EFFECT OF CONTINUOUS N P K FERTILIZATION ON THE GROWTH AND YIELD BEHAVIOUR OF COCONUT WITH SPECIAL REFERENCE TO POTASH NUTRITION AND ITS INTERRELATION WITH OTHER MINERAL NUTRIENTS

By
K. PUSHPANGADAN

THESIS
submitted in partial fulfilment of the requirement
for the degree of
Doctor of Philosophy
Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, TRIVANDRUM

1985

DECLARATION

I hereby declare that this thesis entitled " Effect of continuous NPK fertilization on the growth and yield behaviour of coconut with special reference to potash nutrition and its interrelation with other mineral nutrients " 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.

(K. PUSHPANGADAN)

Vellayani,

CERTIFICATE

Certified that this thesis entitled " Effect of continuous NPK fertilization on the growth and yield behaviour of coconut with special reference to potash nutrition and its interrelation with other mineral nutrients " is a record of research work done independently by Sri K. PUSHPANGADAN under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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

(DR. N. SADANANDAN)
Chairman,
Advisory Committee,
Dean, Faculty of Agriculture,
Kerala Agricultural University.

Vellayani,
4..10..1985.

APPROVED BY

Chairman

DR.N. SADANANDAN

Members:

DR. M.M. KOSHY

DR. C. SRIDHARAN

SHRI K.P. MADHAVAN NAIR

DR. P. SARASWATHY

ACKNOWLEDGEMENT

I wish to place it on record my deep sense of gratitude and indebtedness to Dr. N. Sadanandan, B.Sc.(Hons.) (Agri.), Ph.D., Assoc. I.A.R.I., Dean, Faculty of Agriculture, Kerala Agricultural University for his valuable guidance, constant encouragement, help and critical suggestions, throughout the course of the present thesis.

I am deeply indebted to Dr.C.Sreedharan, Professor and Head, Department of Agronomy, College of Horticulture, Vellanikkara whose inspiration, encouragement and suggestions helped me during the conduct of the study.

I am greatly obliged to Dr. M.M. Koshy, Professor Research Co-ordination, College of Agriculture, Vellayani for his valuable suggestions and evaluation of the script.

I am extremely thankful to Dr. R.S. Aiyer, Professor and Head, Department of Soil Science and Agricultural Chemistry for his inspiring suggestions and critical scrutiny of the script.

My sincere thanks are due to Dr.V.K. Sasidhar, Professor, Department of Agronomy, College of Agriculture, Vellayani for his inspiring suggestions and critical scrutiny of the script.

I am extremely thankful to Sri K.P. Madhavan Nair, Associate Professor, Department of Agronomy for his timely help and constant encouragement.

I am greatly obliged to Dr. P. Saraswathy, Associate Professor, Department of Statistics, College of Agriculture, for the valuable help and guidance in the statistical analysis of the data.

I wish to express my sincere thanks to Sri. Rajendran, P. Assistant Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture for the help rendered in the chemical analysis.

I am very much thankful to Sri. Jacob Thomas, M., Junior Assistant Professor, Department of Statistics, College of Veterinary and Animal Sciences, Mannuthy for the help rendered in the statistical analysis of the data.

My sincere thanks are also due to Smt. M. Suharban, Assistant Professor, Smt. K.R. Sheela, Junior Assistant Professor and Smt. R.Devika, Junior Assistant Professor - my associates in the Instructional Farm, Vellayani for their constant encouragement and manifold assistance.

I am grateful to the staff members of the Coconut Research Sub-Station, Balaramapuram for providing me with the biometric data for the previous years and also for the facilities and generous help extended to me.

I am grateful to the authorities of the Kerala Agricultural University for giving me selection to undertake my studies as a part-time student in the Kerala Agricultural University.

(K.PUSHPANGADAN)

Vellayani,

CONTENTS

	Page No.
INTRODUCTION	1
REVIEW OF LITERATURE ...	6
MATERIALS AND METHODS ...	47
RESULTS	60
DISCUSSION	146
SUMMARY AND CONCLUSION ...	190
REFERENCES	i - xi
APPENDICES	I - XIII

LIST OF TABLES

Table Number		Page Number
1	Annual removal of nutrients (kg/ha) by the coconut palm.	10
2	Nutrient removal by a single palm/year.	11
3	Removal of nutrients by different parts of the palm.	12
4	The effect of PK interaction on the number of nuts per palm.	28
5	Critical levels of NPK.	37
6	Yield groups and critical levels of NPK.	38
7	Treatment combination and schedule of fertilizer application.	59
8 to 23	Number of fronds as influenced by continuous NPK fertilization - June 1972 to December 1979.	61 - 68
24 to 39	Length of fronds as influenced by continuous NPK fertilization - June 1972 to December 1979.	71 - 78
40 to 55	Number of leaflet as influenced by continuous NPK fertilization - June 1972 to December 1979.	80 - 87
56 to 63	Number of female flower as influenced by continuous NPK fertilization - 1972 to 1979.	88 - 91
64 to 69	Setting percentage as influenced by continuous NPK fertilization - 1974 to 1979.	93 - 95

LIST OF TABLES

Table Number		Page Number
70 to 76	Annual yield of nuts per palm due to continuous NPK fertilization - 1976 to 1982.	97 - 100
77	Range in levels of nitrogen and percentage increase in yield of coconut.	101
78	Range in levels of K and percentage increase in yield of coconut.	102
79 - 79a	Cumulative yield of nuts per palm over replications (1976 to 1982).	104 - 104a
80	Regression of yield of coconut as affected by NPK fertilization.	106
81	Weight of unhusked nut due to continuous NPK fertilization.	108
82	Weight of husked nut due to continuous NPK fertilization.	108
83	Thickness of meat due to continuous NPK fertilization.	109
84	Weight of meat due to continuous NPK fertilization.	109
85	Weight of copra due to continuous NPK fertilization.	111
86	Thickness of shell due to continuous NPK fertilization.	113
87	Weight of shell due to continuous NPK fertilization.	113

LIST OF TABLES

Table Number		Page Number
88	Oil content due to continuous NPK fertilization.	116
89	Weight of fibre due to continuous NPK fertilization.	116
90	Nitrogen content of leaf due to continuous NPK fertilization.	118
91	Phosphorus content of leaf due to continuous NPK fertilization.	118
92	Potash content of leaf due to continuous NPK fertilization.	120
93	Calcium content of leaf due to continuous NPK fertilization.	120
94	Magnesium content of leaf due to continuous NPK fertilization.	121
95	Sodium content of leaf due to continuous NPK fertilization.	121
96	Effect of continuous NPK fertilization on leaf nutrient concentrations.	123
97	Simple correlation coefficients between yield and leaf nutrient concentrations.	125
98	Direct and indirect effects of foliar nutrients on yield.	128
99 - 100	Total nitrogen in soil due to continuous NPK fertilization.	130
101 - 102	Phosphorus content in soil due to continuous NPK fertilization.	132
103 - 104	Calcium content in soil due to continuous NPK fertilization.	134

LIST OF TABLES

Table Number		Page Number
105 - 106	Calcium content in soil due to continuous NPK fertilization.	136
107 - 108	Magnesium content in soil due to continuous NPK fertilization.	138
109 - 110	pH of soil due to continuous NPK fertilization.	140
111 - 112	CEC of soil due to continuous NPK fertilization.	143
113 - 114	Organic carbon in soil due to continuous NPK fertilization.	144

LIST OF ILLUSTRATION

Fig. No.		Between pages
1	Layout plan - confounded factorial experiment.	49 - 50
2	Response of N, P and K on the number of fronds.	68 - 69
3	Response of N, P and K on length of fronds.	78 - 79
4	Response of N, P and K on the number of female flowers.	91 - 92
5	Yield trend in coconut at various levels of N, P and K.	100 -101
6	Effect of N, P, K on foliar nutrients.	123 -124
7	Effect of applied N on soil factors at two depths.	144 -145
8	Effect of applied P on soil factors at two depths.	144 -145
9	Effect of applied K on soil factors at two depths.	144 -145

INTRODUCTION

INTRODUCTION

The coconut palm (Cocos nucifera L.) is one of the most widely cultivated tree crops of the world. It is a crop of great antiquity and has been known to exist in India since 3000 years ago. Every part of the tree is put to a variety of uses including shelter and fuel, and the nut is used as a garnish and as an edible oil. The juice tapped from the spadix of the palm is used to produce toddy-an intoxicating beverage-jaggery and the coconut feni. It hasalways been considered an object of reverence in local tradition and has been aptly extolled as the Kalpavriksha - the all giving tree.

India is the third largest coconut producing country of the world with an annual production of about 6200 million nuts from an area of around 1.2 million hectares. What is significant however, is that the demand for these products in India far exceeds the supply and that we are compelled to import about 15000 tonnes of coconut oil which is equivalent to 125 million nuts. The crop makes a significant contribution to the national economy with an annual export earning of around Rs.300 million, mainly through the export trade of coir and coir products.

Coming to Kerala, coconut palm plays an important role in the agrarian economy of the State. It covers an area of over 674378 ha. which is around 32 per cent of the total cultivated area in the State and 42 per cent of the total area under commercial crops. The estimated yield was around 2450 million nuts during the year 1982-'83. This is by itself very significant either in terms of the area or production in India as 62 per cent of the total area and 55 per cent of the total production of the country is concentrated in Kerala. Besides Kerala, the crop is grown in the coastal States of Orissa, Tamil Nadu, Goa, Karnataka and Assam, contributing only at very low proportions to the total extent and production of coconut in the country. The contribution of the crop to the total annual income of the State is around 15 per cent and the agricultural income around 30 per cent. Coconut provides raw material to one of the major traditional industries - the coir industry - which is of considerable importance to the rural economy of the State. The 'copra' - the dried kernel forms the raw material for a variety of industries connected with edible oil, cosmetics and cattle feed. It is estimated that about 70 per cent of the rural population depend on coconut either directly or indirectly, for their source of livelyhood in Kerala. Thus coconut plays a vital role in the economy of the State and is closely associated with the domestic life of the people of Kerala.

The area and production of coconut have been on the increase for the past 25 to 30 years. It is reported that the area has increased by 3.1 per cent per annum and the total production by 3.3 per cent per annum. However, the pitiable feature is that the per palm productivity of our country is only below 40 nuts and the present production of coconut is below the domestic demand. Thus the prospects for further development of this crop is promising not only in Kerala alone but in other States also. On a long term basis the prospects are even better, as the National Commission on Agriculture (1976) places our requirement at 12000 million nuts by 2000 AD.

The present low productivity of coconut in our country is attributed to lack of adequate management for maximum yield and reduction in yield caused by pests and diseases. Among the various diseases, the root-wilt disease is the most serious menace responsible for the maximum economic loss to the country. The annual loss caused by this disease alone has been reported to be approximately 340 million nuts.

The important pre-requisites for maximising the production of coconut are (1) Expansion of area under coconut (2) Genetic improvement of the crop by producing and popularising high yielding disease resistant varieties (3) Adoption of intensive agricultural practices for maximising the production per palm and inturn per unit area and (4) The prevention of decline in the yield by effectively controlling the pests and diseases.

Most of the coconut soils are low in major nutrients. It has been found that continued application of fertilizers to young palms had improved the available nutrient status of the top 50 cm soil, the higher level having superior effect. It is also considered that the continued application of fertilizers had little effect on soil organic carbon and available nitrogen. But there was considerable build up of available P and K in the soil. The role of K in the nutrition of coconut palm has also been well established. It was therefore felt necessary to conduct a critical study on the effect of continued fertilization of NPK in coconut right from the planting of seedlings in 1964 to full bearing stage as on 1982, on soil nutrient status, leaf nutrient content, growth and yield attributes. The objects of the study were

1. To assess the effect of NPK and their interactions at varying levels on growth, yield and productivity of the palm.
2. To elaborate the role of major nutrients with special reference to K nutrition of the palm.
3. To study the effect of continued use of fertilizers on nutrient build up in soil and in coconut palm tissues in relation to growth and yield.
4. To correlate the leaf nutrient content with growth parameters and yield.

5. To suggest fertilizer recommendations based on critical levels of leaf nutrient content.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A brief review of the research conducted on mineral nutrition of coconut and related crops is presented below:

2.1. Mineral nutrition of the coconut palm

Rational manuring is one of the most important means for obtaining higher and stabilised yields from the coconut palm. The quantity and proportion of nutrients supplied through fertilizers should meet the requirements of the palm and should be determined on the basis of soil fertility and productivity of the plantation.

The vital aspect of mineral nutrition of the palm is to ensure the availability of the essential mineral elements in the soil in the required levels and in right proportions for its maximum productivity. The two important approaches for achieving this vital aspect are (1) to assess the mineral demand of the palm for expressing its full production potential and (2) to assess the supply potential of the soil for nutrient elements.

Nathanael (1958) suggested three approaches to study the mineral nutrition of the palm viz (1) to assess the mineral requirements of the palm with the aid of fertilizer experiments and by successive approximation (2) to analyse the soil for its nutrient supplying capacity and (3) to analyse the coconut water and leaves for understanding the level of nutrition of the palm in relation to its productivity as well as the available nutrient status of the soil. Nathanael (1969) further elaborated the conceptual basis to assess the nutrient requirement of the coconut palm by the equation $F = R - S + L$ where F is the quantity of fertilizer nutrient, R is the quantity of nutrient required by the crop for unrestricted growth, S is the quantity of the nutrient supplied by the soil and L is that portion of the fertilizer nutrient not utilized by the crop plant. He calculated the annual removal of the major nutrients by a middle aged palm of the ordinary tall variety as 0.59 kg N, 0.26 kg P_2O_5 and 0.86 kg K_2O, when the yield is about 40 nuts per year. If the mean yield is around 60 nuts, he calculated the nutrient removal at 0.72 kg N, 0.33 kg P_2O_5 and 1.08 kg K_2O per palm per year.

Ollagnier et al. (1970) described two possible methods for studying the mineral nutrition of oil palm. 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 for assessing the deficiency/surplus levels of the nutrient elements in relation to yield.

Recent concepts and approaches in the assessment of nutrient requirements of coconut include (1) estimation of nutrients removed by the palm for its growth and productivity (2) fertilizer trials (3) foliar analysis and soil testing and (4) diagnosis of nutrient deficiencies by visual symptoms.

Any one of the above methods independently may not give a correct picture of the situation. For example, fertilizer trials are location specific and are not condusive for general adoption. Conventional soil analysis is difficult to interpret when a large volume of soil and subsoil is covered by the coconut roots. Very often the composition of the leaves is not related to soil contents as the depth of useful soil and its structure are found more important than the nutrient concentrations. The sustained argument against soil testing is its inability to provide information on the nutrient absorption capacity of the palm. Visual deficiency symptoms generally appear only under established deficiency conditions after passing through stages of hidden hunger. Moreover the occurrence of multiple deficiencies - pests and diseases, unfavourable environmental conditions etc. interfere in the correct diagnosis. The most widely adopted method is foliar analysis and fertilizer recommendation based on established critical levels. This method has a limitation that it fails to differentiate between metabolically active and inactive fractions of the elements in the leaf tissues. The sinergistic/antagonistic interaction between elements may lead to misinterpretation of foliar values. Environmental factors, type of cultivars/hybrids and the genetic potential of the palm change the critical nutrient element values.

As such an integrated approach giving a meaningful interpretation of the different methods based on practical wisdom with respect to each situation is very much required to assess the nutrient requirements of the coconut palm. However, the results and interpretations of various approaches made to understand the nutritional requirement of the palm are reviewed in the following pages.

2.1.1. Removal of nutrients by the palm

Of the various components of nutrient demand viz., (1) Removal of nutrient by the palm (2) Loss by leaching, volatilisation and also weed growth and (3) Immobilisation of nutrient elements at a particular soil-plant system, the quantity of nutrient uptake for optimum production is an important factor for the assessment of the fertilizer requirement of a crop with due consideration and understanding to the fertility status of the soil.

A number of workers as reported by Santiago (1978) have estimated the removal of nutrients by middle aged bearing palms and have obtained widely varying values. This is probably due to variation in agro-climatic conditions, management practices and the plant material itself. Some of the available data are furnished in Table-1.

Most of the workers had taken only the harvested nuts into account in their evaluations. But in coconut,

Table 1

Annual removal of nutrients (kg/ha) by the coconut palm

Sl.No.	Nutrients N	P	K	Ca	Mg	Basis	Reference
1	20.0	2.5	35.0	NA	NA	4900 nuts/ha/year	Pillai (1919)
2	64.0	12.7	79.0	NA	NA	Annual removal/ha.	Jacob and Coyle (1927)
3	92.0	18.1	113.0	NA	NA	6900 nuts/ha./year.	Copeland (1931)
4	74.0	13.2	137.0	12.5	19.4	Annual removal/ha.	Georgie and Teik (1932)
5	91.0	17.6	109.0	NA	NA	Annual removal/ha	Eckstein *et al.* (1937)
6	29.0	3.9	22.0	10.4	13.6	150 palms/ha. 25 nuts/tree.	Cooke (1950)
7	56.0	11.9	70.0	33.9	12.5	173 palms/ha. 40 nuts/tree	Pillai and Davis (1963)
8	96.0	20.8	120.0	61.8	21.9	173 palms/ha. 40 nuts/tree	Ramadasan and Lal (1966)
9	95.0	9.0	117.0	65.0	NA	1.5 tonne copra/ha.	Ouvrier and Ochs (1978)
10	174.0	20.0	249.0	70.0	39.0	6.7 tonne copra/ha.	Ouvrier and Ochs (1978)

the leaves, stipules, spathes and spadices also contribute major items of nutrient removal. A good amount of absorbed nutrients is also retained in the growing stem (Santiago 1978).

The quantity of nutrients removed annually by a single palm (West Coast Tall) yielding an average of 40 nuts and 13 leaves per year through the harvest of nuts or shedding of the different parts as well as the quantity retained by the growing stem worked out from the data of Pillai and Davis (1963) are given in Table-2.

Table 2

Nutrient removal by a single palm per year in g.

N	P	K	Ca	Mg
321	69	406	196	72

The data reveal the quantitative sequential of importance of the major nutrients for adult bearing palms are $K > N > Ca > Mg > P$.

Data on the percentage of nutrients removed through different parts of the palm are presented in Table-3 which reveals that the maximum quantity of K is exhausted through the harvest of bunches while that of Ca and Mg through the shedding of leaves plus stem growth (Pillai and Davis 1963).

Table 3

Removal of nutrients by different parts of the palm (in percentage)

Authority	Parts of the palm	N	P	K	Ca	Mg
Pillai, N.B. and Davis, T.A. 1963.	Nut	43.0	40.0	63.0	15.3	25.0
	Peduncle	4.2	7.0	12.1	3.3	11.4
	Spathe	3.5	2.9	2.7	4.5	4.9
	Leaf with stipules	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

It is further elaborated that the quantity of K exhausted through the harvest of bunches is 78 per cent and that used for the growth of leaves and stem is only 22 per cent. Among all the nutrients, the largest removal as well as the highest proportion in the nut harvested is K which suggests the maximum orientation of K for the productivity of the palm irrespective of its type.

The studies made by Pillai and Davis (1963) on the removal of nutrients by Tall palms in the West Coast of Kerala and that by Ouvrier and Ochs (1978) for the hybrid PB 121 in West Africa were exhaustive. Eventhough the differences in the absolute values between the authors are large, there is a lot of agreement in the pattern of exhaustion. The sequential of importance of the nutrients for coconut palm as reported by Ouvrier and Ochs (1978) was K > Cl > N > Ca > Na > Mg > S > P. It is quite evident that the dominant requirement of the palm is K while P is the least in quantity required. The sequential requirements in quantity for both the Hybrid and Talls are found to be similar. It is reported by Santiago (1978) that the uptake of different nutrients by coconut seedlings is more or less in the same order (K > N > Cl > Ca > Mg > P) with K as the greatest and P the least absorbed.

2.1.2. <u>Nutritional requirement of the coconut palm</u>

The coconut with its massive structure and huge crown and its unique nature of bearing round the year throughout its life of eighty years or more, requires a regular supply of nutrients all the years round since its establishment in the main field. The perennial nature of the palm as well as its extensive root system poses considerable difficulties in carrying out investigations on its mineral requirements. Various field experiments to study the requirements of major nutrients and to a limited extent of micronutrients, on growth and productivity of the palm have been carried out in the major coconut growing countries of the world.

Data on NPK requirements of the palm are grouped under the following three heads viz., (1) the requirement of seedlings in the nursery stage (2) the requirement of young palms in the pre-bearing stage and (3) the requirement of adult bearing plams.

2.1.2(a). NPK requirement of coconut seedlings in the nursery stage

To produce healthy seedlings to facilitate quicker growth and early bearing, it was found necessary to manure the coconut nursery adequately, though it has been generally believed that there is sufficient stored food inside the seednut for the growth of the germinated seedlings in the nursery stage.

In SriLanka (Anon 1941) application of potash to the seed beds produced remarkable effect on the growth of the seedlings in the nursery. In Ivory coast (Anon. 1956) seedlings produced from nuts obtained from palms manured with K displayed better growth than those obtained from unmanured palms. Ziller, R. and Fremond, Y.(1961) suggested that N, P, K, Ca and Mg manuring in the nursery was essential to produce young palms with a satisfactory nutrient status. Fremond et al.(1966) recommended heavy organic and inorganic fertilization of the nursery to produce vigorous seedlings. They suggested that a basal application of 6 tons of well rotten cattle manure along with 400 kg each of ammonium sulphate, superphosphate and muriate of potash per hectare would be beneficial for effectively raising vigorous seedlings. Foale (1968) from Australia reported that the nutrient contribution by the endosperm to the growing seedling decreased from the fourth month after germination. This implies that the young seedlings are actually in short supply of nutrients for a major part of their one year growth in the nursery.

These results indicate the need to change the concept that there is sufficient stored food inside the seednuts. It is therefore, necessary to apply NPK fertilizers in the nursery to produce seedlings with favourable nutrient status so as to facilitate better establishment, faster growth and earlier bearing in the main fields. Nelliat (1973) suggested the application of fertilizers to the nursery in the months of December, February and April to supply 40 kg N, 20 kg P_2O_5 and 40 kg K_2O per application per hectare in the west coast of India.

