves for N, P, K, Ca, Mg, S, Na and Cl were undertaken at 45 days interval for one year from April 1987, statistically analysed and correlated in various ways with the yield at the same intervals.

The already established relationship that coconut yield is significantly influenced by the level of major nutrients viz., N, P and K on the 10th leaf at all the yield levels was confirmed in the present investigation. The benefit of Na application seemed due to the substitutive effect of this nutrient for K. Significance of Cl nutrition emerged positively during the investigation.

Irrespective of the genetic variations and consequent yield differences it was found that N, P, K, S and Cl could influence the yield directly as well as through their interactions. However, higher levels of Ca and Mg had a negative impact on yield.

Analysis of variance studies revealed that there is significant seasonal variations in the yield of coconut palms irrespective of the nutritional status. The optimum time for foliar diagnosis is suggested between April and July.

Higher levels of N, P and K in the index leaves do not imply immediate yield benefits but will be reflected in the yield consequently. Better yields were associated with high S content in the leaves. So was the case with the Cl content.

The eight nutrients considered for study viz., N, P, K, Ca, Mg, S, Na and Cl were found to explain 23 to 27 per cent variations in the yield.

The favourable influence of major nutrients viz., N, P and K was quadratic in nature while the other essential elements helped in maintaining optimum nutrient ratios.

The N, P and K content in the 10th leaf for maximum yield is predicted as 1.91, 0.12 and 1.33 per cent respectively for high yielding palms.

Multipple regression analysis suggested that coconut yield is not a function of individual effects of nutrients but is determined by the simultaneous interaction of all the nutrients.