2.1.2(b) NPK requirement of young palms in the pre-bearing stage

Anandan <u>et al.</u> (1950) found that favourable texture and good fertility status of soil were associated with comparatively excellent growth of some palms in a bulk planting area eventhough all the young palms in the area received identical fertilizer treatments. Salgado, ~~M.L.M.~~ (1948) reported that young palms adequately supplied with K fruited at the fifth year after planting while it took eight years for the unmanured palms to fruit. In Jamaica, Smith (1964) found significant increase in growth characters of young palms due to application of N. Malayan dwarf palms responded well to N application on early growth, frond production, early yield and trunk height. Mathew and Ramadasan (1964) reported that N had a significant effect on all growth characters of young palms in the initial stage, phosphorus increased girth at collar and number of fronds produced, and the effect was reported to be indirect by enhancing the uptake of K, while the application of K increased girth at collar only. The effect of N in increasing the vegetative growth of young palms was also reported by Fremond,1964

Systematic fertilization of young palms is essential not only for faster and vigorous growth, but also for reducing the pre-bearing age (Smith, 1968). In New Guinea, Charles (1968) studied the uptake of nutrients from applied fertilizers by newly planted seedlings. The fertilizers were applied at the time of planting and after one month; two months and three months of planting. He found that there was 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. In the coastal clay soils of Malaysia application of N significantly increased the length and weight of the frond of young palms (Soon and Wat, 1971). The importance of balanced NPK nutrition to young palms from the time of planting in the main field was emphasised by Fremond and Ouvrier (1971). At Veppankulam (Anon, 1971) application of graded doses of fertilizers; the adult palm dosage being 0.34 kg N, 0.23 kg P_2O_5 and 0.45 kg K_2O induced flowering one year ahead of the control (no fertilizer) plots. When double the dosage was applied, the pre-bearing period was further reduced by four months.

In an NPK factorial experiment (Anon, 1972a, Anon, 1974) on young palms of the Tall variety on a sandy loam soil the main effects of N and P and the interaction between N and P and that between N and K were significant in increasing frond production while K had no effect on the growth characters studied. Effect of N was also significant on the length of leaf and leaflets.

These studies indicate the need for NPK fertilization on young palms right from the time of planting in the main field, not only for faster and vigorous growth, but also for reducing the pre-bearing age and to enhance the productivity in subsequent years. Reviewing the NPK nutrition of coconut palm Nelliat (1973) suggested that the adult palm dosage should be given to young palm from the third year onwards. He also suggested that once the seedlings are planted in the main field about one-tenth of the adult palm dosage may be applied after 3 months, one-third after one year, two-thirds after two years and the full dosage after 3 years and onwards.

2.1.2(c). NPK requirement of adult bearing palms.

Judicious manuring is one of the most important means for obtaining sustained yields at a higher level from the coconut palm. Significant yield increases have been achieved by adequate and balanced fertilization under varied soil conditions in all the coconut growing countries of the world.

According to Salgado (1946) N had a beneficial effect on female flower production, while on copra content, it had an adverse effect as a higher number of nuts were required to produce a ton of copra. Phosphorus had no effect on the copra content and had a definite depressing effect on female flower production. From the results of NPK experiment that has been in progress since 1936 in Bandirippuwa Estate in SriLanka, Salgado (1952) observed that N gave a highly significant response in the second year after the commencement of manuring; later on it progressively declined and actually depressed the yield after the tenth year. A high level of N was found to affect adversely the response of K and this might be the cause of a decline in yield by higher doses of N. The response of K went on progressively increasing and reached the peak in the 15th year. Based on the average yield for 9 years the increase in copra was 183 kg/ha at a level of 340 g K_2O per palm and 278 kg per ha at a level of 680 g K_2O per palm once in two years.

Commending upon P manuring of coconut in SriLanka, Halliday ~~(1954)~~ and Sylvester (1954) stated that there was no response to P application at Bandirippuwa where soil contained adequate reserves of P, but experiment on poor laterite soils of Veyanagoda and Ahangama with low P resources in the soil on the other hand, gave spectacular response to P application at the rate of 275 g P_2O_5 per palm once in two years. The increased copra yield in this case was attributed to increased yield of nuts as well as to higher copra content per nut. It was reported that plots treated with NPK gave higher yields than control plots from the third year onwards (Anon., 1957). In the fourth year the increase in yield recorded by the NPK plots was 18.5 nuts per palm as against 4.2 nuts in control plots. The control plots in many cases received manures like green leaves, cattle dung, ash, oil cakes, bone meal etc. which supplied almost the same quantities of plant nutrients received by NPK plots through fertilizers. Thus regular application of NPK fertilizers to the coconut palms was quite beneficial and resulted in marked increase in yield.

Menon and Pandalai (1958) reviewed the work done in India upto 1958 on the various aspects of fertilizer application to coconut palm and the folllowing effects of fertilization was reported.

1. There was a general response to application of N and K while response to P was seen only under certain restricted conditions.
2. The response to manuring was dependent to a large extent on the availability of nutrients in the soil.
3. A minimum period of 3 years was required to obtain the full response of fertilizer in coconuts.
4. Nitrogen had a beneficial effect on female flower production, K had little effect, while P had a depressing effect.
5. Nitrogen had an adverse effect on copra content while K had a very beneficial effect, but P had no effect on copra weight.
6. Oil and protein contents of copra were not influenced by the different nutrients.
7. Experimental evidence was too meagre to express any conclusive opinion regarding the alleged superiority of organic form of fertilizers over in organic forms.

Nathanael (1959) suggested an increased ratio of N and K to P particularly on soil of low fertility. Smith (1964) reported that neither N nor K influenced nut size, but P did favourably. According to him, the number of nuts per bunch was the most variable component of yield of coconut and it was also the one that was most easily influenced by fertilizer treatments. He presented the results of fertilizer response by coconut on two contrasting coconut soils viz. Belfield Clay (pH 5.5) and St.Annclay (pH 6.3). His results showed that N deficiency limited female flower production, bunch production rate and yield, P deficiency reduced the nut size and K deficiency reduced fruit set and yield.

Nethsinghe (1961) and Eden *et al*.(1963) discussed coconut nutrition and fertilizer requirements in relation to soil conditions existing in SriLanka. The only main effect which had shown statistical significance was that of K. Although N by itself gave no significant response, its presence was essential for the maximum response to K. Neither the main effect nor the interaction of P was a limiting factor at the upper levels of NK combination. Marar and Pandalai (1961) concluded that the effects of N and K were equal and additive. They quantitatively fixed the effect of N at 10.7 nuts, K at 11.3 nuts and NK at 20.8 nuts per palm per year. Murray and Smith (1962) reported from Trinidad that response to N was proportional to the pre-treatment bearing level of the palm. The pour bearers showed greater responses to applied N. The palms giving an annual yield of 100 nuts and more showed no improvement in

Productivity due to N fertilization. It was suggested that NPK manuring had both productive and economic advantages for coconut. The yield of nuts increased by nearly 34 per cent and that of copra by 14 per cent (Anon. 1964). Lekshmanachar (1964) reported from the results of coconut fertilizer demonstration trials conducted in growers' gardens that the balanced NPK manuring had helped to increase the yield appreciably. A detailed analysis showed that it was possible to increase the production of coconuts by nearly 23 per cent and copra out turn by 44 per cent by regular manuring and proper intercultural operations.

Pandalai and Marar (1964) reported that a regularly cultivated and fertilized plot produced 48.2 nuts as against a neglected plot with 15.3 nuts over a period of 25 years. N and K at 1.5 pounds each per tree improved yields yearly while P did not show any improvements on yields. However, in the seventh year of fertilizing, copra production was lowered by about 2.0 per cent in the N plot but increased by 20 per cent in the K plot. Rawther <u>et al</u>.(1966) found that regular application of an annual dose of 0.35 kg N, 0.34 kg P_2O_5 and 0.68 kg K_2O per palm progressively increased yields. Dolorne (1966) found that in palms of the semilarge African variety normally yielding 3000 tons of copra per year from a plantation of 8000 ha, the yield went upto 7000 tons per year by fertilizing the existing palms at 500 g and 1000g N and 1000g and 1500 g K_2O per young and adult palms respectively. Thomas (1968) found that addition of 320 g N, 340 g P_2O_5 and 450 g K_2O per palm per year in a single application during August-September resulted in the maximum yield. Summarising the data from the fertilizer experiments in SriLanka, Salgado (1968) reported that female flower production was increased by 15 per cent by the application of N. The application of potash at the rate of 680 g K_2O per palm increased the fruit setting by 35 per cent over the control. The NP interaction had a positive effect on number of bunches and female flowers per bunch. He found that 340 g K_2O applied once in two years gave response in the third year. Studies conducted in Jamaica showed that N increased trunk height, female flower production and number of nuts. Increased rate of N application resulted in corresponding increase in frond production upto the highest level tried viz. 760 g N per palm per year. However, high N treatment induced K deficiency (Anon.,1968). It was also reported from Jamaica that the beneficial effect of N was due to an increased production of bunches ranging from 11.1 to 12.8 per cent and female flower production from 20 to 40 per cent, although there was reduction in fruit setting (Anon., 1968). Further results from SriLanka (Anon, 1968) showed that the main effects of N, P and K and the interactions of NP,NK and PK were significant in respect of yields of nuts. Muhamed ~~and~~ et al. ~~Venkateswaran~~ (1969) reported from simple fertilizer trials with N, P and K in coconut cultivators holdings in sandy loam soils of Tanjavur District, Tamilnadu the maximum positive response to the application of N at 0.68 kg, P at 0.227 kg and K 0.454 kg per palm per year with a net profit of Rs.10.53 per palm per year. Mulyar and Nelliat (1971) obtained response to application of N in terms of yield from the third year onwards and the mean increase in nut production was 16.9 per cent. There was practically no response to P for the first eight years, but from the nineth year onwards significant increase in nut production was obtained. Potash gave significant increase in yield from the fifth year onwards. They also found that for palms yielding less than 60 nuts annually, the optimum dose of N ranged between 400 and 600 g with a mean of 480 g and that of K ranged between 890 and 1210 g per palm per year. According to them N adversely affected all the nut characters studied viz. weight of whole nut, weight of husked nut, volume of husked nut, and copra weight per nut. These characters were highly improved by K nutrition while P had negligible effect. Although N application increased the yield of nuts by 16.9 per cent, copra yield was increased only by 6 per cent. With K, the increase in nut production and copra production were 12 per cent and 22 per cent respectively.

Barrant (1975) reported the beneficial effects of N and NK interaction on the yield of Malayan Dwarf palm growing on K deficient soil.

Reviewing the NPK nutrition of coconut, Nelliat (1978) suggested that the general requirement of fertilizer elements for palms yielding an average of 50 nuts per annum would be 500 g N, 320 g P_2O_5 and 1200 g K_2O per palm per year. He also recommended a higher dose of 1000 g N, 500 g P_2O_5 and 2000 g K_2O per palm per year for palms with high yield potential. An excellent and exhaustive review on the present status of mineral nutrition and fertilization of the coconut around the world has been made most recently by Manciot, ~~Ollagnier and~~ et al. ~~Oehs~~ (1979).

2.1.2(d) K nutrition of coconut palm

The coconut palm is a heavy consumer of potash. Studies conducted in all the coconut growing countries of the world have shown that potash is a dominant nutrient of the palm and outstanding increase in yield have been obtained by its application. The severity and frequency of K deficiency in most of the coconut growing areas of the world has been found to be one of the limiting factors in the economic production of coconut. The cause is mainly attributed to soils which rarely possess the large quantities of K required by the palm.

According to Salgado (1953) potash deficiency led to chlorosis and leaf scorching and the development of poor crown with short fronds. The palms remained stunted with thin trunks. Menon (1956) reported foliar yellowing in palms due to K deficiency. Tip scorching of leaves had been well known to be a nutrient deficiency symptom which was corrected by K manuring (Menon et al.1958). Pillai (1959) observed general flacidity and drying of leaf tips and necrotic patches of leaflets of older leaves on young palms growing in pots which were not supplied with K. In the fertilizer demonstration trials conducted all over the west coast of India, John and Jacob (1959) found that application of 340 g N, 340 g P_2O_5 and 680 g K_2O per palm per year resulted in an increase of 35 per cent in nut production and 44 per cent in copra production over cultivators' practice. When they failed to obtain response to the above dosage, significant yield increase were obtained when the K_2O level was raised to 900 g per palm per year. Raising the levelsto 900 g N, 1135 g P_2O_5 and 1135 g K_2O resulted in a further increase in yield. Ziller and Prevot (1962) reported that addition of 1.5 kg muriate of potash resulted in 62 per cent increase in yield of nuts and 23 per cent increase in copra weight per nut, ie. a gross increase of 1.1 to 1.2 tons of copra per hectare.

Smith (1964) reported that in Jamaica when the palms were coming to bearing, the early inflorescence usually had either no or only few female flowers and this situation persisted on very infertile soils. Here application of N had increased the female flowers produced and this was reflected in an increased yield. In another experiment at Industry (Jamaica) palms with a very low yield caused by lack of female flowers responded to application of fertilizers by producing more female flowers and increasing their mean yield from 21 to 42 nuts per palm. The increased production of female flowers was attributed to the effect of N and the yield increases to that of K. He also reported that in certain situations in Jamaica, where the yield and number of flowers were already high and the limiting factor was the inability of the palms to hold more nuts. In such situations the yield was increased further by the application of potassic fertilizers. Female flower production and fruit setting provided a field guide to the N and K requirement of the palm.

Summarising the contributions of IRHO, Paris to the study of mineral nutrition, Fremond (1964) reported that N significantly increased the number of female flowers, number of nuts and copra out turn. The effect of N on coral soils became more marked when Iron and Manganese deficiencies were corrected. Higher doses of N not only depressed yield of nuts but the weight of copra per unit was also reduced. Phosphorus was not found to have much beneficial effect either in increasing yield of nuts or copra content. But in the presence of potash, phosphorus was found to have beneficial effects on the number of nuts and yield of copra per nut as shown in the following table (4).

Table 4

The effect of PK interaction on the number of nuts per palm

	P+	P-	Difference
K+	77.7	65.1	12.6
K-	38.2	35.2	3.6
Difference	39.5	29.9	..

The application of K resulted in the improvement of all production factors such as fruit setting, number of bunches, number of female flowers per bunch, number of nuts, average copra per nut and ultimately the total copra out turn per palm. Mathew and Ramadasan (1964) noticed necrosis of foliage tips on young coconut palms under K deficiency conditions. In the absence of K, coconut seedlings developed little dots along the margin of old leaves which in severe case coalesce and giving an appearence of firing. Characteristic visible symptoms of K deficiency in coconut were described by various workers (Anon, 1969; Anon, 1970; Fremond et al. 1966 and Manciot et al. 1979). The symptoms are so specific that an experienced observer can easily diagnose them. The first visual symptom is the development of rust coloured spots in longitudinal bands on either side of the mid-rib, their diameter ranging from 0.5 to 3-4 mm which is accompanied by slight yellowing of the lamina, and the yellowing is more marked towards the tip of the leaflets. Thereafter the deficient tree gives an yellow appearance to the oldest leaves assuming orange red tinge. Only the youngest leaf remains green. The yellowing is never uniform and is accompanied by numerous irregular brown blotches resulting from the rusty spots. Yellowing is more concentrated near the periphery of the leaf area than the central portion. The individual leaflet is green where it is attached to the rachis than towards the tip where necrosis sets in. Yellowing is always more intense along the edges of a leaflet, leaving a central green band along the mid-ribs. The yellowed surfaces soon become necrotic appearance than of yellowing. This is characteristically different from Mg deficiency where the palm shows more of a chlorotic appearance than of necrotic. Further K deficiency is characterised by yellowing of leaves in the middle of the crown in the early stages and drying up of older leaves in the advanced stages. Usually the lower leaves on the crown of a K deficient tree are seen dead or drying and hanging down beside the trunk. The growth, in general is reduced, the trunk becomes slendor, leaflets become short and the number of inflorescences, nut set and nuts per bunch get reduced.

Studies conducted in the Phillippines showed that the beneficial effect of K was due to the increased leaf area and improved leaf angle and leaf colour which resulted in better utilisation of sunlight and ultimately caused increased number of fronds, inflorescences, female flowers, nut set and weight of nuts. Palms suffering from moderate potash deficiency responded quickly to applied K while severe and prolonged K deficient palms took two to three years to show response. The nut size decreased rapidly in the absence of K. With an annual dose of 500 g K_2O per palm it remained unaffected, when 100 g K_2O was applied the nut size improved. It was estimated that the increased copra out turn due to K fertilization could be apportioned as 30 per cent to the increase in the number of nuts and 70 per cent to the increase in size (Vonkoxkull 1971). Studying the relationships among root, CEC, yield and mono and divalent cations in coconut, Wahid <u>et al.</u>(1974) reported a positive correlation of both soil and leaf K contents with yield, indicating the role of K in increasing the yield of coconut. Coomans (1977) observed foliar discolouration in the form of rust coloured patches. Severe K deficiency in coconut has been noted on tertiary and quartarnary sands of West Africa, on coastal sands of Sambava (Madagascar), on coral soils of the Oceanian atolls, on sandy soils in the east west of SriLand and on the exhausted lateritic zones of India (Manciot *et al.* 1979).

2.1.2 (e). Calcium requirement of the palm

In Trinidad, Verteuil (1934) found that application of mixed fertilizers along with lime increased the yield of coconut. In Malaya, Wilshaw (1941) reported that lime application alone gave an increase in yield of good nuts as well as the weight of copra per nut. Contrary to this, application of Ca to Tall coconuts in Ivory Coast in the form of calcium carbonate for four consecutive years did not modify the Ca levels in leaves and has no influence on yield. They found that no improvement on growth or yield could be expected from calcic fertilizer application.

2.1.2 (f) Magnesium requirement of the palm

Pot experiments conducted at the coconut research institute, SriLanka showed that the absence of Mg resulted in the development of typical deficiency symptoms in coconut seedlings (Anon., 1960). Bachy (1962) reported that magnesium was found to be one of the limiting nutrient elements in the nutrition of seedlings and young palms especially when the soil supply of Mg is low. Studies conducted in West Africa showed that application of Mg along with P and K fertilizers brought about highly significant improvement in the vigour of seedlings in the nursery stage. Fremond <u>et al</u>.(1966) recommended application of 60 g $MgSO_4$ per plant in the nursery along with similar quantities of double superphosphate and muriate of potash. Studying the nutritional requirement of Malayan Dwarf Variety of coconut in Jamaica, Smith (1968) observed that Mg had no effect on growth or yield of young palms grown on a thin black clay soil developed over white lime stone. The foliar Mg level was 0.32 per cent which was well above the critical level of Mg. But on a different site with deep infertile black clay soil developed over soft yellow lime stone, Mg application had beneficial effects in the early years particularly on frond growth. He also reported that Mg application increased available soil P and foliar P content. Studying the fertilization of hybrid coconut in Ivory Coast, Coomans (1977) reported that balanced application of N, K and Mg was indispensible from the time of planting especially on poor soils. Prolonged use of K fertilizers especially at high rates has been reported to depress foliar Mg content and induce Mg deficiency conditions in the palm. Santiago (1978) observed that the leaf Mg content was positively correlated with all the seedling characters viz., girth, diameter, height, number of leaves and leaf splitting, but the correlation coefficients were not significant. Cecil et al.(1978) found that application of Mg SO_4/Dolomite improved visual symptoms such as yellowing and increased yield. Mg deficiency is also caused by primary deficiency resulting from inadequate soil supply of Mg. Specific instances of absolute Mg deficiency conditions in the soil were reported in West Africa, SriLanka and India (Cecil et al. 1978). Manciot et al.(1979) reported that application of Mg fertilizers corrected Mg deficiency very well, raised the Mg levels of leaf, improved growth and increased the production, provided the K supply was adequate. The main effect of Mg on yield could be as much as 40 per cent when K was in the sufficiency level, but unlike potash Mg acted only on the number of nuts per tree and had no effect on the copra per nut.

2.1.2 (g) Sodium requirement of the palm

Briones (1931) made a study on the salt requirement of coconut seedlings grown in pots and found that moderate quantities of sodium chloride were invigorating while a heavier application was harmful. Jacques (1932) reported that commonsalt was also required for the nutrition of the palm. Salgado (1951) found that addition of commonsalt at the rate of 0.5 kg per young plant per month on a rocky laterite soil gave a distinct difference in vigour, size and colour after 15 months compared to untreated plants. Menon (1958) reported that in laterite soils addition of commonsalt in the pits for planting seedlings was known to soften the laterite bed and helped early penetration of tender roots. The coconuts grow well on soils rich in sodium although there is no direct relationship between the sodium content of soil and that of the leaves (Freemond, 1964). Results obtained from young coconuts in the early stages of production showed that application of Nacl could increase significantly the number of inflorescences, the number of female flowers and the number of nuts per palm. The copra content was also increased (Fremond, 1964). Ollagnier and Ochs (1971) reported that either as a direct manure or as an indirect soil ameliorant, the addition of commonsalt in coconut gardens has been a very old and popular practice among coconut growers in Kerala (India) Jawa and Columbia. In Kerala, it has been widely applied to the soil as well as into the crown of the palm, often and mixed with wood ash and it is believed that commonsalt could increase productivity of the palm. However, there is no direct proof on the effect of Na in increasing the yield of coconut. Since Na was applied in all the above studies in the form of NaCl it is quite probable that the improvements in growth and yield obtained with the application of NaCl might be the effect of chlorine which has been considered recently as an important nutrient element in the nutrition of the palm for its growth and enhanced productivity.

2.1.3. Foliar analysis

The fourteenth leaf of an adult palm (8 years and above) has been widely accepted as the standard leaf for foliar diagnostic studies under normal conditions. This leaf is considered as one which has attained physiological maturity, but has not entered the phase of senescence. For young palms upto 4 years of age, the fourth leaf and for 5-7 years, the 9th leaf have been accepted for this purpose (Anon., 1961). Largely as a result of pioneering work of I.R.H.O. Scientists in West Africa, foliar analysis has been widely adopted as a diagnostic tool for predicting the nutrient requirements of the palm. Though there are certain limitations, the studies conducted by I.R.H.O. Paris and the remarkable results reported by Magat (1979) have sufficiently illustrated that leaf analysis is a very fruitful method for predicting the fertilizer requirement of the palm (Manciot *et al.* 1979).

The concept of 'critical level' defined by I.R.H.O. is the percentage content of an element in the standard leaf below which the application of that particular element has every chance of increasing growth/yield.

2.1.3(a) Nitrogen, Phosphorus and Potassium

Prevot et al. (1961) reported that the results of foliar diagnosis showed that K treatments strongly increased the K content of the tissues and that organic manure had a supplementary effect, but that the addition of N reduced the K content. This depressing effect of N on leaf potassium was again found in which this reduction of the high K levels accompanied a favourable action of ammonium sulphate on production. Grundar and Bachy (1963) were of the opinion that for optimal growth and yield, the sum of K, Ca and Mg should be 2.7 per cent of the dry weight of leaf and 67-70 per cent of this should be K. This works out at 1.8 to 1.9 per cent K on dry matter basis. Romney (1965) presented evidence to show that Malayan Dwarfs had higher critical levels of N and K than Jamaican Talls.

The critical levels of nitrogen, phosphorus and potassium suggested by Fremond et al. (1966) for the Talls are given below:

Table 2.5

Critical levels of NPK (expressed as percentage in dry matter in frond 14)

Nitrogen	(N)	1.8 - 2.0
Phosphorus	(P)	.. 0.12
Potassium	(K)	0.8 - 1.0

Nethsinghe (1966) indicated that for young palms (4 year old) the optimum foliar content of N to be 2.2 per cent, P. 0.14 per cent and K 2.1 per cent. According to Smith (1968) the critical level of N for Malayan Dwarfs in Jamaica was 1.9 per cent and palms responded favourably when N content was below this level. Indirakutty and Pandalai (1968) studied the nutrient composition of West Coast Tall palms and categorised them under three productivity groups viz.

1. Palms producing less than 40 nuts per year (low yielders)
2. Palms producing 40-80 nuts per year (Medium yielders)
3. Palms producing more than 80 nuts per year (high yielders).

They found that the foliar N, P and K contents were more in palms yielding more nuts. Their mean foliar contents determined were as follows:

Table 2.6

Yield groups and critical levels of NPK (expressed in percentage dry matter)

Yield groups	N (per cent)	P (per cent)	K (per cent)
1. Low yielders	1.64	0.12	0.81
2. Medium yielders	1.76	0.13	1.11
3. High yielders	1.86	0.14	1.30

Work carried out in SriLanka (Anon, 1969) revealed that the fourteenth leaf of adult palms contained 1.98 per cent N, 0.13 per cent P and 0.87 per cent K. Cecil (1969) reported that the N, P and K contents (frond 14) of healthy palms of high productivity were 1.93: 0.198 and 1.23 per cent respectively. According to Smith (1969) the critical level of K operated only when the N level was less than 1.8 per cent. In Malaya, Kanapathy (1971) suggested tentative optimum levels of 1.8 per cent N, 0.12 per cent P and 0.8 - 1.11 per cent K for the Talls, 1.8 - 2.0 per cent K for the Semi Talls and 1.9 - 2.0 per cent N, 0.12 per cent P and 0.75 - 1.00 per cent K for the dwarfs. Vanuoxkull (1971) found that the foliar nutrient levels of palms yielding more than 100 nuts per year in the Phillippines were 1.96 per cent N, 0.10 per cent P, and 1.26 per cent K. Ramanandan ~~et al.~~ and Pillai (1972) reported that the soil nitrogen status was improved when N was added in combination with P and K and P improved when applied along with N or K. However, in the case of K, its status in the soil had improved by supplying K alone. Studying the correlation between yield and nutrient contents of soil and leaf Wahid et al.(1974) reported that the K content of soils as well as leaf correlated positively with yield. They suggested that the critical level of K, 0.8 to 1.0 per cent was found to hold good in coconut. Kamala Devi et al.(1974) reported that average leaf N and K contents rose from 1.40 per cent and 0.46 per cent respectively (without fertilizer) to 1.55 and 0.92 with the higher application rate, but leaf P and Ca contents were not affected. Ramanandan ~~et al.~~ and Pillai (1974) reported that analysis of leaf samples collected during summer and rainy season showed that during both the seasons, leaves of palms with regular cultivation and manuring contained significantly higher amounts of N and K. The available K in the 0-30 cm and 30-60 cm depths of soil was significantly greater in the regular cultivation and manuring than in no cultivation and manuring plot.

Eventhough the ctitical levels are found to vary with factors such as climate and variety of palms, commendable achievements were made by I.R.H.O. Scientists in this line and their values viz., N. 1.8 to 2.0 per cent P. 0.12 per cent and K. 0.80 to 1.0 per cent for the Talls provide a very valuable guide for general adoption until specific levels for a particular variety or hybrid for a particular climatic zone have been established (Child, 1974). Pillai et al.(1975) reported the nutrient composition (Frond 14) of different categories of palms growing on different soil types of Kerala (India) being 1.82; 0.13 and 1.08 per cent of N, P and K respectively. In Jamaica (Barrant, 1977) the foliar contents (frond 14) of N and K were lower than the I.R.H.O. levels, while P content fully agreed with the 0.12 per cent level. The mean values of N, P and K ranged from 1.54 to 1.88; 0.10 to 0.16 and 0.63 to 0.93 per cent respectively. It was also revealed that P had no significant response on yield while N and K did respond significantly to increased applications followed by increases in foliar contents. The critical levels of NPK (frond 14) adopted at present in the Phillippines are 1.8 per cent N, 0.12 per cent P and 0.8 to 1.0 per cent K which are the same as those suggested by I.R.H.O. Paris (Magat, 1979). Margate et al.(1979) observed that Kcl fertilization improved the N status of leaf, which was correlated with yield increases. The N level was raised from 1.78 per cent to a maximum of 2.03 per cent. The P and K contents ranged from 0.140 - 0.156 per cent and 1.270 - 1.463 per cent respectively. However, the increase in yield of nuts and copra outturn were not significantly correlated with improvements in P and K levels in the leaf which suggest that the supply of these two nutrients (P and K) was more than the required level and was not limiting the growth and productivity of the palm. Studying the effects of NPK fertilizers on the yield and leaf nutrient concentrations of adult coconut on a lateritic gravelly soil in SriLanka, Loganathan and Balakrishna Murthy (1979) reported that sulphate of ammonia had a positive influence on leaf N but the relation was not statistically significant. Application of P fertilizer increased leaf P and Ca. Supply of muriate of potash, increased leaf K and Cl and decreased Ca and Mg. Partial correlation of yield with either leaf K (r_{yk} k = 0.26 at constant cl) or leaf cl (r_{ycl} cl = 0.50 at constant K) showed that the correlation coefficients were not significant. This was due to the strong correlation of two nutrients in the leaf ($r_{kcl} = 0.97$) suggesting that the marked response of coconut to muriate of potash application was due both to K and cl in the fertilizer.

2.1.3 (b). Calcium, Magnesium and Sodium

In SriLanka, Nethsinghe (1963) reported that an Mg content of 0.25 - 0.30 per cent (frond 6) would indicate sufficiency of Mg, but if it falls below 0.2 per cent, deficiency symptoms could be possible. However, his values for Mg in palms that were green ranged from 0.135 to 0.271 per cent and in chlorotic palms from 0.063 to 0.147 per cent. Freemond (1964) reported that the critical levels of Ca and Mg initially suggested by I.R.H.O. were 0.5 and 0.3 per cent respectively for the Tall variety. However, values higher or lower than these levels have been widely reported on healthy plantations without any adverse effect on yield or foliar conditions. Fremond et al.(1966) suggested a maximum level of 0.40 per cent Na beyond which adverse effects would be expected. The range of foliar Na contents reported by different workers are 0.27 - 0.31 (Smith, 1967); 0.23 - 0.46 (Smith, 1968); 0.31 - 0.39 (Pillai et al. 1975) and 0.21 - 0.39 (Barrant 1977). The Ca and Mg contents of palms under three yield groups reported by Indirakutty and Pandalai (1968) did not vary significantly. Their mean values for Ca and Mg were 0.28 and 0.05 per cent respectively. The Mg values reported by them were very low. Cecil (1969) reported 0.48 per cent of Ca and 0.29 per cent of Mg in healthy palms (frond 14) under excellent growth conditions, 0.38 per cent Ca and 0.08 per cent Mg in palms showing severe Mg deficiency symptoms and 0.37 per cent Ca and 0.18 per cent Mg in palms in the marginal conditions without any visual symptoms of deficiencies. In Malaya, Kanapathy (1971) proposed the optimum levels of 0.15 - 0.30 per cent Ca and 0.3 per cent Mg for Talls, semitalls and Dwarfs. In India, Kamala Devi <u>et al</u>.(1973) studied the mineral content of three high yielding genotypes viz. high yielding Talls, Dwarf X tall and Tall x Dwarf hybrids under three levels of fertilization. Irrespective of types of fertilizer levels, the Ca content (frond 9) registered a more or less constant value of 0.30 per cent. The Mg levels for the three genotypes did not vary significantly and the average value was 0.18 per cent. However, the Mg content at 500 g N, 500 g P_2O_5, 1000 g K_2O level of fertilization was 0.19 per cent which was significantly higher than the Mg content of 0.16 per cent obtained at 1000-1200-2000 g level of fertilization. Mg deficiency was one of the causes for delayed flowering in coconut palms in certain parts of Bandirippuwa Estate, Lunuvila-Ceylon. The mean Mg content (frond 14) of 11 year old non-bearing palms was 0.17 per cent. The corresponding Ca levels for non-bearing and bearing palms were 0.260 and 0.254 per cent respectively (De Silva <u>et al</u>.1973). Magat (1976) reported that the critical level of Ca and Mg initially suggested by I.R.H.O. appeared to be too high to be used as a guide for

Phillippine conditions. According to him the critical levels of Ca and Mg followed in the Phillippines at present are 0.3 and 0.2 per cent respectively. Most of the results from Jamaica show that foliar Ca and Mg levels are comparatively higher which range from 0.4 to 0.7 per cent Ca and 0.3 to 0.5 per cent Mg and the yield increases due to the fertilizer application were not related to any increase or decrease of Ca or Mg content in the leaf (Barrant, 1977). In the Phillippines the Mg content of palms under various levels of potassium chloride fertilization ranged from 0.19 to 0.21 per cent and Ca levels from 0.40 to 0.498 per cent (Margate and Magat, 1979). Magat (1979) had presented the critical leaf analytical data from 10 fertilizer trials conducted in Devas and Misaonis Oriental Provinces of the Phillippines. He had found that Ca levels (frond 14) ranged from 0.14 to 0.42 per cent with an average of 0.30 per cent except in one location viz. Laguindingan where the parent material is limestone and the Ca level of palms there was 0.68 per cent. The range of Mg level was from 0.16 to 0.48 per cent with an average of 0.29 per cent. Manciot <u>et al.</u> (1979) presented data on Ca and Mg content of palms from various fertilizer trials conducted at different parts of the world. The Ca levels of adult palms were generally found to range from 0.2 to 0.4 per cent while higher values were obtained on coral soils. The Mg levels were also found to vary generally from 0.2 to 0.4 per cent except in Ivory Coast where values lower than 0.2 per cent were met with. It may be stated in this context that in Ivory Coast, the application of Mg had a highly significant response in increasing yield of nuts per tree and total copra per tree and the foliar Mg content was also increased at a highly significant level. The foliar Mg content (frond 14) in the absence of Mg application was 0.098 per cent and when Mg was applied it was 0.229 per cent. They further reported that in Ivory Coast there was a good relationship between Mg levels and the number of green leaves on the crown. In the case of hybrid PB 121, when the Mg levels were below 0.11 per cent, there were lesser than 12 green leaves, for levels between 0.11 and 0.17 per cent there were 13 to 20 leaves and for Mg levels above 0.17 per cent there were more than 30 green leaves on the crown. Magot (1979) suggests that the critical levels viz. 0.3 per cent Ca and 0.2 per cent Mg in frond 14 appear to have a broader applicability as a diagnostic aid. According to Manciot et al.(1979) the level of 0.40 per cent previously suggested by I.R.H.O. should be taken as a rough guide, as coconut groves giving excellent yields have Na levels below 0.10 per cent. Manciot et al.(1980) reported that Ca contents are appreciably increased by nitrogen or phosphate fertilizers. Potassium manuring tends rather to depress the levels.

2.1.3(c) Standard critical levels of major nutrients

Based on the foregoing review, the following foliar levels are tentatively taken as standard critical levels for the purpose of discussion in this investigation.

Nutrients		Standard critical levels (per cent dry matter)
Nitrogen	(N)	1.8 - 2.0
Phosphorus	(P)	0.12
Potassium	(K)	0.8 - 1.0
Calcium	(Ca)	0.30
Magnesium	(Mg)	0.20
Sodium	(Na)	Upto 0.40

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Location

The field experiment to study " The effect of continued NPK fertilization on the growth and yield behaviour of coconut with special reference to K nutrition and its interrelation with other mineral nutrients ", was laid out as early in 1964 at the Coconut Research Sub-Station, Balaramapuram in Trivandrum District of Kerala State. The station lies between 8° and 29° latitudes and longitudinally at 76° 57'. The altitude of the location is 64 meters. The area is having an average slope ranging from 1 to 3 per cent.

3.2 Climate

The experimental area enjoys a humid tropical climate. The mean annual rainfall ranges between 1200 mm and 1500 mm. The average maximum temperature was 37.7°C while the minimum temperature 23.4°C.

3.3 Soil

The soil of the experimental site is red sandy loam and is classified as ' Vellayani Series ' developed from the weathering of the underlying tertiary sand stones and clays. Soil is deep and well drained and the internal drainage is good. Irrigation in the area is totally wanting.

3.4 Cropping history

After the acquisition of the experimental site during 1964 by the Department of Agriculture, Kerala State, old trees in the site were clearfelled and uprooted. The area was laid out into suitable blocks for experimental purposes. No intercrop was grown in the area previously and also subsequent to the layout of this experiment.

3.5 Design and layout

Design	3^3 confounded factorial design confounding NPK_2^2 in replication 1 and $NP_2^2K_2^2$ in replication 2.
No. of replications	2
No. of blocks per replication	3
No. of plots per block	9
Treatments	27 nutrient combinations (Adult dose per palm per year)

Nitrogen	3 levels
Phosphorus	3 levels
Potash	3 levels

N_0 – no nitrogen
P_0 – no phosphorus
K_0 – no potash
N_1 – 340 g nitrogen per tree per year
P_1 – 225 g phosphorus per tree per year
K_1 – 450 g potash per tree per year
N_2 – 680 g nitrogen per tree per year
P_2 – 450 g phosphorus per tree per year
K_2 – 900 g potash per tree per year

Treatment combinations and schedule of fertilization are presented in Table 7.

Plot size	22.5 x 22.5 m
No. of experimental palms per plot	4
Total number of experimental palms	54 x 4 = 216
No. of border palms	347
Spacing of palms	7.5 x 7.5 m

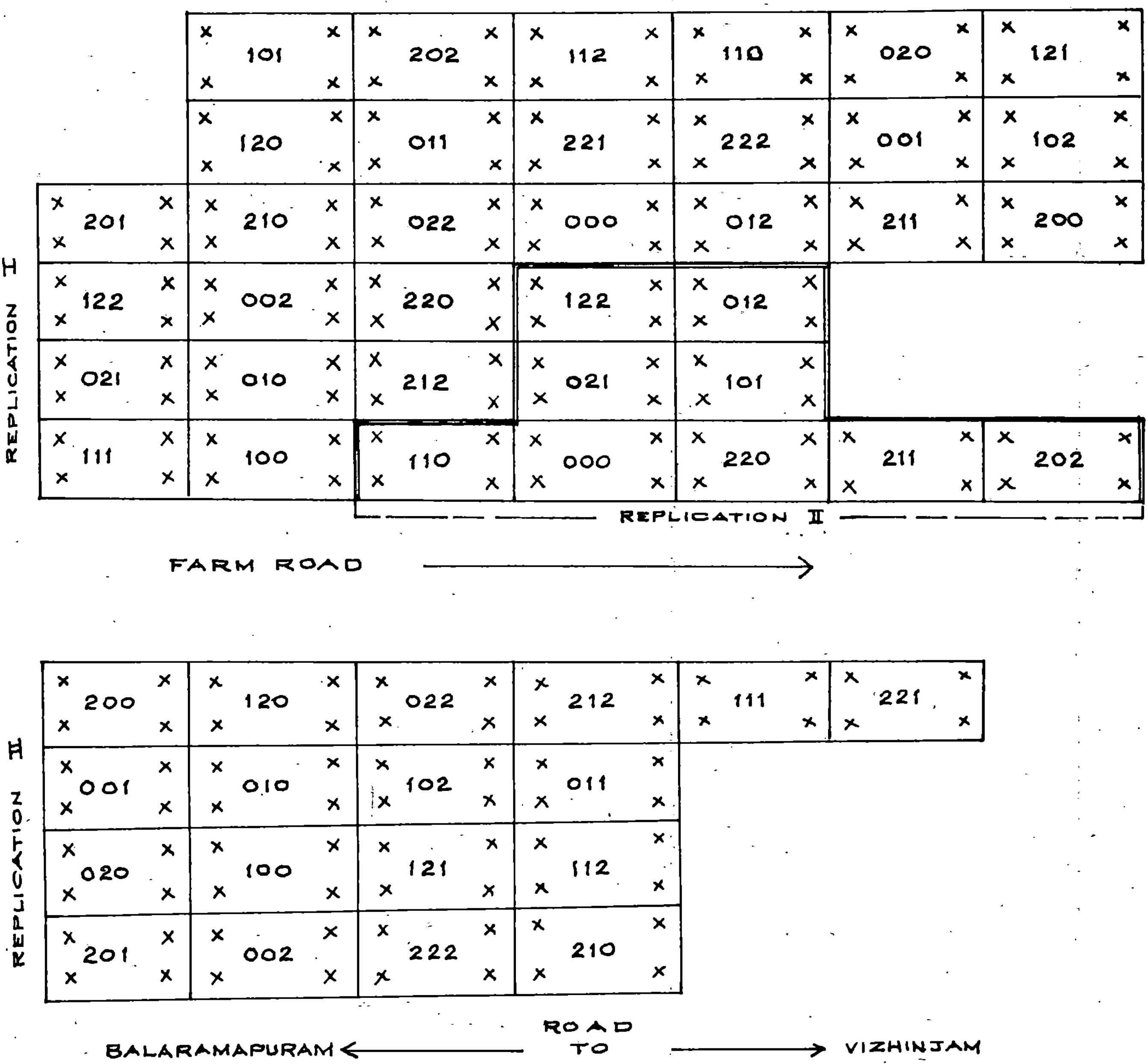
The field map showing the layout of the experiment is given in Fig. I.

COCONUT RESEARCH SUB-STATION
BALARAMAPURAM

NPK FERTILIZER EXPERIMENT (WITH SEEDLINGS)

LAY-OUT PLAN

DATE OF START. 17-6-64, No. Ag. 2·10·1·6



TOTAL AREA - 9 HECTARE
EXPERIMENTAL AREA - 3·643 HECTARE
LAY OUT - 3^3 CONFOUNDED FACTORIAL DESIGN
REPLICATION - 2.

FIG. 1.

3.6 Planting material

One year old coconut seedlings var. - West Coast Tall raised in the coconut nursery of the Department of Agriculture at Valiyathura, Trivandrum were planted in the experiment. Seedlings of uniform growth, girth and vigour were selected for the purpose. The seedlings were planted in pits of one meter cube size at a spacing of 7.5 m in the square system of planting. In each experimental plot four seedlings planted in the middle of the plot were tagged as the experimental trees leaving the palms common to the adjacent plots as border palms. Thus there are 216 experimental palms and 347 border palms in the experimental field (Fig. No. I).

3.7 Sources of nutrients

All the nutrients, N, P and K were supplied in the form of simple fertilizers - N in the form of ammonium sulphate, P in the form of single superphosphate and K as muriate of potash analysing 20.5 per cent N, 16 per cent P_2O_5 and 60 per cent K_2O respectively.

The nutrients N, P and K were applied in a single dose during early June with the commencement of South West Monsoons. Basins were opened around the palms having 1.8 m radius from the boll and trenches of size 20 cm width and 20 cm depth were dug at the distal end of the basin all around, and fertilizers were spread uniformly in the trenches and then covered with earth. The experimental palms were given fertilizers as per the treatment schedule and the border trees with the recommended doses of 650 g N, 450 g P and 900 g K per tree per year as per the Package of Practices recommendations. However, the young palms were fertilized at half the rates only for the first two years of planting the seedlings.

3.8 Biometric observations

The following growth parameters for the period from 1972 to 1979 at half yearly intervals ending June and December were taken for the purpose of this study.

3.8.1 Number of fronds produced during the half year

The rate of frond production was recorded by marking the youngest open frond on each occasion.

3.8.2 Length of fronds

The length of frond was measured from the base of the stipule to the tip of the frond.

3.8.3 Number of leaflets

The number of leaflets found on one side of the frond was counted and recorded. Since the number of leaflets are equal on each side the leaflets on one side alone was recorded for purposes of analysis.

From 1972 onwards when the first bunch was noticed in the experimental palm, the following additional observations were also made.

3.8.4 Number of female flowers

Female flower production was recorded on each bunch by counting the number of buttons and the number of scars of the shed buttons.

3.8.5 Setting percentage

Setting percentage was computed from the total number of flowers produced and the total number of nuts harvested including barren nuts. Since initial flowering in 1972 was sparse and also considering the time involved in setting of nuts, the data from 1974 onwards was taken to have a more coverage of palms.

3.8.6 Number of good nuts and yield of nuts per tree per year

The seedlings planted in 1964 commenced bearing in 1974; but it was found to be uneven and not uniform. An almost uniform bearing was noted in 1976 and hence the yield data from 1976 to 1982 were recorded. From each bunch harvested at periodical intervals of 60 days the number of good nuts was counted and recorded. The annual yield of nuts from each experimental tree was computed for analysis.

3.8.7 Cumulative yield of nuts from each experimental plot

The total yield obtained from the four experimental trees in each plot was also computed and recorded for 7 years from 1976 to 1982.

For the present study the following additional observations were also incorporated to cover the growth and yield characters of the palm, the soil factors and foliar nutrient status of the palm as it was not included in the original project. As such data on the above factors for 1982 were recorded for analysis.

3.9 Growth and yield characters

3.9.1 Weight of unhusked nut

One nut from each experimental tree was randomly selected from the harvest done in April 1982. Thus four nuts were collecte from the four experimental trees in a plot. Whenever the number of nuts harvested from a single plot was less than four, then all the available nuts from that plot were collected for study of nut characters. The weight of unhusked nuts thus collected were taken and the average weight computed.

3.9.2 Weight of husked nut

The weight of husked nut was taken and the average weight recorded.

3.9.3 Weight of husk

The average weight of husk was computed and recorded.

3.9.4 Thickness of meat

The husked nuts were broken equally into two halves and the thickness of meat of all the husked nuts was measured with a vernier scale and the average thickness was computed.

3.9.5 Thickness of shell

Thickness of shell was also recorded by adopting the same procedure followed for measuring the thickness of meat.

3.9.6 Weight of meat

The meat contents from all the sampled nuts were removed from the shells and the total weight of meat taken. Then the average weight of meat per nut was calculated and recorded.

3.9.7 Weight of shell

Weight of shell was also computed by the same procedure adopted for recording weight of meat.

3.9.8 Weight of copra

The meat contents collected from the sampled nuts was dried in the sun uniformly, keeping the period of exposure to sun constant. Thus the meat was dried for 7 days for the purpose of extracting oil. The total weight of copra obtained after the seven days drying was taken and the average weight of copra per nut was calculated.

3.9.9 Oil percentage

The oil content of a fixed quantity of copra obtained from each plot was extracted with carbon - tetra chloride by the Soxhlet extract apparatus (A.O.A.C. 1969).

3.9.10 Fibre content

The busk obtained from the sampled nuts was bundled independently, tagged and kept immersed in the brackish waters of the Kadinamkulam kayal in Chirayinkil Taluk of Trivandrum District for a period of six months which is the optimum period for proper retting of coconut husks. The retted husks were taken out, cleaned by washing, the rind removed by peeling off, and subjected to threshing with wooden hammer which was the conventional method of extracting fibre from retted husks. After the pith was totally removed, the fibre was weighed and the average weight of fibre per coconut husk was computed.

3.10 Soil factors

3.10.1 Collection of soil samples

Soil samples were collected from two depths 0-50 cm and 50-100 cm from each experimental plot. Four soil cores were taken from four different sites in each experimental plot and composited to get a representative sample of each plot during 1982. All the samples were analysed for total nitrogen, available P, available K, cation exchange capacity and organic carbon.

3.10.2 Nitrogen

Total nitrogen was estimated by the modified Kjeldahl method (Jackson, 1973).

3.10.3 Available P

Extraction of available P was made by Bray 1 extractant with a soil to extractant ratio 1:10 and was estimated by Chlorostannous - reduced molybdophosphoric blue color method in hydrochloric acid system (Jackson 1973).

3.10.4 Available K

Available K was extracted with 1 N ammonium acetate solution (pH 7.0) with a soil extractant ratio of 1:5 shaken for five minutes in a mechanical shaker. The K in the extract after filtration was estimated in an automatic spectrophotometer (Jackson, 1973).

3.10.5 Cation exchange capacity

The estimation of cation exchange capacity was done by the standard analytical procedure outlined by Black (1965).

3.11 Foliar analysis

3.11.1 Collection of leaf sample

The fourteenth leaf of an adult palm (8 years and above) has been widely accepted as the standard leaf for foliar diagnostic studies under normal conditions. This leaf is regarded as one which has reached physiological maturity but has not entered the phase of senescens Anon.(1961), Prevot and Bachy (1962) Zillar and Prevot (1962).

Leaf samples were collected in March 1982. The procedures adopted for collection and preparation of leaf samples were according to specifications described by I.R.H.O. The fourteenth leaf was selected for sampling. Five leaflets each from either side, in the middle of the frond, of the four experimental palms in each plot was collected for the purpose. The mid ribs and marginal edges were removed and the central 15 cm portions from each leaflet was taken. The samples were cleaned and were dried in an air oven at 60 ± 5°C for hours. After drying, the samples were ground and powdered in a Wiley mill with stainless steel blades to pass through a 0.5 mm sieve. From the general composite sample, a representative sample was taken plot-wise for analysis. All the samples were analysed for total N, P, K, Ca, Mg and Na and expressed as percentage.

3.11.2 Statistical analysis

The data on various biometric observations, soil analysis and foliar analysis were analysed statistically through analysis of variance technique (Cochran and Cox, 1957). The interactions NPK^2 and NP^2K^2 were estimated from replication II and I respectively as they confounded respectively in replication I and II. The main effects and interaction effects were compared by using the appropriate CD given by

$$CD = t_{22}\ (.05) \sqrt{\frac{2\ MSE}{\text{Effective number of replication}}}$$

Where MSE = SE

where MSE is the estimate of error variance.

Response surfaceswere fitted to study the relationship between the response (yield) on the factor levels (treatments). The following quadrate model was used to fit the yield data

$$Y = b_0 + b_1 N + b_2 P + b_3 K + b_{11} N^2 + b_{22} P^2 + b_{33} K^2 +$$

$$b_{12} NP + b_{13} NK + b_{23} PK$$

where b_0, b_i, b_{ii}, b_{ij}, $i \neq j$, $i = 1, 2, 3$ are the parameters of the response surface (Das and Giri, 1979).

The significance of b-coefficients was tested by applying students' t-test given by

$$t = \frac{b}{SE\ (\ b\ )} \quad \text{(Snedecor, 1967)}$$

The cause and effect relationship of foliar nutrients to applied nutrient was investigated by Path coefficient analysis (Wright, 1923 a).

Table 7

Treatment combinations and schedule of fertilizer application

Sl. No.	Treatment combinations	Levels of nutrients			Quantity of fertilizers per year per palm		
		N	P	K	A.S.	S.S.P.	M.O.P
1	N_0 P_0 K_0	0	0	0	0	0	0
2	N_0 P_0 K_1	0	0	450	0	0	750
3	N_0 P_0 K_2	0	0	900	0	0	1500
4	N_0 P_1 K_0	0	225	0	0	1406	0
5	N_0 P_1 K_1	0	225	450	0	1406	750
6	N_0 P_1 K_2	0	225	900	0	1406	1500
7	N_0 P_2 K_0	0	450	0	0	2812	0
8	N_0 P_2 K_1	0	450	450	0	2812	750
9	N_0 P_2 K_2	0	450	900	0	2812	1500
10	N_1 P_0 K_0	340	0	0	1659	0	0
11	N_1 P_0 K_1	340	0	450	1659	0	750
12	N_1 P_0 K_2	340	0	900	1659	0	1500
13	N_1 P_1 K_0	340	225	0	1659	1406	0
14	N_1 P_1 K_1	340	225	450	1659	1406	750
15	N_1 P_1 K_2	340	225	900	1659	1406	1500
16	N_1 P_2 K_0	340	450	0	1659	2812	0
17	N_1 P_2 K_1	340	450	450	1659	2812	750
18	N_1 P_2 K_2	340	450	900	1659	2812	1500
19	N_2 P_0 K_0	680	0	0	3318	0	0
20	N_2 P_0 K_1	680	0	450	3318	0	750
21	N_2 P_0 K_2	680	0	900	3318	0	1500
22	N_2 P_1 K_0	680	225	0	3318	1406	0
23	N_2 P_1 K_1	680	225	450	3318	1406	750
24	N_2 P_1 K_2	680	225	900	3318	1406	1500
25	N_2 P_2 K_0	680	450	0	3318	2812	0
26	N_2 P_2 K_1	680	450	450	3318	2812	750
27	N_2 P_2 K_2	680	450	900	3318	2812	1500

A.S. Ammonium sulphate = 20.5% N
S.S.P Single superphosphate = 16.0% P_2O_5
M.O.P Muriate of potash = 60% K_2O

RESULTS

RESULTS

An investigation to study the effect of continued N P K fertilization of coconut with special reference to its nutrition of K was undertaken with coconut seedlings fertilized ever since its planting at the coconut Research Station, Balaramapuram. The data collected on growth, yield, yield attributes, critical levels of nutrient contents in the foliage as related to yield, and the residual fertility status of the soil are statistically analysed and presented.

4.1 Biometric observations

4.1.1 Number of fronds per palm

The number of fronds produced annually in all the four experimental palms per plot was recorded and the average number of fronds produced per palm computed. The data thus computed and analysed for the periods from 1972 to 1979 are presented in Tables from 8 to 23.

From the data it is seen that in general the main effects of N_1 and N_2 were significant over N_0 in the production of fronds in all the years except for June 1972, 1974, 1977 and 1979. The main effect of P was found to be significant only during 1972 to 1974; for the remaining period of the observation, the influence of P was not significant in increasing the annual production of fronds. The direct effect of K_1 and

Table 8

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1972

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	3.46	3.89	4.21	3.85	3.26	4.17	4.13	P_0	3.13	3.81	3.61	3.51
N_1	3.12	4.68	4.55	4.12	4.21	4.62	4.52	P_1	3.44	4.96	4.63	4.34
N_2	3.96	4.46	4.53	4.31	3.39	4.71	4.85	P_2	3.29	4.74	5.29	4.43
Mean	3.51	4.34	4.43	..	3.29	4.50	4.50	Mean	3.29	4.50	4.50	..

C.D. for marginals - 0.390 C.D. for combinations - 0.696

Table 9

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1972

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.42	4.88	5.69	4.99	4.38	5.29	5.32	P_0	4.04	4.71	5.33	4.70
N_1	3.92	6.19	5.74	5.28	3.83	6.14	5.87	P_1	3.94	6.96	6.14	5.68
N_2	5.78	5.97	6.51	6.08	4.40	6.63	7.24	P_2	4.60	6.39	6.96	5.98
Mean	4.70	5.68	5.98	..	4.20	6.02	6.14	Mean	4.20	6.02	6.14	..

C.D. for marginals - 0.642 C.D. for combinations - 1.124

Table 10

Number of fronds as influenced by continuous NPK fertilization

Month ~~Date~~ of observation - June 1973

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	5.21	5.47	5.53	5.40	4.26	5.96	5.99	P_0	4.65	5.89	5.83	5.46
N_1	5.10	6.61	6.72	6.14	4.74	6.82	6.87	P_1	4.96	7.21	6.72	6.30
N_2	6.07	6.81	6.71	6.63	5.11	7.38	7.40	P_2	4.50	7.30	7.71	6.42
Mean	5.46	6.30	6.42	..	4.70	6.72	6.75	Mean	4.70	6.72	6.75	..

C.D. for marginals - 0.485 C.D. for combinations - 0.840

Table 11

Number of fronds as influenced by continuous NPK fertilization

Month ~~Date~~ of observation - December 1973

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.38	4.40	4.50	4.43	3.86	4.92	4.50	P_0	3.97	4.65	4.50	4.38
N_1	3.74	5.56	5.56	4.95	3.94	5.40	5.50	P_1	4.00	5.88	5.64	5.17
N_2	5.01	5.56	5.65	5.41	5.14	6.13	5.96	P_2	3.97	5.92	5.81	5.24
Mean	4.38	5.17	5.24	..	3.98	5.48	5.32	Mean	3.98	5.48	5.32	..

C.D. for marginals - 0.499 C.D. for combinations - 0.865

Table 12

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1974

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.58	5.03	4.93	4.85	4.69	4.75	5.10	P_0	4.47	4.79	5.08	4.78
N_1	4.74	5.24	5.85	5.27	4.42	5.78	5.63	P_1	4.60	5.71	5.43	5.25
N_2	5.01	5.47	5.70	5.39	4.55	5.79	5.83	P_2	4.60	5.83	6.04	5.49
Mean	4.78	5.25	5.49	..	4.55	5.44	5.52	Mean	4.55	5.44	5.52	..

C.D. for marginals - 0.471 C.D. for combinations - 0.816

Table 13

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1974

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	3.75	3.83	4.33	3.97	3.46	4.13	4.33	P_0	3.60	3.96	4.35	3.97
N_1	3.64	5.01	4.81	4.49	4.14	4.70	4.64	P_1	3.93	5.34	4.92	4.63
N_2	4.51	5.04	5.06	4.87	3.76	5.93	5.48	P_2	3.82	5.20	5.18	4.73
Mean	3.97	4.63	4.73	..	3.78	4.73	4.82	Mean	3.78	4.73	4.82	..

C.D. for marginals - 0.411 C.D. for combinations - 0.712

Table 14

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1975

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.75	4.61	4.75	4.70	4.65	4.79	4.67	P_0	4.72	5.01	5.08	4.94
N_1	4.51	5.29	5.65	5.15	4.14	5.56	5.75	P_1	4.36	5.67	5.21	5.08
N_2	5.56	5.33	5.75	5.55	4.60	6.33	5.71	P_2	4.31	6.01	5.83	5.38
Mean	4.94	5.08	5.38	..	4.46	5.56	5.38	Mean	4.46	5.56	5.38	..

C.D. for marginals - 0.356 C.D. for combinations - 0.617

Table 15

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1975

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.29	4.78	4.79	4.62	4.27	4.83	4.75	P_0	4.03	4.89	4.53	4.48
N_1	4.17	6.14	5.40	5.24	4.57	5.69	5.45	P_1	4.71	6.17	5.64	5.50
N_2	4.99	5.60	5.77	5.45	4.11	6.07	6.17	P_2	4.22	5.54	6.20	5.32
Mean	4.48	5.50	5.32	..	4.32	5.53	5.45	Mean	4.32	5.53	5.45	..

C.D. for marginals - 0.428 C.D. for combinations - 0.742

Table 16

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1976

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.50	4.63	4.54	4.56	4.21	4.50	4.96	P_0	5.26	4.20	4.67	4.84
N_1	4.35	5.21	5.43	4.99	4.85	5.26	4.88	P_1	4.47	5.21	5.22	4.96
N_2	5.68	5.06	4.92	5.22	5.21	5.04	5.40	P_2	4.54	5.00	5.35	4.96
Mean	4.84	4.96	4.96	..	4.75	4.94	5.08	Mean	4.75	4.94	5.08	..

C.D. for marginals - 0.390   C.D. for combinations - 0.676

Table 17

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1976

	P_0	P_1	P_2	Mean	K_0	K_0	K_2		K_0	K_1	K_2	Mean
N_0	4.63	4.70	5.03	4.78	4.45	4.79	5.11	P_0	4.95	5.21	5.47	5.21
N_1	5.47	5.90	5.90	5.76	4.86	6.11	6.31	P_1	4.64	5.88	6.00	5.51
N_2	5.52	5.92	5.92	5.79	4.88	6.29	6.20	P_2	4.60	6.11	6.14	5.62
Mean	5.21	5.51	5.62	..	4.73	5.73	5.87	Mean	4.73	5.73	5.87	..

C.D. for marginals - 0.341   C.D. for combinations - 0.590

Table 18

Number of fronds as influenced by continuous NPK fertilization

Month of observation - June 1977

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	5.29	5.38	5.32	5.33	4.85	5.54	5.61	P_0	6.26	5.57	5.60	5.81
N_1	5.21	5.92	6.10	5.74	5.58	5.88	5.77	P_1	5.06	6.33	6.38	5.81
N_2	6.93	6.11	6.09	6.38	6.37	6.61	6.41	P_2	5.18	6.13	6.20	5.83
Mean	5.81	5.81	5.83	..	5.50	6.01	5.94	Mean	5.50	6.01	5.94	..

C.D. for marginals - 0.573 C.D. for combinations 0.993

Table 19

Number of fronds as influenced by continuous NPK fertilization

Month of observation - December 1977

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	5.13	4.90	5.02	5.01	4.45	5.13	5.49	P_0	5.24	5.54	5.42	5.40
N_1	5.33	6.03	5.95	5.76	5.27	6.38	5.96	P_1	4.68	6.24	6.30	5.65
N_2	5.74	6.03	6.53	6.10	4.93	6.57	6.79	P_2	4.72	6.03	6.75	5.83
Mean	5.40	5.65	5.83	..	4.88	5.93	6.08	Mean	4.88	5.93	6.08	..

C.D. for marginals - 0.431 C.D. for combinations - 0.757

Table 20

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1978

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	5.63	5.50	5.74	5.62	4.96	6.00	5.90	P_0	5.82	6.15	5.99	5.98
N_1	5.64	6.70	6.50	6.27	5.87	6.72	6.23	P_1	5.40	7.04	6.21	6.21
N_2	6.69	6.45	6.76	6.63	5.89	7.17	6.86	P_2	5.50	6.70	6.81	6.33
Mean	5.98	6.21	6.33	..	5.57	6.63	6.33	Mean	5.57	6.63	6.33	..

C.D. for marginals - 0.451 C.D. for combinations - 0.782

Table 21

Number of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1978

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.00	4.19	4.01	4.05	3.89	4.13	4.14	P_0	3.90	4.51	4.53	4.31
N_1	4.33	4.95	4.50	4.59	4.08	4.92	4.78	P_1	4.17	4.88	4.50	4.51
N_2	4.61	4.46	5.04	4.70	3.79	5.06	5.27	P_2	3.69	4.71	5.15	4.52
Mean	4.31	4.51	4.52	..	3.92	4.70	4.73	Mean	3.92	4.70	4.73	..

C.D. for marginals - 0.426 C.D. for combinations - 0.738

Table 22

Number of fronds as influenced by continuous NPK fertilization

Month Date of observation - June 1979

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	5.82	5.23	5.60	5.50	5.33	5.47	5.85	P_0	5.80	5.93	5.92	5.88
N_1	5.68	5.52	5.93	5.71	5.65	6.08	5.40	P_1	5.12	5.97	5.55	5.54
N_2	6.15	5.88	5.60	5.88	5.27	6.12	6.25	P_2	5.33	5.77	6.03	5.71
Mean	5.88	5.54	5.71	..	5.42	5.89	5.83	Mean	5.42	5.89	5.83	..

C.D. for marginals - 0.577 C.D. for combinations - 0.998

Table 23

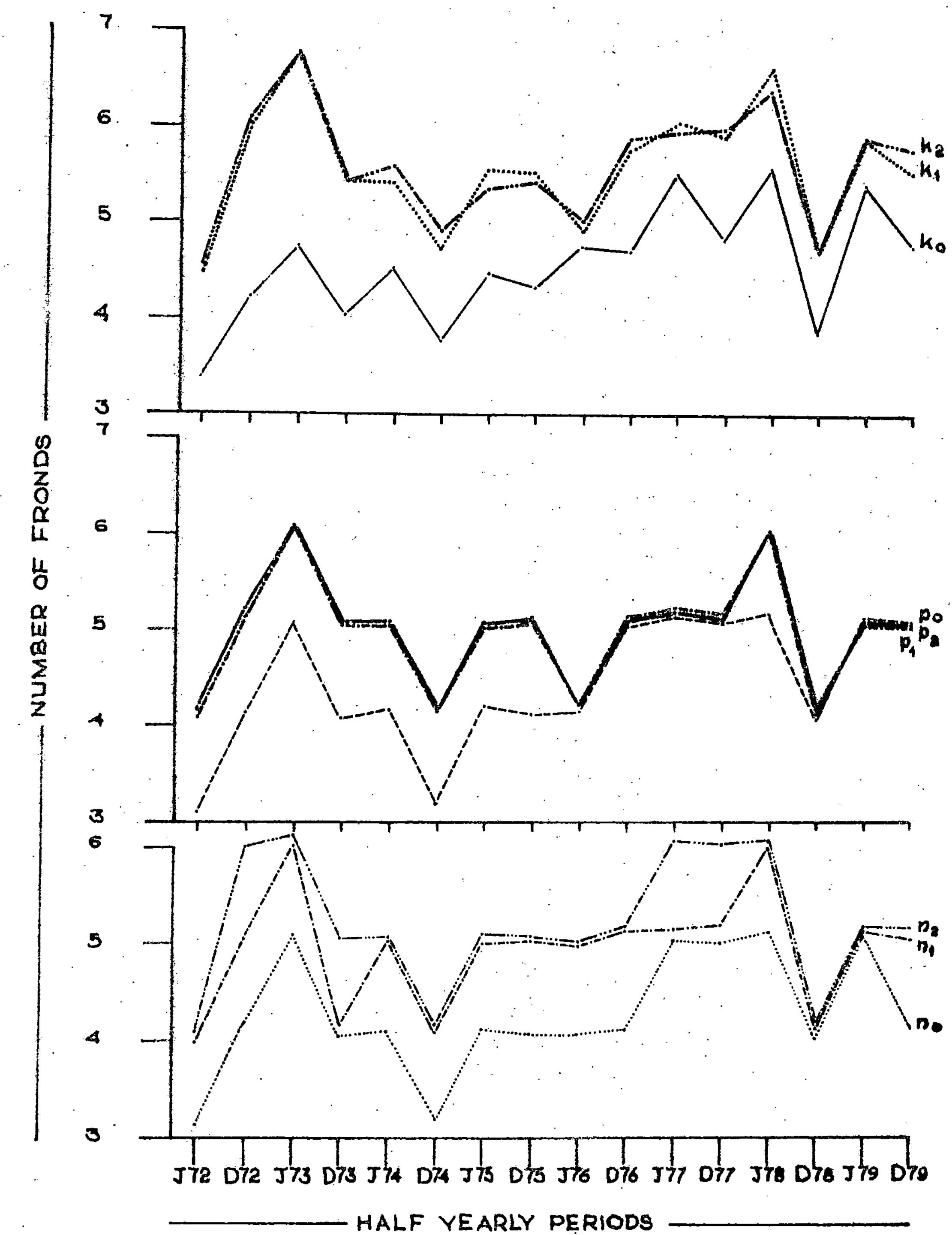
Number of fronds as influenced by continuous NPK fertilization

Month Date of observation - December 1979

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	5.07	4.43	5.04	4.85	4.50	5.07	4.98	P_0	5.00	5.82	5.42	5.41
N_1	5.33	5.63	5.08	5.35	4.43	5.78	5.83	P_1	4.38	5.41	5.89	5.23
N_2	5.82	5.61	5.66	5.70	4.93	5.88	6.30	P_2	4.48	5.49	5.80	5.26
Mean	5.41	5.23	5.26	..	4.63	5.57	5.73	Mean	4.62	5.57	5.73	..

C.D. for marginals - 0.486 C.D. for combinations - 0.842

FIG: 2 RESPONSE OF N, P AND K ON THE NUMBER OF FRONDS



K_2 were significant over the K_0 level viz. zero level for all the years except for June 1976, 1977 and 1979. However, the higher levels of K_1 and K_2 were found to be on par. With zero level of K the number of fronds produced was 3.3 per palm per annum while it was 4.5 when the level of K was raised from (K_0) zero level to K_1 viz. 450 g K_2O per palm per year. The results showed that there was a tendency for a quadratic response to P and K when the doses were increased above the minimum levels.

During the second half of 1972, main effects of N,P and K only were found to be significant. All the factors increased the number of fronds produced with the incremental levels of their applications. The number of fronds increased from 5 to 5.3 when the level of N was raised from the N_0 level to N_1 level (340 g N per tree per year) and to 6.1 at N_2 level (680 g N per tree per year). The number of fronds produced per annum corresponding to P_0 , P_1 and P_2 levels i.e 0, 225 and 450 g per tree per year were 4.7, 5.7 and 6.0 respectively. A similar increasing trend was evinced with increased levels of K also. However, it was observed that the higher levels of P_1 and P_2 and that of K_1 and K_2 were not significant to each other and were on par.

From 1972 to 1975 the main effects of NPK were significant. Thereafter the effect of N alone was significant, which however, was not found to be significant in 1979. There was no response to P after 1975 though the palms were regularly fertilized with P. The response to K was also found to be not significant during the first half of 1976, first half of 1977 and in 1979.

Most of the interaction effects were not significant in almost all the years. However, P_1K_2 was significant in the first half of 1973, second half of 1974 and in the second half of 1976. But NP was significant only in the first half of 1976. The presence of NK interaction was observed only in 1975.

4.1.2 Length of frond

Observations on length of fronds were recorded half yearly from June 1972 to December 1979 and the results are presented in Tables from 24 to 39.

From the data presented in Tables 24 to 39 it was revealed that even without the addition of N fertilizers, the length of fronds was on par with N_1 and N_2 levels of fertilization viz. 340 and 680 g N per tree per year during all the periods of observation from 1972 to 1979. The main effect of P was also found to be similar as that of N, though a significant response to P was observed during 1972. But the main effect of K was significant during all the periods of observation

Table 24

Length of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1972 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2
N_0	405.0	428.0	434.0	422.0	351.0	458.0	458.0
N_1	365.0	454.0	429.0	416.0	320.0	475.0	453.0
N_2	464.0	450.0	422.0	425.0	383.0	467.0	475.0
Mean	391.0	444.0	428.0	..	335.0	467.0	462.0

	K_0	K_1	K_2	Mean
P_0	344.0	399.0	431.0	391.0
P_1	344.0	506.0	482.0	444.0
P_2	316.0	395.0	472.0	428.0
Mean	335.0	467.0	462.0	..

C.D. for marginals - 32.0 C.D. for combinations - 56.0

Table 25

Length of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1972 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2
N_0	418.0	453.0	448.0	438.0	396.0	459.0	486.0
N_1	393.0	464.0	455.0	437.0	343.0	489.0	479.0
N_2	427.0	433.0	508.0	456.0	342.0	474.0	552.0
Mean	413.0	450.0	469.0	..	351.0	474.0	506.0

	K_0	K_1	K_2	Mean
P_0	363.0	419.0	456.0	413.0
P_1	341.0	513.0	496.0	450.0
P_2	350.0	490.0	566.0	469.0
Mean	359.0	474.0	506.0	..

C.D. for marginals - 24.0 C.D. for combinations - 42.0

Table 26

Length of fronds as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1973 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mea
N_0	404.0	444.0	428.0	425.0	379.0	433.0	464.0	P_0	414.0	415.0	461.0	430.
N_1	405.0	432.0	424.0	420.0	344.0	458.0	458.0	P_1	321.0	506.0	467.0	431.
N_2	480.0	480.0	430.0	443.0	302.0	491.0	534.0	P_2	262.0	462.0	529.0	428.
Mean	430.0	431.0	428.0	..	342.0	461.0	486.0	Mean	342.0	461.0	486.0	..

C.D. for marginals - 56.0 C.D. for combination 97.0

Table 27

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1973 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	408.0	476.0	407.0	431.0	393.0	426.0	473.0	P_0	384.0	436.0	444.0	421.
N_1	378.0	460.0	490.0	443.0	372.0	495.0	461.0	P_1	385.0	498.0	515.0	466.
N_2	478.0	462.0	488.0	476.0	399.0	501.0	527.0	P_2	396.0	489.0	501.0	462.
Mean	421.0	466.0	462.0	..	384.0	474.0	487.0	Mean	388.0	474.0	487.0	..

C.D. for marginals 38.0 C.D. for combinations - 66.0

Table 28

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1974 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	430.0	483.0	433.0	449.0	398.0	448.0	500.0	P_0	384.0	457.0	472.0	448.0
N_1	406.0	468.0	492.0	456.0	381.0	498.0	488.0	P_1	390.0	515.0	525.0	477.0
N_2	476.0	479.0	494.0	483.0	399.0	518.0	532.0	P_2	403.0	493.0	523.0	473.0
Mean	438.0	477.0	473.0	..	392.0	486.0	507.0	Mean	392.0	488.0	507.0	..

C.D. for marginals - 29.0 C.D. for combinations 51.0

Table 29

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1974 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	422.0	487.0	437.0	449.0	382.0	454.0	511.0	P_0	395.0	479.0	495.0	456.0
N_1	433.0	490.0	492.0	471.0	403.0	498.0	513.0	P_1	386.0	540.0	521.0	482.0
N_2	514.0	471.0	497.0	494.0	412.0	537.0	533.0	P_2	416.0	470.0	541.0	475.0
Mean	456.0	482.0	475.0	..	399.0	496.0	519.0	Mean	399.0	496.0	519.0	..

C.D. for marginals - 34.0 C.D. for combinations - 59.0

Table 30

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1975 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	471.0	475.0	478.0	475.0	418.0	484.0	522.0	P_0	408.0	461.0	485.0	452.0
N_1	413.0	471.0	469.0	449.0	386.0	457.0	504.0	P_1	400.0	487.0	513.0	467.0
N_2	472.0	455.0	479.0	468.0	404.0	488.0	514.0	P_2	400.0	481.0	539.0	473.0
Mean	452.0	467.0	473.0	..	403.0	476.0	513.0	Mean	403.0	476.0	513.0	..

C.D. for marginals - 35.0   C.D. for combinations - 62.0

Table 31

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1975 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	469.0	489.0	468.0	475.0	426.0	491.0	509.0	P_0	401.0	485.0	483.0	456.0
N_1	452.0	483.0	490.0	475.0	420.0	492.0	512.0	P_1	416.0	521.0	513.0	483.0
N_2	447.0	478.0	489.0	472.0	358.0	514.0	512.0	P_2	416.0	492.0	538.0	482.0
Mean	456.0	483.0	482.0	..	411.0	499.0	511.0	Mean	411.0	499.0	511.0	..

C.D. for marginals - 32.0   C.D. for combinations - 56.0

Table 32

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1976 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	467.0	463.0	452.0	461.0	421.0	479.0	482.0	P_0	428.0	470.0	486.0	461.0
N_1	445.0	496.0	492.0	477.0	420.0	505.0	507.0	P_1	405.0	524.0	509.0	479.0
N_2	472.0	478.0	477.0	476.0	407.0	498.0	523.0	P_2	415.0	488.0	518.0	474.0
Mean	461.0	479.0	474.0	..	..	494.0	504.0	Mean	416.0	494.0	504.0	..

C.D. for marginals - 23.0 C.D. for combinations - 41.0

Table 33

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1976 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	464.0	480.0	481.0	475.0	433.0	495.0	497.0	P_0	424.0	476.0	492.0	464.0
N_1	463.0	502.0	508.0	491.0	414.0	516.0	544.0	P_1	412.0	542.0	538.0	496.0
N_2	464.0	504.0	509.0	493.0	386.0	540.0	552.0	P_2	398.0	533.0	568.0	500.0
Mean	464.0	496.0	500.0	..	411.0	517.0	531.0	Mean	411.0	517.0	531.0	..

C.D. for marginals - 26.0 C.D. for combinations - 45.0

Table 34

Length of frond as influenced by continuous NPK fertilization

Month ~~Date~~ of observation - June 1977 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	508.0	501.0	510.0	506.0	465.0	513.0	541.0	P_0	474.0	502.0	519.0	498.0
N_1	492.0	540.0	505.0	513.0	448.0	554.0	536.0	P_1	443.0	571.0	568.0	527.0
N_2	495.0	540.0	529.0	522.0	438.0	552.0	575.0	P_2	435.0	545.0	565.0	515.0
Mean	498.0	527.0	515.0	..	456.0	539.0	550.0	Mean	451.0	539.0	550.0	..

C.D. for marginals - 26.0   C.D. for combinations - 46.0

Table 35

Length of frond as influenced by continuous NPK fertilization

Month ~~Date~~ of observation - December 1977 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	451.0	517.0	530.0	499.0	466.0	549.0	489.0	P_0	473.0	554.0	476.0	501.0
N_1	528.0	589.0	542.0	553.0	475.0	594.0	590.0	P_1	468.0	600.0	607.0	559.0
N_2	524.0	570.0	595.0	563.0	435.0	601.0	653.0	P_2	434.0	500.0	642.0	555.0
Mean	501.0	559.0	555.0	..	459.0	581.0	575.0	Mean	459.0	581.0	575.0	..

C.D. for marginals - 56.0   C.D. for combinations 97.0

Table 36

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1978 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	544.0	501.0	508.0	518.0	458.0	540.0	555.0	P_0	491.0	536.0	538.0	521.0
N_1	497.0	544.0	526.0	522.0	445.0	562.0	560.0	P_1	412.0	604.0	558.0	525.0
N_2	528.0	529.0	536.0	529.0	424.0	606.0	557.0	P_2	425.0	568.0	577.0	523.0
Mean	521.0	525.0	523.0	..	442.0	569.0	557.0	Mean	442.0	569.0	557.0	..

C.D. for marginals 37.0

C.D. for combinations 65.0

Table 37

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1978 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	513.0	496.0	487.0	498.0	461.0	513.0	521.0	P_0	463.0	576.0	528.0	502.0
N_1	487.0	515.0	503.0	502.0	452.0	522.0	531.0	P_1	429.0	532.0	532.0	498.0
N_2	506.0	482.0	538.0	508.0	414.0	538.0	574.0	P_2	435.0	523.0	567.0	508.0
Mean	502.0	498.0	508.0	..	442.0	523.0	542.0	Mean	442.0	523.0	542.0	..

C.D. for marginals - 31.0

C.D. for combinations - 55.0

Table 38

Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1979 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2
N_0	544.0	521.0	514.0	526.0	489.0	536.0	554.0
N_1	516.0	532.0	538.0	529.0	454.0	550.0	581.0
N_2	519.0	555.0	543.0	539.0	447.0	589.0	581.0
Mean	526.0	536.0	513.0	..	463.0	559.0	572.0

	K_0	K_1	K_2	Mean
P_0	475.0	538.0	566.0	526.0
P_1	465.0	582.0	561.0	536.0
P_2	450.0	556.0	589.0	531.0
Mean	463.0	559.0	572.0	..

C.D. for marginals - d6.0 C.D. for combinations - 63.0

Table 39

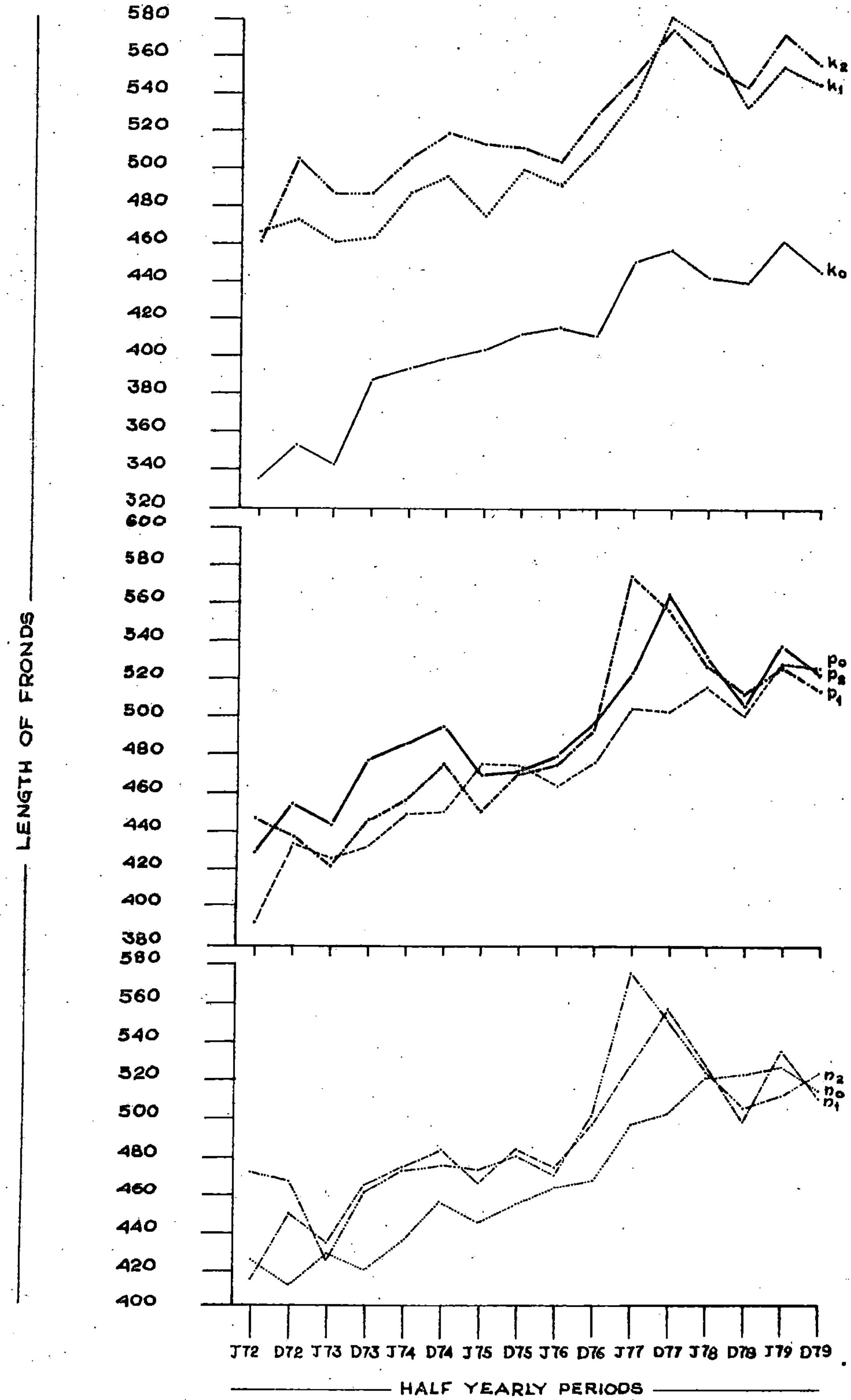
Length of frond as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1979 (cm)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2
N_0	532.0	511.0	522.0	522.0	458.0	552.0	545.0
N_1	498.0	513.0	522.0	511.0	444.0	541.0	550.0
N_2	519.0	518.0	528.0	522.0	431.0	554.0	580.0
Mean	516.0	514.0	524.0	..	447.0	549.0	558.0

	K_0	K_1	K_2	Mean
P_0	466.0	540.0	544.0	516.
P_1	433.0	554.0	555.0	514.
P_2	443.0	554.0	575.0	524.
Mean	447.0	549.0	558.0	..

C.D. for marginals - 26.0 C.D. for combinations - 46.0

FIG. 3 RESPONSE OF N.P AND K ON LENGTH OF FRONDS



from 1972 to 1979 and was linear in nature. The interaction effects were found to be inconsistent.

4.1.3 Number of leaflets

The average number of leaflets found on one side of the leaf was recorded and presented in Tables from 40 to 55.

From the results it was revealed that the main effects of N and P were not significant in almost all the years of observations from 1972 to December 1979. However, nitrogen was found to be significant in increasing the number of leaflets during the second half of 1973 and in 1974. Response of P was significant only during the second half of 1973 and second half of 1974. Though the effect of N was not significant for the rest of the periods of study an increasing trend in the number of leaflets was observed. A similar trend was observed for P also. Main effect of K was significant in all the periods of observation except in the first half of 1973 and the second half of 1975. A significant increase in the number of leaflets was observed due to K application, over the zero level of K. However, there was no significant difference in the number of leaflets between the K_1 and K_2 levels. The rate of increase in the number of leaflets was less at the higher doses of K_2 over the K_1 level.

4.1.4 Number of female flowers

The data on the number of female flowers produced during

Table 40

Number of leaflet as influenced by continuous NPK fertilization
Month ~~Date~~ of observation – June 1972

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	132.0	91.0	96.0	106.0	76.0	148.0	95.0	P_0	76.0	144.0	92.0	104.0
N_1	86.0	102.0	98.0	95.0	73.0	106.0	107.0	P_1	77.0	110.0	101.0	96.0
N_2	94.0	95.0	95.0	95.0	74.0	107.0	104.0	P_2	70.0	107.0	112.0	96.0
Mean	104.0	96.0	96.0	..	74.0	120.0	102.0	Mean	74.0	120.0	102.0	..

C.D. for marginals – 30.0 C.D. for combinations – 52.0

Table 41

Number of leaflet as influenced by continuous NPK fertilization
Month ~~Date~~ of observation – December 1972

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	95.0	97.0	101.0	97.0	85.0	99.0	109.0	P_0	83.0	100.0	104.0	96.0
N_1	88.0	114.0	109.0	102.0	78.0	113.0	115.0	P_1	80.0	114.0	118.0	104.0
N_2	105.0	102.0	114.0	107.0	82.0	115.0	124.0	P_2	82.0	112.0	126.0	106.0
Mean	96.0	104.0	106.0	..	82.0	109.0	116.0	Mean	82.0	109.0	116.0	..

C.D. for marginals – 7.0 C.D. for combinations 13.0

Table 42

Number of leaflet as influenced by continuous NPK fertilization

Month ~~Date~~ of observation - June 1973

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	99.0	97.0	106.0	101.0	98.0	91.0	112.0	P_0	98.0	105.0	107.0	103.0
N_1	102.0	114.0	114.0	110.0	97.0	120.0	113.0	P_1	95.0	108.0	116.0	106.0
N_2	109.0	108.0	123.0	113.0	110.0	116.0	114.0	P_2	112.0	114.0	117.0	115.0
Mean	103.0	106.0	115.0	..	102.0	109.0	113.0	Mean	102.0	109.0	113.0	..

C.D. for marginals - 10.0 C.D. for combinations - 18.0

Table 43

Number of leaflet as influenced by continuous NPK fertilization

Month ~~Date~~ of observation - December 1973

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	88.0	90.0	83.0	87.0	82.0	90.0	89.0	P_0	83.0	93.0	88.0	88.0
N_1	81.0	94.0	100.0	92.0	84.0	101.0	90.0	P_1	81.0	100.0	99.0	93.0
N_2	97.0	96.0	101.0	98.0	86.0	100.0	107.0	P_2	88.0	98.0	98.0	95.0
Mean	88.0	93.0	95.0	..	84.0	97.0	95.0	Mean	84.0	97.0	95.0	..

C.D. for marginals - 7.0 C.D. for combinations - 12.0

Table 44

Number of leaflet as influenced by continuous NPK fertilization
Month ~~Date~~ of observations - June 1974

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	96.0	95.0	94.0	95.0	88.0	99.0	99.0	P_0	89.0	104.0	103.0	99.0
N_1	89.0	102.0	108.0	100.0	90.0	106.0	104.0	P_1	87.0	108.0	103.0	99.0
N_2	111.0	100.0	108.0	106.0	91.0	111.0	116.0	P_2	94.0	104.0	113.0	103.0
Mean	99.0	99.0	103.0	..	90.0	105.0	106.0	Mean	90.0	105.0	106.0	..

C.D. for marginals - 7.0   C.D. for combinations - 3.0

Table 45

Number of leaflet as influenced by continuous NPK fertilization
Month ~~Date~~ of observations - December 1974

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	75.0	100.0	93.0	89.0	68.0	97.0	104.0	P_0	69.0	97.0	106.0	90.0
N_1	95.0	108.0	104.0	102.0	89.0	107.0	118.0	P_1	83.0	109.0	112.0	102.0
N_2	99.0	96.0	117.0	102.0	87.0	107.0	113.0	P_2	95.0	104.0	110.0	103.0
Mean	90.0	102.0	103.0	..	81.0	104.0	109.0	Mean	81.0	104.0	109.0	..

C.D. for marginals - 8.0   C.D. for combinations - 14.0

Table 46

Number of leaflet as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1975

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	105.0	105.0	103.0	106.0	100.0	106.0	110.0	P_0	98.0	97.0	105.0	100.0
N_1	90.0	109.0	103.0	100.0	98.0	99.0	108.0	P_1	96.0	113.0	112.0	107.0
N_2	104.0	108.0	106.0	106.0	95.0	110.0	112.0	P_2	92.0	105.0	114.0	104.0
Mean	100.0	107.0	104.0	..	97.0	105.0	110.0	Mean	95.0	105.0	110.0	..

C.D. for marginals - N.S   C.D. for combinations - N.S

Table 47

Number of leaflet as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1975

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	104.0	110.0	103.0	106.0	98.0	109.0	110.0	P_0	94.0	97.0	107.0	100.0
N_1	94.0	110.0	123.0	109.0	116.0	101.0	110.0	P_1	103.0	113.0	110.0	108.0
N_2	101.0	104.0	106.0	104.0	94.0	111.0	107.0	P_2	111.0	111.0	111.0	111.0
Mean	100.0	108.0	111.0	..	103.0	107.0	109.0	Mean	103.0	107.0	109.0	..

C.D. for marginals - 11.0   C.D. for combinations 19.0

Table 48

Number of leaflets as influenced by continuous NPK fertilization
Month ~~Date~~ of observations - June 1976

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	106.0	98.0	104.0	103.0	89.0	109.0	109.0	P_0	91.0	106.0	107.0	102.0
N_1	95.0	104.0	103.0	101.0	86.0	108.0	108.0	P_1	89.0	113.0	112.0	105.0
N_2	104.0	112.0	104.0	106.0	86.0	116.0	117.0	P_2	81.0	115.0	115.0	104.0
Mean	102.0	105.0	104.0	..	87.0	111.0	111.0	Mean	87.0	111.0	111.0	..

C.D. for marginals - 7.0 C.D. for combinations - 12.0

Table 49

Number of leaflets as influenced by continuous NPK fertiliz-ation
Month ~~Date~~ of observation - December 1976

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	106.0	102.0	97.0	102.0	91.0	106.0	108.0	P_0	94.0	105.0	105.0	101.0
N_1	94.0	112.0	109.0	105.0	88.0	112.0	106.0	P_1	82.0	117.0	120.0	106.0
N_2	108.0	105.0	105.0	104.0	83.0	112.0	118.0	P_2	87.0	109.0	117.0	104.0
Mean	101.0	106.0	104.0	..	87.0	110.0	114.0	Mean	87.0	110.0	114.0	..

C.D. for marginals - 7.0 C.D. for combinations - 12.0

Table 50

Number of leaflets as influenced by continuous NPK fertilization

~~Date~~ Month of observation - June 1977

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	108.0	106.0	107.0	107.0	96.0	110.0	114.0	P_0	99.0	110.0	113.0	107.0
N_1	105.0	114.0	110.0	110.0	97.0	115.0	117.0	P_1	92.0	121.0	120.0	111.0
N_2	109.0	113.0	112.0	111.0	92.0	120.0	122.0	P_2	94.0	114.0	120.0	110.0
Mean	107.0	111.0	110.0	Mea..	95.0	115.0	118.0	Mean	95.0	115.0	118.0	..

C.D. for marginals - 5.0 C.D. for combinations - 9.0

Table 51

Number of leaflets as influenced by continuous NPK fertilization

~~Date~~ Month of observation - December 1977

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	112.0	110.0	110.0	111.0	99.0	114.0	120.0	P_0	108.0	112.0	110.0	110.0
N_1	103.0	117.0	115.0	112.0	99.0	120.0	111.0	P_1	93.0	123.0	126.0	114.0
N_2	113.0	114.0	125.0	117.0	98.0	121.0	113.0	P_2	96.0	121.0	134.0	117.0
Mean	110.0	114.0	117.0	..	99.0	118.0	123.0	Mean	99.0	118.0	123.0	..

C.D. for marginals - 7.0 C.D. for combinations - 13.0

Table 52

Number of leaflets as influenced by continuous NPK fertilization

Month ~~Date~~ of observation - June 1978

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	99.0	101.0	97.0	99.0	85.0	104.0	109.0	P_0	85.0	103.0	106.0	98.0
N_1	96.0	103.0	102.0	100.0	82.0	110.0	110.0	P_1	82.0	111.0	108.0	100.0
N_2	98.0	96.0	103.0	99.0	79.0	110.0	108.0	P_2	72.0	111.0	113.0	101.0
Mean	98.0	100.0	101.0	..	82.0	108.0	109.0	Mean	82.0	108.0	109.0	..

C.D. for marginals - 7.0 C.D. for combinations - 13.0

Table 53

Number of leaflets as influenced by continuous NPK fertilization

~~Date~~ Month of observation - December 1978

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	105.0	101.0	105.0	104.0	97.0	107.0	107.0	P_0	93.0	107.0	106.0	102.0
N_1	97.0	109.0	107.0	104.0	91.0	110.0	112.0	P_1	91.0	112.0	112.0	105.0
N_2	104.0	104.0	108.0	106.0	83.0	112.0	122.0	P_2	87.0	110.0	123.0	107.0
Mean	102.0	105.0	107.0	..	90.0	110.0	114.0	Mean	90.0	110.0	114.0	..

C.D. for marginals - 6.0 C.D. for combinations - 11.0

Table 54

Number of leaflets as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - June 1979

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	108.0	109.0	105.0	107.0	98.0	110.0	113.0	P_0	105.0	111.0	113.0	110.0
N_1	108.0	110.0	109.0	109.0	97.0	114.0	117.0	P_1	91.0	118.0	119.0	109.0
N_2	114.0	109.0	106.0	109.0	91.0	119.0	119.0	P_2	90.0	113.0	116.0	106.0
Mean	110.0	109.0	106.0	..	95.0	114.0	116.0	Mean	95.0	114.0	116.0	..

C.D. for marginals - 4.0 C.D. for combinations - 7.0

Table 55

Number of leaflets as influenced by continuous NPK fertilization
Month ~~Date~~ of observation - December 1979

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	109.0	108.0	109.0	109.0	100.0	114.0	110.0	P_0	103.0	113.0	119.0	110.0
N_1	108.0	111.0	109.0	109.0	98.0	116.0	114.0	P_1	91.0	110.0	115.0	108.0
N_2	114.0	106.0	109.0	110.0	91.0	111.0	122.0	P_2	95.0	116.0	117.0	109.0
Mean	110.0	108.0	109.0	..	96.0	116.0	116.0	Mean	96.0	116.0	116.0	..

C.D. for marginals - 6.0 C.D. for combinations - 10.0

Table 56

Number of female flower as influenced by continuous NPK fertilization

Year of observation - 1972

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	1.33	9.08	8.72	6.38	0	7.75	11.39	P_0	0	0.46	4.33	1.60
N_1	0.46	6.04	18.80	8.43	0	4.58	20.70	P_1	0	18.58	29.00	15.88
N_2	3.00	32.57	32.54	22.70	0	20.37	47.73	P_2	0	13.67	46.43	20.03
Mean	1.60	15.88	20.03	..	0	10.90	26.61	Mean	0	10.90	26.61	..

C.D. for marginals - 9.04 C.D. for combinations 15.65

Table 57

Number of female flower as influenced by continuous NPK fertilization

Year of observation - 1973

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.96	12.54	23.54	12.35	0	17.96	19.08	P_0	0.0	3.54	8.67	4.07
N_1	2.00	29.25	82.20	17.84	1.17	17.90	34.40	P_1	2.96	33.92	34.30	23.74
N_2	9.25	29.42	47.71	28.79	2.96	29.46	53.96	P_2	1.17	37.86	64.50	31.17
Mean	4.07	23.74	31.17	..	1.38	21.77	35.83	Mean	1.38	21.77	35.88	..

C.D. for marginals 12.67 C.D. for combinations - 21.95

Table 58

Number of female flowers as influenced by continuous NPK fertilization

Year of observation - 1974

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.92	14.21	15.92	10.35	0.96	14.71	15.38	P_0	0	7.46	11.58	6.35
N_1	3.38	43.21	29.30	24.99	1.04	24.17	49.70	P_1	2.13	52.29	56.10	36.84
N_2	14.75	53.11	48.32	38.73	1.08	44.17	70.93	P_2	0.96	23.39	58.37	30.87
Mean	6.35	36.84	30.87	..	1.03	27.68	45.35	Mean	1.03	27.68	45.35	..

C.D. for marginals - 11.78 C.D. for combinations - 20.40

Table 59

Number of female flowers as influenced by continuous NPK fertilization

Year of observation - 1975

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	6.38	23.79	16.68	15.62	0.46	25.71	20.68	P_0	0.46	28.64	23.04	17.05
N_1	7.47	69.58	55.50	44.19	1.04	47.21	84.30	P_1	3.04	90.37	84.50	59.33
N_2	37.29	84.61	80.04	67.31	2.07	93.82	106.12	P_2	0.10	47.72	104.53	50.74
Mean	17.05	59.33	50.75	..	1.14	55.58	70.38	Mean	1.14	55.58	70.38	..

C.D. for marginals - 16.00 C.D. for combinations - 27.71

Table 60

Number of female flowers as influenced by continuous NPK fertilization
Year of observation - 1976

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	9.13	18.25	12.03	13.13	0	21.87	14.73	P_0	4.48	23.62	18.51	15.5
N_1	11.05	45.12	31.42	29.20	0.38	30.36	56.55	P_1	1.42	64.37	55.07	40.2
N_2	26.44	57.48	52.55	45.49	2.73	62.33	76.41	P_2	0	26.87	69.12	32.0
Mean	15.54	40.29	32.00	..	1.97	38.29	47.57	Mean	1.97	38.29	47.57	..

C.D. for marginals - 10.67 C.D. for combinations - 18.47

Table 61

Number of female flowers as influenced by continuous NPK fertilization
Year of observation - 1977

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	8.75	20.00	15.87	14.87	3.04	16.87	24.71	P_0	5.23	29.78	33.85	22.9
N_1	26.42	62.84	43.35	44.20	3.62	52.97	76.01	P_1	2.42	80.12	83.61	55.3
N_2	33.69	83.32	89.58	68.86	2.94	87.10	116.55	P_2	1.96	47.04	99.82	49.6
Mean	20.95	55.39	49.60	..	3.20	52.31	72.43	Mean	3.20	52.31	72.43	..

C.D. for marginals - 6.34 C.D. for combinations - 10.98

Table 62

Number of female flowers as influenced by continuous NPK fertilization
Year of observation - 1978

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	20.71	27.71	22.40	23.61	5.33	29.97	35.69	P_0	7.68	37.66	41.94	29.10
N_1	23.61	50.67	53.60	45.98	2.00	57.83	78.10	P_1	2.83	80.83	72.70	52.14
N_2	42.97	68.04	79.07	63.36	4.07	85.21	100.80	P_2	0.89	54.33	99.92	51.71
Mean	29.10	52.14	51.71	..	3.80	57.61	71.54	Mean	3.80	57.61	71.54	..

C.D. for marginals - 11.24 C.D. for combinations - 19.27

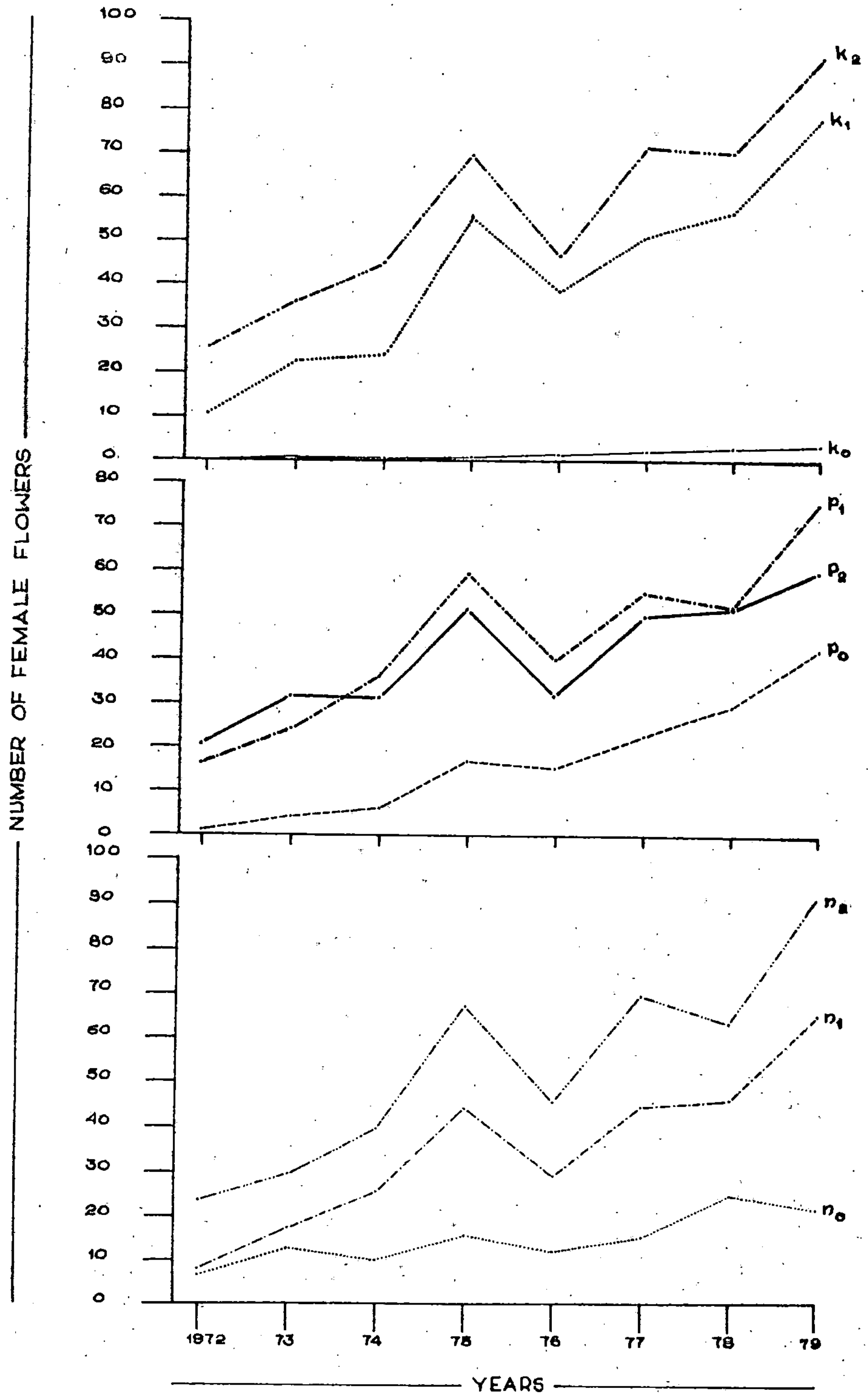
Table 63

Number of female flowers as influenced by continuous NPK fertilization
Year of observation - 1979

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	22.08	22.06	18.44	20.86	3.78	24.61	34.18	P_0	8.22	61.03	57.63	42.29
N_1	40.41	90.72	65.00	65.38	4.74	85.90	105.40	P_1	2.82	114.02	110.20	75.70
N_2	64.38	114.32	93.82	90.84	4.68	126.60	146.20	P_2	2.17	62.07	113.02	59.09
Mean	42.29	75.70	59.09	..	4.40	79.04	93.64	Mean	4.40	79.04	93.64	..

C.D. for marginals - 12.23 C.D. for combinations - 21.18

FIG: 4 RESPONSE OF N, P AND K ON THE NUMBER OF FEMALE FLOWERS



the period from 1972 to 1979 are presented in Tables from 56 to 63. From the data it is revealed that the main effects of N, P and K were significant throughout the period of study. As the fertilizers levels were increased, the number of female flowers produced were also increased. It is found that the main effect of N and K was linear, whereas the effect of P was linear only during the first two years and subsequently it behaved in a quadratic fashion.

Among the interaction effects, NK, PK interactions were significant for all the years and the treatment combination $N_2P_1K_2$ produced the maximum number of female flowers in almost all the years. Palms that received no potash produced no flowers during 1972, and during the subsequent years the production of female flowers was very poor as compared to other treatment combinations.

4.1.5 <u>Setting percentage</u>

The percentage setting of nuts to total number of female flowers produced was computed for each palm annually from 1974 to 1979. The data were analysed effecting angular transformation and presented in Tables from 64 to 69.

The main effect of N was found to increase the setting of nuts in 1974, 1975, 1977 and 1979. The main effect of P was significant in 1974, 1975 and 1979 while the main effect of K

Table 64

Setting percentage as influenced by continuous NPK fertilization
(after angular transformation)
Year of observation - 1974

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	3.88	13.45	12.84	10.06	3.83	13.37	12.93	P_0	1.40	14.04	9.42	8.28
N_1	7.11	22.46	14.92	14.83	4.40	19.46	20.66	P_1	7.33	25.90	25.98	19.74
N_2	13.86	23.89	22.38	19.84	4.33	23.78	31.41	P_2	3.83	16.95	29.66	16.71
Mean	8.28	19.74	16.71	..	4.18	18.86	21.69	Mean	4.18	18.86	21.69	..

C.D. for marginals - 5.10 C.D. for combinations - 8.83

Table 65

Setting percentage as influenced by continuous NPK fertilization
(after angular transformation)

Year of observation - 1975

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	9.69	14.41	8.53	10.88	4.08	14.77	11.80	P_0	4.08	19.75	13.67	12.50
N_1	11.47	21.87	15.45	16.26	4.39	21.81	22.54	P_1	7.59	25.81	24.10	19.19
N_2	16.33	21.28	22.03	19.88	4.60	25.69	29.34	P_2	1.40	16.70	27.90	15.34
Mean	12.50	19.19	15.34	..	4.36	20.70	21.89	Mean	4.36	20.77	21.89	..

C.D. for marginals - 4.04 C.D. for combinations - 6.10

Table 66

Setting percentage as influenced by continuous NPK fertilization
(after angular transformation)
Year of observation - 1976

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	21.70	17.79	12.62	17.36	7.82	20.34	20.94	P_0	6.29	26.19	29.60	19.36
N_1	17.61	22.62	15.71	18.98	4.39	24.43	28.12	P_1	10.31	25.46	25.53	20.50
N_2	18.77	21.09	21.51	20.46	5.78	26.55	29.07	P_2	1.40	19.47	30.00	16.96
Mean	19.36	20.50	16.96	..	5.99	23.77	27.04	Mean	5.99	23.77	27.04	..

C.D. for marginals - 5.54 C.D. for combinations - 9.59

Table 67

Setting percentage as influenced by continuous NPK fertilization
(after angular transformation)
Year of observation - 1977

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	21.17	12.90	13.95	15.94	9.22	21.13	17.48	P_0	14.71	26.48	21.64	20.95
N_1	20.99	28.95	22.79	24.24	19.64	26.90	27.63	P_1	18.04	25.93	23.61	22.34
N_2	20.66	25.18	24.36	23.29	13.31	26.60	29.96	P_2	8.82	21.94	29.82	20.19
Mean	20.95	22.34	20.19	..	13.86	24.59	25.02	Mean	13.86	24.59	25.02	..

C.D. for marginals - 5.47 C.D. for combinations 9.48

Table 68

Setting percentage as influenced by continuous NPK fertilization
(after angular transformation)
Year of observation - 1978

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	20.58	15.39	18.79	18.25	10.50	21.27	22.99	P_0	16.51	22.81	20.56	19.96
N_1	14.72	22.44	17.19	18.11	5.63	25.03	23.69	P_1	5.39	25.12	26.71	19.04
N_2	24.59	19.28	20.08	22.32	11.67	26.57	28.72	P_2	5.88	25.04	28.13	19.68
Mean	19.96	19.04	19.68	..	9.26	24.29	25.13	Mean	9.26	24.29	25.13	..

C.D. for marginals - 4.00　　　　C.D. for combinations - 6.93

Table 69

Setting percentage as influenced by continuous NPK fertilization
(after angular transformation)
Year of observation - 1979

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	31.79	25.45	15.87	24.37	9.65	27.51	35.96	P_0	24.75	36.15	37.05	32.65
N_1	29.38	35.76	25.72	30.27	18.64	34.73	37.49	P_1	14.33	37.35	40.63	30.77
N_2	36.77	31.09	24.47	32.11	16.99	38.72	40.62	P_2	6.21	20.46	36.39	23.35
Mean	32.64	30.77	23.35	..	15.09	33.65	38.02	Mean	15.09	33.65	38.02	..

C.D. for marginals - 5.46　　　　C.D. for combinations - 9.45

was significant throughout the period under study. An apparent increase in setting percentage was observed in all years for nitrogen though not significant during 1976 and 1978.

No significant differences in setting percentage were noted at N_1 level over N_0 level in every alternate years of observations. No remarkable increase in setting percentage was evinced at N_1 and N_2 levels of nitrogen, but the response was significant to N_2 in all the years over the zero level of nitrogen. A quadratic response to P was observed in all years of study. In years where significant effect to P was noted, it was restricted between zero and P_1 level of P only (225 g P per tree per year).

A pronounced increase in setting percentage was observed at K_1 level over zero level of K. But the rate of increase in setting percentage was comparatively less when the level of K was raised from K_1 to K_2 ie from 450 g per tree per year to 900 g per tree per year.

Interaction effects were not significant.

4.1.6 <u>Yield of nuts</u>

The average annual yield of coconuts per tree for each treatment was analysed statistically for seven years from 1976 to 1982 and the mean yields are presented in Tables from 70 to 76.

Table 70

Annual yield of nuts per palm due to continuous NPK fertilization
Year of observation - 1976

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	6.50	18.00	12.83	12.47	0.17	18.50	18.67	P_0	0.67	29.17	26.33	18.72
N_1	14.17	77.67	47.17	46.33	0.00	41.67	97.33	P_1	2.50	83.83	88.50	58.28
N_2	35.50	79.17	72.83	62.50	3.00	83.33	101.17	P_2	0.00	30.50	102.33	44.28
Mean	18.72	58.28	44.28	..	1.06	47.83	72.39	Mean	1.06	47.83	72.39	..

C.D. for marginals - 18.91 C.D. for combinations - 32.75

Table 71

Annual yield of nuts per palm due to continuous NPK fertilization
Year of observation '77

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	15.17	31.83	23.50	23.50	6.16	26.17	38.17	P_0	6.83	57.33	47.33	37.
N_1	39.67	101.00	79.50	73.39	2.83	92.17	125.17	P_1	2.83	111.17	140.33	84.
N_2	56.67	121.50	127.50	101.89	3.50	126.50	175.67	P_2	2.83	76.33	151.33	76.
Mean	37.17	84.78	76.83	..	4.17	81.61	113.00	Mean	4.17	81.61	113.00	..

C.D. for marginals - 25.60 C.D. for combinations - 44.33

Table 72

Annual yield of nuts per palm due to continuous NPK fertilization

Year of observation - 1978

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	18.00	35.67	28.33	27.33	3.66	36.33	42.00	P_0	5.17	50.17	55.33	36.89
N_1	29.67	117.00	70.00	72.22	1.33	88.83	126.50	P_1	3.67	121.00	130.17	84.94
N_2	63.00	102.17	117.35	94.15	5.83	124.17	152.50	P_2	2.00	78.17	135.50	71.89
Mean	36.89	84.94	71.89	..	3.61	83.11	107.00	Mean	3.61	83.11	107.00	..

C.D. for marginals - 23.12 C.D. for combinations - 40.05

Table 73

Annual yield of nuts per palm due to continuous NPK fertilization

Year of observation - 1979

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	24.50	31.67	22.67	26.28	3.84	34.33	40.67	P_0	7.00	85.17	81.83	58.00
N_1	48.83	156.67	64.00	89.83	2.17	111.83	155.50	P_1	2.33	156.00	206.00	121.44
N_2	100.67	176.00	152.33	143.00	3.83	177.50	247.67	P_2	0.50	82.50	156.00	79.67
Mean	58.00	121.44	79.67	..	3.28	107.89	147.94	Mean	3.28	107.89	147.94	..

C.D. for marginals- 22.32 C.D. for combinations - 38.66

Table 74

Annual yield of nuts per palm due to continuous NPK fertilization
Year of observation - 1980

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	32.67	30.83	23.50	29.00	5.33	37.17	44.50	P_0	14.00	84.33	38.50	62.28
N_1	53.33	133.17	81.00	89.50	5.17	113.50	149.83	P_1	3.33	150.33	151.33	101.67
N_2	100.83	140.00	143.83	128.22	7.33	173.00	204.33	P_2	0.50	89.00	158.83	82.78
Mean	62.28	101.67	82.78	..	5.94	101.89	132.89	Mean	5.94	107.89	132.89	..

C.D. for marginals - 17.46 C.D. for combinations - 30.23

Table 75

Annual yield of nuts per palm due to continuous NPK fertilization
Year of observation - 1981

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	59.00	64.33	62.00	61.78	25.00	65.17	95.17	P_0	25.00	125.83	152.67	101.17
N_1	87.33	140.83	87.50	105.22	7.00	139.50	169.17	P_1	23.67	161.50	177.33	120.83
N_2	157.17	157.33	145.50	153.33	22.67	204.17	233.17	P_2	6.00	121.50	167.50	98.33
Mean	101.17	120.83	98.33	..	18.72	136.28	165.83	Mean	18.72	136.28	165.83	..

C.D. for marginals - 28.13 C.D. for combinations 48.72

Table 76

Annual yield of nuts per palm due to continuous NPK fertilization

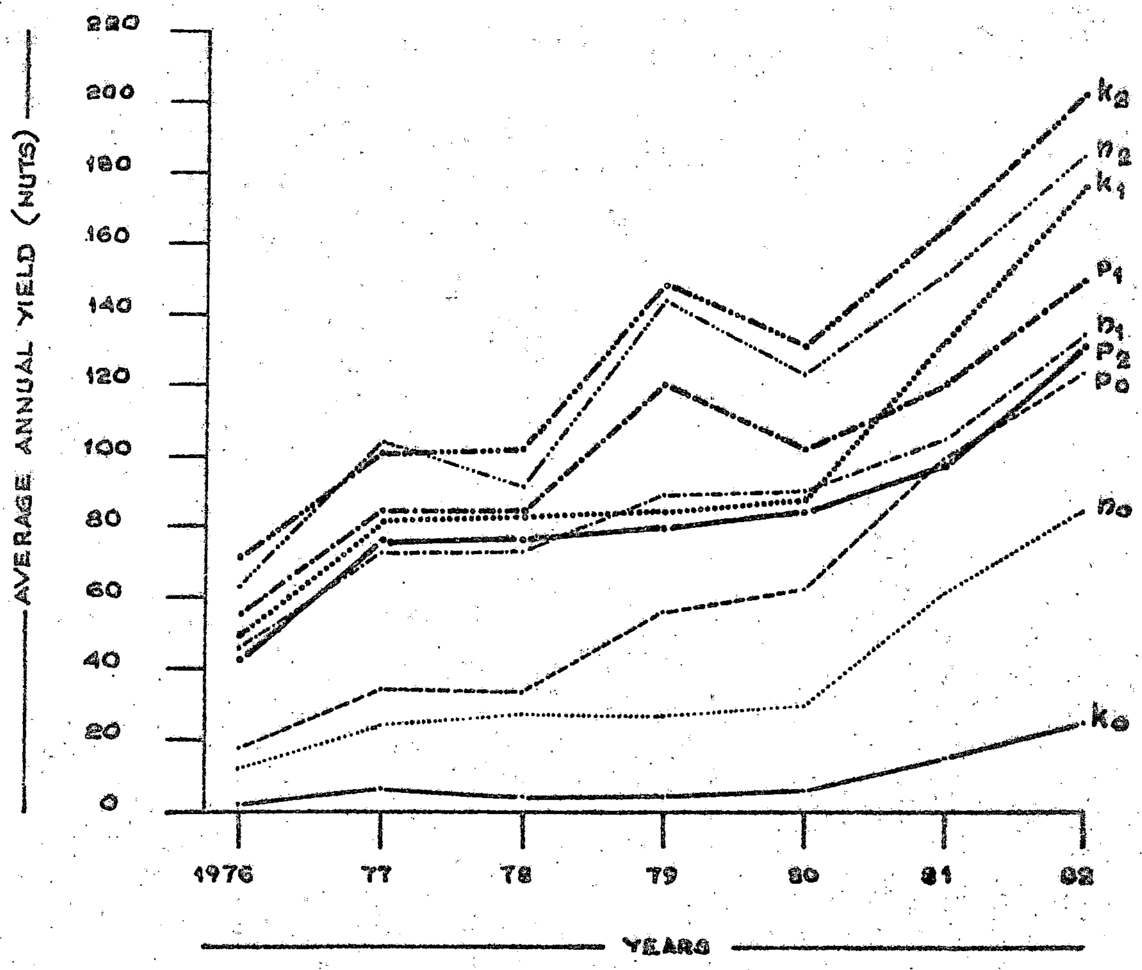
Year of observation - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	100.83	65.17	95.38	87.11	38.97	107.17	115.17	P_0	41.67	165.67	164.00	123.78
N_1	98.33	199.17	115.17	137.56	19.33	179.67	213.67	P_1	20.67	206.03	233.33	153.44
N_2	172.17	196.00	184.50	184.22	17.53	251.50	283.67	P_2	13.50	166.33	215.17	131.67
Mean	123.78	153.44	131.67	..	25.28	179.44	204.17	Mean	25.28	179.44	204.17	..

C.D. for marginals - 15.73

C.D. for combinations - 27.25

FIG: 5 YIELD TREND IN COCONUT AT VARIOUS LEVELS OF N, P AND K



A positive response to nitrogen was observed during all the years under study from 1976 to 1982. During 1976 the yield of coconut increased 272 per cent when the fertilizer dose was increased from the zero level to N_1 level (340 g N per tree per year), while the increase for the N_2 level (680 g N per tree per year) was 402 per cent. But the yield increase between the higher doses of nitrogen ie. N_1 and N_2 was only 35 per cent. The rates of increase in yield of coconuts during the consecutive period from 1976 to 1982, with the incremental doses of nitrogen from N_0 to N_1, N_0 to N_2 and from N_1 to N_2 are tabulated below in percentages.

Table 77
Range in levels of nitrogen and percentage increase in yield of coconuts

Year	N_0 to N_1	N_0 to N_2	N_1 to N_2
1976	272	402	35
1977	212	334	39
1978	164	245	30
1979	242	444	59
1980	209	342	43
1981	70	148	46
1982	58	111	34

A spectacular decline in the rate of increase in yield of nuts was noticed from N_0 to N_1 level and N_0 to N_2 level during the years from 1981 to 1982.

The main effect of P was significant in all the years except for 1981. Though the response of P was significant between P_0 and P_1 level it was detected to be quadratic in nature. P_2 level was found to be on par with P_0 level during 1979 and 1982.

A marked response of K towards yield was recorded in all years from 1976 to 1982. The percentage increase in yield of nuts from 1976 to 1982 from K_0 to K_1 (450 g K per tree per year) K_0 to K_2 (900 g K per tree per year) and K_1 to K_2 levels of K fertilization are presented in Table 78.

Table 78

Range in levels of K and percentage increase in yield of coconut

Year	K_0 to K_1	K_0 to K_2	K_1 to K_2
1976	4412	6729	51
1977	1857	2610	38
1978	2202	2864	29
1979	3189	4410	37
1980	1716	2137	23
1981	648	810	22
1982	610	708	14

As in the case of nitrogen, a remarkable decline in the rate of increase for K also was noticed for the years 1981 and 1982.

Among the interactions, NK and PK interactions were significant for all the years under study. But NP interaction was found significant in 1979, 1980 and 1982 only. The interaction effect of P with N at the highest level (N_2) gave a linear response while it was quadratic with N at lower levels viz. N_0 and N_1. NK interaction produced a linear effect on yield. A similar response was noted for PK interaction also. The NPK interaction was detected from 1979 onwards only.

Cumulative yield of nuts obtained per palm for the period from 1976 to 1982 is presented in Table 79.

From the data it is revealed that the main effects of N, P and K and the interactions of NK and PK were significant while the NP interaction was inconsistent. The most striking of the results is that the palms not supplied with K at all gave only a bear minimum yield of 7.75 nuts ($N_2P_2K_0$) though they were supplied with the highest levels of N and P viz. 680 g N and 450 g P per tree per year and that the palms which received the highest level of K viz. 900 g K per tree per year gave the maximum yield of 405 nuts in seven years ($N_2P_1K_2$). The second highest yield of 391 nuts was also

Table 79

Cumulative yield of nuts per palm over replications (1976 - 1982)

Sl. No.	Treat-ment	Yield	Sl. No.	Treat-ment	Yield
1	000	39.38	15	112	391.88
2	001	53.75	16	120	1.88
3	002	47.63	17	121	120.12
4	010	13.75	18	122	308.25
5	011	141.25	19	200	21.25
6	012	52.88	20	201	232.50
7	020	9.25	21	202	260.75
8	021	50.12	22	210	18.75
9	022	146.00	23	211	320.12
10	100	14.63	24	212	405.00
11	101	152.88	25	220	7.75
12	102	104.75	26	221	314.75
13	110	11.75	27	222	384.12
14	111	294.45			

Table - 79 a

Cumulative yield of nuts per palm over replications

(1976 - 1982)

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	62.79	69.29	68.46	66.85	20.79	81.71	98.84	P_0	25.08	146.37	153.58	108.35
N_1	90.75	232.69	143.42	155.62	9.42	189.15	268.29	P_1	14.75	251.88	282.25	183.31
N_2	171.50	247.96	235.54	218.39	15.92	289.13	349.96	P_2	6.29	161.67	279.46	149.14
Mean	108.35	183.31	149.14	..	15.38	186,66	238.76	Mean	15.38	186.66	238.76	..

C.D. for marginals - 37.89

C.D. for combinations - 65.63

obtained from the treatment combination having the highest level of K ($N_1P_1K_2$). The cumulative yield data also showed that the yield was increasing in a linear fashion for applied N and K. The yield of nuts for zero level of nitrogen and the highest level of nitrogen were 66.85 and 218.4 nuts respectively while that for zero level of potash and the highest level of potash were 15.38 and 238.76 nuts respectively. The response was quadratic for higher levels of P. The interaction effect of NK and PK were significant while that of NP was not.

4.1.6 (i). <u>Response surface from NPK fertilization</u>

The response surfaces were fitted to annual yield data with respect to applied N, P and K from 1976 to 1982. The fitted responses are presented in Table 80.

The partial linear regression (b_1 and b_3) of yield on N and K were significant throughout the period of study. The linear regression (b_2) of yield on P was significant during the early periods of study. The quadratic coefficients of N were not significant all through the periods of study while that of P and K were significant.

The interaction of N with P is described by the partial regression coefficient b_{12}; which was not significant except for 1980. The coefficients of b_{13} and b_{23} explained significant interactions between N and K; and P and K. The R^2 values showed that the fitted surfaces explain the data satisfactorily.

Table 80

Regression of yield of coconuts as affected by NPK+ fertilization (value of regression coefficients along with their standard error)

Regression coefficients	1976	1977	1978	1979	1980	1981	1982
b_0	71.59**	107.26**	109.28**	146.80**	134.35**	148.78**	197.85 **
	(9.34)	(10.84)	(12.04)	(11.62)	(9.09)	(14.65)	(8. 19)
b_1	25.03**	39.19**	33.42 **	58.64**	49.36**	45.78 **	48.56**
b_2	12.78*	19.83**	14.72*	11.11	10.58*	- 1.42	3.94
b_3	35.67**	54.42**	48.92**	72.06**	63.61 **	73.81**	89.44**
	(4.56)	(6.17)	(5.97)	(5.38)	(4.21)	(6.78)	(3.79)
b_{11}	-8.86	-10.69	-5.92	-5.47	-11.31	2.38	-1.89
b_{22}	-26.78**	-27.78*	-33.33**	-52.89**	-29.31**	-21.08	-25.72**
b_{33}	-11.11	-23.03**	-30.58 **	-32.56 **	-37.72**	-44.25**	-64.72**
	(7.89)	(10.68)	(9.65)	(9.32)	(7. 29)	(11.74)	(6.56)
b_{12}	7.75	15.63	11.00	12.96	13.42*	-3.67	4.46
b_{13}	19.92**	35.04**	27.08 **	52.17*	39.46**	35.08 **	47.50 **
b_{23}	20.38**	27.00**	16.67*	20.58**	21.17 **	8.46	19.83**
	(5.58)	(7.76)	(6.83)	(6.59)	(5.05)	(8.30)	(4.64)
R^2	0.55	0.80	0.71	0.81	0.91	0.77	0.75

The figures in the parenthesis are standard errors of regression coefficients

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

+ Fitted regression are in terms of X_1, X_2, X_3 where

$$X_1 = \frac{N-340}{340}, \quad X_2 = \frac{P-225}{450}, \quad X_3 = \frac{K-450}{450}$$

4.2. Nut characteristics

4.2.1 Weight of unhusked nut

The data on mean weight of unhusked nuts are presented in Table 81. The results of analysis revealed that the weight of unhusked nut was significantly influenced by N and K application; but the effects were quadratic in nature. The average effect of P was not significant and was found to decrease the weight.

4.2.2 Weight of husked nut

The data on average weight of husked nuts are presented in Table 82. It was found that the main effects of N and K were significant, while P was not. The average effect of P was found to be negative. The response with regard to N and K was quadratic. The maximum weight of husked nut was recorded for P_1K_2 combination followed by N_1K_1 and N_2K_2.

4.2.3 Thickness of meat

The data on average thickness of meat were analysed and the mean values are presented in Table 83.

Thickness of meat was found to be significantly influenced by K application. The response to N and K was quadratic. P exhibited a negative effect. The PK and NPK interactions were found significant.

Table 81

Weight of unhusked nut due to continuous NPK fertilization (kg)

Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	1.08	0.87	0.94	0.96	0.19	1.32	1.37	P_0	0.79	1.34	1.12	1.08
N_1	1.35	1.14	1.08	1.19	0.81	1.37	1.38	P_1	0.37	1.35	1.38	1.03
N_2	0.83	1.09	1.85	0.92	0.34	1.32	1.11	P_2	0.20	1.32	1.39	0.96
Mean	1.08	1.03	0.96	..	0.45	1.34	1.24	Mean	0.45	1.34	1.24	..

C.D. for marginals - 0.19 C.D. for combinations - 0.32

Table 82

Weight of husked nut due to continuous NPK fertilization (g)

Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	442	397	383	407	79	574	570	P_0	316	577	475	456
N_1	567	486	481	511	310	611	612	P_1	157	571	617	448
N_2	360	462	352	391	165	535	474	P_2	80	571	565	405
Mean	456	448	405	..	184	573	552	Mean	184	573	552	..

C.D. for marginals - 85 C.D. for combinations - 147

Table 83

Thickness of meat due to continuous NPK fertilization (cm)
Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	1.05	0.87	0.85	0.92	0.19	1.27	1.30	P_0	0.71	1.25	1.06	1.01
N_1	1.16	1.06	1.09	1.10	0.73	1.25	1.32	P_1	0.40	1.24	1.35	1.00
N_2	0.81	1.06	0.87	0.91	0.40	1.22	1.11	P_2	0.22	1.26	1.33	0.94
Mean	1.01	1.00	0.94	..	0.44	1.25	1.25	Mean	0.44	1.25	1.25	..

C.D. for marginals - 0.19

C.D. for combinations - 0.33

Table 84

Weight of meat due to continuous NPK fertilization (g)
Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	328	289	285	301	52	426	420	P_0	235	425	355	338
N_1	421	362	354	379	225	457	455	P_1	112	423	453	329
N_2	266	337	257	289	123	388	350	P_2	57	422	417	299
Mean	338	329	299	..	135	425	408	Mean	135	423	408	..

C.D. for marginals - 66

C.D. for combinations - 115

4.2.4 Weight of meat in nuts

The data on average weight of meat per nut were analysed and the mean values are presented in Table 84.

Main effects of N and K were significant, while that of P was not significant. The interaction effects of PK and NPK were also found to be significant. The response of N towards weight of meat was quadratic. The weight of meat increased from 301 g at zero level to 379 g at N_1 level (340 g N per tree per year) which decreased to 287 g when the dose of nitrogen was increased to N_2 level (680 g N per tree per year).

A marked increase in weight of meat was observed at K_1 level (450 g K per tree per year) as compared to zero level of K. However, a marginal decrease in the weight of meat was observed when the level of K was increased from K_1 to K_2 (900 g K per tree per year).

The average effect of P was not only significant, but was negative. However, P in combination with N and K contributed to increased weight of meat.

4.2.5 Weight of copra

The data on weight of copra are presented in Table 85. It was found that the main effects of N and K and interaction effects of PK and NPK had significant influence on weight of

Table 85

Weight of copra due to continuous NPK fertilization (g)
Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	125	110	91	108	21	155	150	P_0	81	166	132	126
N_1	159	132	136	142	80	170	177	P_1	48	151	166	122
N_2	95	125	100	106	50	137	133	P_2	21	145	162	109
Mean	126	122	109	..	50	154	153	Mean	50	154	153	..

C.D. for marginals - 21

C.D. for combinations - 38

copra. The effect of N was found to be quadratic. With zero level of N the weight of copra was 109 g which was increased to 143 g at N_1 level and then decreased to 107 g at N_2 level. Though the effect of K was significant, no marked difference in weight of copra was noted between K_1 and K_2 levels. The weight of copra increased from 51 to 155 g from zero level to K_1 level of K. The maximum weight of copra was recorded for N_2K_2 combination. The main effect of P was found to be negative, though not significant.

4.2.6 Thickness of shell

The data on mean thickness of shell are presented in Table 86.

From the data it is revealed that the thickness of shell was statistically significant for N and K levels of fertilization. The combined effect of N and K, and P and K were also found significant. The differences in the thickness of shell at the various levels of N were significant and quadratic. But for K the differences were marginal at K_1 and K_2 levels, though the response was quadratic.

4.2.7 Weight of shell

Average weight of shell was analysed and the mean values are presented in Table 87.

Table 86

Thickness of shell due to continuous NPK fertilization (cm)
Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.25	0.24	0.23	0.24	0.02	0.34	0.36	P_0	0.19	0.37	0.31	0.29
N_1	0.39	0.30	0.31	0.33	0.23	0.38	0.39	P_1	0.09	0.33	0.37	0.26
N_2	0.23	0.24	0.24	0.24	0.07	0.36	0.28	P_2	0.05	0.38	0.35	0.26
Mean	0.29	0.26	0.26	..	0.11	0.36	0.34	Mean	0.11	0.36	0.34	..

C.D. for marginals - 0.04 C.D. for combinations 0.07

Table 87

Weight of shell due to continuous NPK fertilization (g)
Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	113	107	97	106	20	148	150	P_0	80	152	119	117
N_1	146	123	126	132	84	154	157	P_1	44	148	164	119
N_2	93	125	94	104	42	146	123	P_2	22	149	147	106
Mean	117	119	106	..	49	149	143	Mean	49	149	143	..

C.D. for marginals - 19.0 C.D. for combinations - 34.0

The main effects of N and K were found significant. The weight of shell for zero level of N was 106 g which increased to 132 g for N_1, but decreased to 104 g for N_2. Though the response to K was significant with the initial level of 450 g K_2O per tree per year, no significant difference in weight was noted between K_1 and K_2 levels. However, P exhibited no response to weight of shell.

4.2.8 Oil content

The data analysed for percentage of oil content as influenced by the various treatments are presented in Table 88.

From the data it was revealed that the main effect of N and K had significantly influenced the oil content in the nuts. The response of N was however found to be quadratic in nature, with the applied dose of 340 g N per tree per year the percentage of oil increased by 24 per cent but when the level of applied N was raised to 680 g N per tree per year the oil content was found to be depressed by 20 per cent and was on par with zero level of nitrogen to the palms.

The effect of P was found to be negative. The oil percentage decreased with incremental doses of applied P. The response of K was conspicuously significant at all levels of K tried in the experiment. The percentage oil content in the nuts increased from 21.87 to 56.91 and to 58.16

with the applied doses of 450 g K and 900 g K per tree per year respectively over zero level of potash. The percentage increase was computed to be 160 and 165 for K_1 and K_2 levels over K_0 level. However, the increase in oil content due to K_2 level of applied K viz. 900 g K per tree per year over the K_1 level of applied K (450 g K per tree per year) was only marginal and was on par. The oil content was found to be of the highest order viz. 67 per cent for the treatment combination $N_1P_1K_2$.

4.2.9 Weight of fibre

The weight of fibre obtained from the husks retted for six months was recorded in October 1983 and presented in Table 89. It was revealed that the weight of fibre was significantly influenced by K fertilization while the response to N and P was not significant. The interaction effect of K with N and P also influenced the weight of fibre. The effect of nitrogen on fibre weight was on the increase upto N_1 (340 g N per tree per year) level only and with the increase in dose to N_2 (680 g N per tree per year), the weight was decreased. A negative response to P was also observed. The effect of K was found to be linear. The percentage increase in weight of fibre from K_0 to K_1, K_0 to K_2 and K_1 to K_2 levels were 144, 156 and 155 respectively. However, the difference between K_1 and K_2 was not appreciable.

Table 88

Oil content due to continuous NPK fertilization (percentage)

Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	40.87	39.63	38.23	42.24	9.83	55.27	61.63	P_0	38.38	54.53	50.47	47.79
N_1	56.53	51.90	49.20	52.54	38.53	58.60	60.50	P_1	17.57	59.10	63.50	46.59
N_2	37.98	48.23	48.87	42.15	17.25	56.87	52.33	P_2	9.67	57.10	60.90	42.56
Mean	47.79	46.59	42.56	..	21.87	56.91	58.16	Mean	21.87	56.91	58.16	..

C.D. for marginals - 9.62 C.D. for combinations - 16.66

Table 89

Weight of fibre due to continuous NPK fertilization (g)

Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	235	185	233	217	51	287	314	P_0	188	273	301	254
N_1	299	237	233	256	207	289	273	P_1	106	287	275	222
N_2	228	246	184	219	87	269	301	P_2	52	286	312	216
Mean	254	222	216	..	115	282	296	Mean	115	282	296	..

C.D. for marginals - 43 C.D. for combinations - 75

4.3. Foliar analysis

Leaf samples for foliar analysis were collected during 1982.

4.3.1 Nitrogen

The leaf samples were analysed for their content of N and the results are presented in Table 90.

From the data presented in Table, it is found that the main effects of N and K were significant while the effect of P was not significant in increasing the leaf nitrogen.

An increase in the application of nitrogen resulted in an increase in foliar nitrogen. At zero level of nitrogen foliar N was 1.00 per cent which increased to 1.10N at N_1 level (340 g nitrogen per tree per year) and to 1.20 at N_2 level (680 g nitrogen per tree per year). A quadratic response to foliar nitrogen was noted at increased levels of K.

4.3.2 Phosphorus

The phosphorus contents as obtained from the analysis of leaf samples are presented in Table 91.

Foliar phosphorus was not influenced by N, P or K application continuously. At all the levels of NPK the foliar P content was found to be almost equal.

Table 90

Nitrogen content of leaf due to continuous NPK fertilization (percentage)

Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	1.00	1.05	1.07	1.04	1.03	1.05	1.05	P_0	1.00	1.10	1.17	1.09
N_1	1.09	1.17	1.03	1.10	1.00	1.14	1.14	P_1	1.10	1.19	1.17	1.15
N_2	1.17	1.24	1.28	1.22	1.17	1.21	1.31	P_2	1.10	1.12	1.17	1.13
Mean	1.09	1.15	1.13	..	1.07	1.13	1.17	Mean	1.07	1.13	1.17	..

C.D. for marginals - 0.07 C.D. for combinations - 0.12

Table 91

Phosphorus content of leaf due to continuous NPK fertilization (percentage)

Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.18	0.18	0.21	0.19	0.19	0.19	0.19	P_0	0.18	0.20	0.18	0.19
N_1	0.20	0.20	0.20	0.20	0.17	0.21	0.20	P_1	0.20	0.21	0.19	0.20
N_2	0.18	0.20	0.21	0.20	0.20	0.21	0.17	P_2	0.20	0.20	0.21	0.20
Mean	0.19	0.20	0.20	..	0.19	0.21	0.19	Mean	0.19	0.21	0.19	..

C.D. for marginals - 0.018 C.D. for combinations - 0.031

4.3.3 Potassium

Data on the K content of leaves are presented in Table 92.

The K content of leaf was enhanced by K application alone, and as such no significant increase was recorded for N and P. However, significant decrease in foliar K was observed at higher doses of N. The effect of P on foliar K was found to be inconsistent. But the foliar content of K was steadily increased with the increased levels of K application to the palms. At zero level of K, foliar K was 1.00per cent which was increased to 1.30at K_1 level and 1.60per cent at K_2 level.

4.3.4 Calcium

Results of analysis on the calcium content of leaves are furnished in Table 93.

From the data it is revealed that foliar Ca was not influenced by any one of the major nutrients tried in this investigation. The magnitude of foliar calcium percentage was almost similar at each level of N or P, but at various levels of K a varied trend was observed. At K_1 level foliar calcium was found to be more as compared to K_0 and K_2 level. Calcium content under K_0 and K_2 levels behaved almost in the same fashion.

Table 92

Potash content of leaf due to continuous NPK fertilization (percentage)
Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	1.58	1.55	1.61	1.58	1.31	1.60	1.83	P_0	0.95	1.43	1.85	1.33
N_1	1.47	1.30	1.27	1.35	0.96	1.22	1.66	P_1	1.00	1.14	1.47	1.34
N_2	0.95	1.16	1.08	1.06	0.79	1.02	1.40	P_2	1.11	1.28	1.58	1.32
Mean	1.33	1.34	1.32	..	1.02	1.28	1.63	Mean	1.02	1.28	1.63	..

C.D. for marginals - 0.227 C.D. for combinationss - N.S

Table 93

Calcium content of lead due to continuous NPK fertilization(percentage) Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.180	0.025	0.020	0.075	0.027	0.180	0.019	P_0	0.019	0.180	0.019	0.073
N_1	0.020	0.430	0.045	0.028	0.031	0.049	0.028	P_1	0.037	0.038	0.030	0.036
N_2	0.022	0.400	0.037	0.033	0.025	0.037	0.037	P_2	0.027	0.045	0.033	0.035
Mean	0.073	0.036	0.035	..	0.028	0.089	0.028	Mean	0.028	0.089	0.028	..

C.D. for marginals - N.S C.D. for combinations - N.S

Table 94

Magnesium content of leaf due to continuous NPK fertilization
(percentage)
Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.12	0.12	0.12	0.12	0.14	0.10	0.13	P_0	0.13	0.13	0.11	0.12
N_1	0.11	0.15	0.13	0.13	0.13	0.15	0.12	P_1	0.14	0.13	0.18	0.13
N_2	0.13	0.13	0.14	0.13	0.12	0.15	0.12	P_2	0.13	0.14	0.13	0.13
Mean	0.12	0.13	0.13	..	0.13	0.13	0.12	Mean	0.13	0.13	0.12	..

C.D. for marginals 0.017 C.D. for combinations - 0.302

Table 95

Sodium content of leaf due to continuous NPK fertilization
(percentage)
Year of sampling - 1982

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.135	0.122	0.115	0.124	0.129	0.114	0.079	P_0	0.192	0.117	0.082	0.130
N_1	0.147	0.111	0.167	0.141	0.170	0.135	0.189	P_1	0.133	0.193	0.109	0.145
N_2	0.140	0.172	0.128	0.147	0.117	0.133	0.119	P_2	0.151	0.132	0.126	0.136
Mean	0.130	0.145	0.136	..	0.189	0.147	0.105	Mean	0.159	0.147	0.105	..

C.D. for marginals - 0.029 C.D. for combinations - 0.051

4.3.5 Magnesium

Magnesium contents of the leaves as obtained in the analysis are given in Table 94.

The various treatments of NPK applied to the palms did not show any significant effect on foliar magnesium content. The magnitude of foliar Mg was almost the same in all treatments.

4.3.6 Sodium

Data on sodium content of leaves as influenced by NPK fertilization of the palms are presented in Table 95.

From the data it is revealed that the application of N and P did not influence the Na content of the leaf; but significant response was observed for foliar Na to K application. The foliar Na decreased significantly at higher levels of K while it was not significantly different at K_0 and K_1 levels.

4.3.7 Effect of continuous NPK fertilization on leaf nutrient concentrations

A quadratic function of the form $Y = a_0 + a_1N + a_2P + a_{11}N^2 + a_{22}P^2 + a_{33}K^2 + a_{12}NP + a_{13}NK + a_{23}PK$ was fitted to describe the effect of NPK fertilization on leaf nutrient concentrations. The partial regression coefficients in the above multiple regression equation with respect to leaf

Table 96

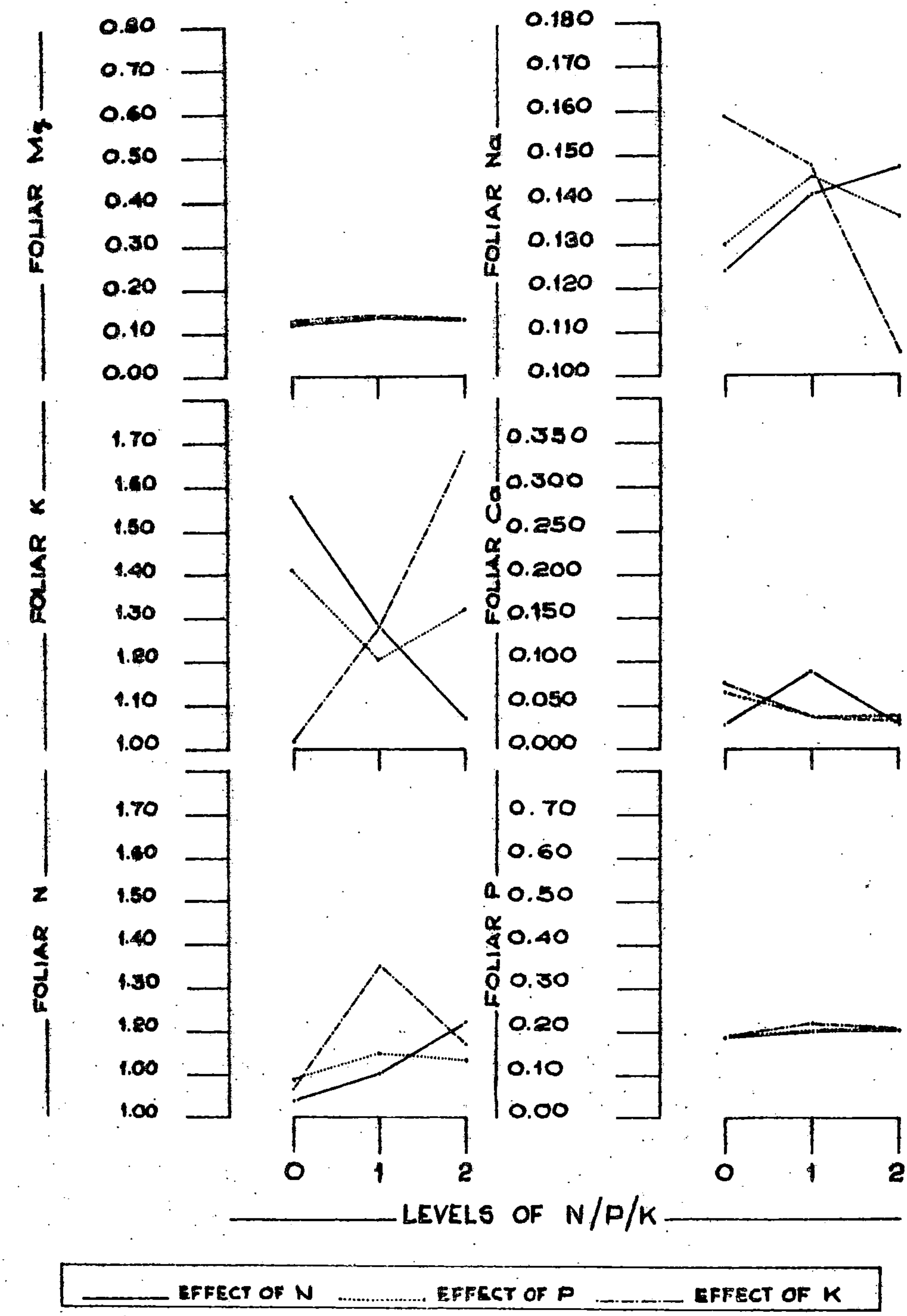
Effect of continuous NPK fertilization on leaf nutrient concentrations
Year of sampling - 1982

Regression coefficients	N	P	K	Ca	Mg	Na
b_0	1.175183	0.211352	1.052592	0.046422	0.141146	0.045902
b_1	0.121111**	0.006361	-0.256667*	0.004853	0.005017	0.005822
b_2	-0.008333	0.004085	-0.045000	0.006972	0.006300	0.002892
b_3	0.078333*	-0.000583	0.306111*	0.000008	-0.005133	0.031122*
b_{11}	-0.011111	-0.009973	0.855560	-0.008324	0.004467	-0.135706
b_{22}	-0.075514	-0.006639	0.200556	-0.007599	-0.001362	-0.157164
b_{33}	-0.047221	-0.010306	0.080556	-0.007974	0.003171	-0.113923
b_{12}	0.053333	-0.007417	-0.033333	0.002962	-0.006372	0.001862
b_{13}	-0.012500	-0.000750	-0.045000	0.004533	-0.005239	0.000358
b_{23}	0.018333	0.002542	-0.306111	0.000155	-0.006622	0.021233

* Significant at 5% level

** Significant at 1% level

FIG: 6 EFFECT OF N, P, K ON FOLIAR NUTRIENTS



nutrients N, P, K, Ca, Mg and Na are presented in Table 96.

Nitrogen supplied in the form of ammonium sulphate produced a significant positive response on foliar nitrogen and a significant negative effect on foliar K. Though the response of N has a positive influence on leaf concentration of P, Ca, Mg and Na, the relationship was not statistically significant.

Continued application of phosphorus in the form of single superphosphate resulted in a negative response on foliar N and foliar K and a positive response for P, Ca, Mg and Na. However, the relationship of applied P on leaf concentration of these nutrients was not statistically significant. Addition of K in the form of muriate of potash significantly increased leaf concentrations of N, K and Na, but had no effect on P, Ca and Mg.

4.3.8 Simple correlation coefficients between yield and leaf nutrient concentrations

Simple correlations between yield and leaf nutrient concentrations are shown in Table 97. The yield was significantly correlated to leaf P and leaf Ca only. Significant correlations were also found to exist for P and Ca. ~~with yields~~.

The correlation between yield and leaf N was not significant though positively related. Similar results were

Table 97

Simple correlation coefficients between yield and leaf nutrient concentrations

Yield	N	P	K	Ca	Mg	Na
N - 0.2589	..	..	..	..	..	..
P - 0.3469**	0.0781	..	..	..	..	..
K - 0.1366	-0.0641	-0.0656	..	..	..	..
Ca - 0.3222**	0.1105	0.3044	-0.1903	..	..	..
Mg - 0.2252	0.1041	0.0992	-0.3240**	0.1336	..	..
Na - 0.1710	-0.1899	-0.0616	-0.5064**	0.1175	0.2153	..

** Significant at 1 per cent level

also observed for leaf K and Mg, but Na was found to have a negative effect on yield.

No correlation was observed for leaf N with other leaf nutrients. A negative correlation was observed for leaf K with all the other nutrients, which although was not significant between N, P and Ca, was significant in the case of Mg and Na.

Positive correlations were noted for leaf Ca with all other nutrients. These correlations were significant in the case of K while it was not, for the other nutrients. Similar results were obtained for leaf Mg also. Sodium was negatively correlated with other leaf nutrients except for leaf Ca and Mg.

4.3.9 Direct and Indirect effects of foliar nutrients on yield

The cause and effect relationship of foliar nutrients on yield was explained by path analysis. Considering the yield (effect) as a function of various casual factors (foliar nutrients), the direct and indirect contribution of these foliar nutrients to the effect was given in Table 98 along with the correlation coeffecients of these factors with yield.

The correlations between yield and the foliar nutrients have been partitioned into direct and indirect effects of foliar nutrients.

The maximum direct effect was explained by foliar K (0.2692) though its correlation with yield was only 0.1389 which was not significant. This low correlation was due to the negative indirect effect of foliar K via N, P, Ca and Mg. The direct effect of foliar Ca was 0.2517 while its correlation with yield was 0.3223 which is significant. This increase in correlation was due to the positive indirect effects of foliar Ca via N, P, and Mg. The direct effect of foliar Mg was 0.2505 while its correlation with yield was 0.2282. The small reduction in correlation was due to the negative indirect effect of foliar Mg via N and K. The direct effect of foliar P was 0.2432 while its correlation with yield was 0.3468 which was significant. The positive indirect effect of foliar P via N, Ca, Mg and Na enhanced its correlation with yield. The direct effect of foliar N was 0.1888 while its correlation with yield was 0.2589 which was not significant. This increase in correlation was the result of positive indirect effects of foliar N via P, Ca, Mg and Na. The direct effect of foliar Na was negative and negligible (-0.0724) and its correlation with yield was also small (-0.1710).

From the above results the maximum direct effect was explained by foliar K followed by foliar Ca, Mg, P and N.

Table 98

Direct and indirect effects of foliar nutrients on yield

	N	P	K	Ca	Mg	Na	(r)
N	0.1888	0.0190	-0.0166	0.0278	0.0261	0.0137	0.2589
P	0.0147	0.2432	-0.0170	0.0766	0.0248	0.0045	0.3468**
K	-0.0121	-0.0159	0.2592	-0.0479	-0.0811	0.0367	0.1389
Ca	0.0209	0.0740	-0.0493	0.2517	+0.0335	-0.0085	0.3223**
Mg	0.0196	0.0241	-0.0840	0.0336	0.2505	-0.0156	0.2282
Na	-0.3580	-0.0150	-0.1313	0.0296	0.0539	-0.0724	-0.1710

The underlined figures are the direct effects of foliar nutrients on yield

** Significant at 1 per cent level

Residual effect 0.68

4.4 Soil analysis for nutrient status in the soil

Analysis of soil samples collected from depths ranging from 0-50 cm and also from 50-100 cm was done for the various nutrient elements retained in the soil due to continued application of major nutrients viz. N, P and K at different levels. The results of analysis are presented in Tables from 99 to 114.

4.4.1 Total nitrogen (percentage)

a. Depth 0-50 cm

The total nitrogen percentage of soil as presented in Table 99 was found to be more in plots which have been fertilized with the highest level of nitrogen viz. 680 g per tree per year. But no significant differences in soil nitrogen percentage were observed in samples collected from plots fertilized continuously with 340 g N per tree per year or in plots with no applied nitrogen.

Continued application of different levels of P was not found to contribute significantly towards nitrogen status in the soil. However, significant difference in nitrogen percentage in the soil was noticed with K fertilization. The levels of 450 g K per tree per year and 900 g K per tree per year were on par; but N was substantially low in plots with zero level of applied K.

Table 99

Total nitrogen in soil due to continuous NPK fertilization
(percentage)

Year of sampling - 1982 Depth of sampling 0-50 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.07	0.07	0.07	0.071	0.07	0.07	0.08	P_0	0.06	0.08	0.07	0.074
N_1	0.07	0.08	0.07	0.074	0.06	0.07	0.08	P_1	0.07	0.09	0.07	0.082
N_2	0.08	0.09	0.09	0.089	0.08	0.09	0.09	P_2	0.07	0.08	0.08	0.078
Mean	0.074	0.082	0.078	..	0.069	0.080	0.083	Mean	0.069	0.083	0.080	..

C.D. for marginals - 0.010 C.D. for combinations - 0.017

Table 100

Total nitrogen in soil due to continuous NPK fertilization
(percentage)

Year of sampling - 1982 Depth of sampling - 50-100 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.041	0.047	0.039	0.042	0.038	0.049	0.030	P_0	0.050	0.045	0.043	0.047
N_1	0.048	0.045	0.048	0.047	0.056	0.045	0.041	P_1	0.047	0.052	0.047	0.047
N_2	0.048	0.050	0.041	0.047	0.050	0.39	0.059	P_2	0.043	0.047	0.036	0.043
Mean	0.047	0.047	0.043	..	0.048	0.048	0.041	Mean	0.048	0.047	0.043	..

C.D. for marginals - 0.0087 C.D. for combinations - 0.0152

b. Depth 50-100 cm

The data of analysis are presented in Table 100. Soil samples collected and analysed from a depth ranging from 50-100 cm did not show any significant difference in soil nitrogen due to application of N, P and K at different levels or due to their combinations.

4.4.2 Available soil phosphorus

a. Depth 0-50 cm

The soil analytical data are presented in Table 101. The soil P was not significantly influenced by the various levels of N, P and K applied in this experiment. A marginal decrease in soil P was observed at the different levels of N, P and K, though the differences were not significant, indicating that higher levels of N, P and K produce only a negative effect on the P status in the soil.

b. Depth 50-100 cm

P status in the soil at a depth ranging from 50-100 cm as presented in Table 102 was also found to be similar to that at depth from 0-50 cm. However, interaction effects of PK, NP_2K and NP_2K_2 showed significant difference in soil P content though the main effects were not positive.

Table 101

P content in soil due to continuous NPK fertilization (ppm)

Year of sampling - 1982 Depth of sampling 0-50 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	8.37	6.32	9.84	8.18	10.06	6.85	7.61	P_0	9.36	7.38	7.20	7.98
N_1	7.50	9.13	10.07	8.90	7.55	10.53	8.61	P_1	8.84	10.12	8.02	8.90
N_2	8.08	11.53	8.84	9.49	10.19	10.19	8.02	P_2	9.60	10.13	9.02	9.58
Mean	7.98	8.90	9.58	..	9.27	9.10	8.08	Mean	9.27	9.10	8.08	..

C.D. for marginals - 8.18 C.D. for combinations - 5.51

Table 102

P content in soil due to continuous NPK fertilization (ppm)

Year of sampling - 1982 Depth of sampling 50-100 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	17.30	15.76	20.76	17.94	17.04	19.09	17.69	P_0	18.16	24.10	14.55	19.23
N_1	18.27	24.86	16.14	19.76	25.50	15.76	18.01	P_1	27.81	15.71	11.71	20.07
N_2	22.14	19.61	15.63	19.13	22.29	22.30	13.07	P_2	18.58	17.04	16.92	17.51
Mean	19.23	20.07	17.51	..	21.52	19.05	16.26	Mean	21.52	19.05	16.26	..

C.D. for marginals - N.S C.D. for combinations - N.S

4.4.3 Potassium

The results of soil analysis of K at depths from 0-50 cm and from 50-100 cm are presented in Tables 103 and 104.

a. Depth 0-50 cm

The continued fertilization with N, P and K at different levels was not found to influence the K status in the soil. Application of N at 340 g per tree per year raised the soil status of K from 50.55 to 58.33 ppm while with 680 g N per tree per year, the soil K content was raised only upto 53.33 ppm. Similar trend in soil K was also observed for P and K applications. Soil samples analysed from plots applied with 225 g P per tree per year and 450 g P per tree per year showed 56.7 and 51.1 ppm in the soil; while those plots which did not receive any N, P or K gave a result of 50.6, 54.4 and 52.8 ppm respectively in the soil; thereby indicating the quadratic response of soil K at various levels of continued N, P and K fertilization. The content of K in plots applied with 450 g K per tree per year was 56.7 ppm while that fertilized with 900 g K per tree per year it was only 52.8 ppm.

b. Depth 50-100 cm

A differential response to soil K was observed in soil samples analysed from a depth ranging from 50-100 cm with reference to N application. Though the difference in soil

Table 103

Potassium content in soil due to continuous NPK fertilization (ppm).

Year of sampling - 1982 Depth of sampling 0-50 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	50.00	51.67	50.00	50.55	46.67	53.33	51.67	P_0	51.67	58.33	53.33	54.44
N_1	56.67	66.67	40.96	58.33	60.00	61.67	53.33	P_1	59.55	55.00	58.33	56.67
N_2	56.67	51.67	51.67	53.33	51.67	55.00	53.33	P_2	50.00	56.67	46.67	51.11
Mean	54.44	56.67	51.11	..	52.78	56.67	52.78	Mean	52.78	56.67	52.78	..

C.D. for marginals - 9.56 C.D. for combinations - 16.57

Table 104

Potassium content in soil due to continuous NPK fertilization (ppm)

Year of sampling - 1982 Depth of sampling 50-100 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	37.67	40.17	37.50	38.44	37.17	38.83	39.33	P_0	37.17	44.00	44.83	42.00
N_1	43.83	51.00	42.17	45.67	37.17	46.00	30.83	P_1	31.33	43.00	42.17	38.83
N_2	37.33	32.50	31.97	33.83	33.83	38.67	32.00	P_2	36.67	36.50	38.17	37.11
Mean	42.00	38.83	37.11	..	35.06	41.72	34.05	Mean	35.06	41.72	34.05	..

C.D. for marginals - 7.85 C.D. for combinations - 13.60

K was significant on account of continued N application, it was again found to be quadratic in nature. However, no significant differences in soil K were observed either at different levels of P and K or their combinations.

4.4.4 Calcium

The results of soil analysis for Ca content in the soil due to continued N, P and K fertilization at different levels are presented in Tables 105 and 106. No significant difference in soil calcium was observed at various levels of N, P and K or their combinations in depths 0-50 cm and 50-100 cm. A decrease in calcium though not significant, was observed at higher levels of applied nitrogen. Soil calcium was 77.2 ppm at zero level of nitrogen while it was 68.6 ppm and 51.1 ppm at 340 g N and 680 g N per tree per year respectively. A quadratic type of response to soil calcium was noted at various levels of P and K. Soil Ca was 58.6 ppm and 64.3 ppm at zero levels of P and K respectively. This was increased to 70.8 ppm with 225 g P per tree per year but decreased to 67.5 ppm at 450 g of applied P per tree per year. With regard to applied K in the soil the content of soil calcium increased to 74.7 ppm at 450 g K per tree per year and then decreased to 57.9 ppm in plots which received the highest level of 900 g K per tree per year.

Table 105

Calcium content in soil due to continuous NPK fertilization (~~percentage~~)

Year of sampling - 1982 Depath of sampling 0-50 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	77.50	87.08	67.08	77.22	83.33	75.83	72.50	P_0	74.17	57.50	44.17	58.61
N_1	65.83	91.25	48.75	68.61	77.83	74.17	54.58	P_1	57.50	85.00	70.00	70.83
N_2	32.50	34.17	86.67	51.11	32.50	74.16	46.66	P_2	61.25	81.67	59.58	67.50
Mean	58.61	70.83	67.50	..	64.31	74.72	57.92	Mean	64.31	74.72	57.92	..

C.D. for marginals - 24.10 C.D. for combinations - 41.74

Table 106

Calcium content in soil due to continuous NPK fertilization(~~percentage~~)

Year of sampling - 1982 Depth of sampling 50-100 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	58.50	43.33	57.47	53.10	59.33	46.16	53.84	P_0	53.00	35.83	39.99	42.94
N_1	47.00	62.00	33.25	47.58	53.83	51.08	37.83	P_1	41.17	44.67	60.50	48.78
N_2	23.33	26.83	45.96	35.61	22.17	39.83	44.83	P_2	41.17	52.42	40.17	44.58
Mean	42.94	48.78	44.58	..	45.11	45.69	45.50	Mean	45.11	45.69	45.50	..

C.D. for marginals - 30.40 C.D. for combinations - 17.14

4.4.5 Magnesium

The results of soil analysis are presented in Tables 107 and 108. The magnesium status of the soil was not influenced by the main effects of N and K, but significant differences were observed at various levels of P. Soil magnesium was significantly low (19.2 ppm) for plots supplied with the highest dose of 450 g P per tree per year; while the difference was only marginal at zero level and 225 g P per tree per year.

Among the various interaction effects, the interaction effect of NK was found to be significant. Phosphorus in combination with K at the P_0K_1 level showed the highest amount of magnesium in the soil (46.7 ppm). For P_0K_0 and P_0K_2 combinations the amounts of Mg in the soil were 36.7 and 18.3 ppm respectively.

At P_1K_0 interaction, Mg status in the soil was found to be 31 ppm while it was decreased to 25 ppm for P_1K_1 combinations and again increased to 41.7 ppm for P_1K_2 combinations. Not much significance was exhibited for P_2 in combination with K levels.

Samples analysed from depth ranging from 50–100 cm showed significant differences in soil Mg at various levels of P only. The nature of soil Mg at P levels was linear. At P_0 level Mg status was 13 ppm while it was 19.2 ppm at P_1 level and 23.3 ppm at P_2 level.

Table 107

Magnesium content in soil due to continuous NPK fertilization
(percentage)

Year of sampling - 1982 Depth of sampling - 0-50 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	33.33	30.00	19.17	27.50	30.00	19.17	33.33	P_0	36.66	46.66	18.33	33.89
N_1	35.00	40.00	19.17	31.39	36.67	31.67	25.89	P_1	30.00	25.00	41.67	32.22
N_2	33.33	26.67	19.17	26.39	21.67	43.33	14.17	P_2	21.67	22.50	13.33	19.17
Mean	33.89	32.22	19.17	..	29.44	31.39	24.44	Mean	29.44	31.39	24.44	..

C.D. for marginals - 7.73 C.D. for combinations - 13.39

Table 108

Magnesium content in soil due to continuous NPK fertilization
(percentage)

Year of sampling - 1982 Depth of sampling - 50-100 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	13.91	26.83	13.33	18.03	26.83	12.50	20.33	P_0	29.67	29.00	11.17	23.28
N_1	22.50	25.17	12.83	20.17	14.75	23.67	18.50	P_1	17.33	18.33	22.08	19.25
N_2	20.50	18.67	12.83	17.33	15.83	27.50	8.67	P_2	16.00	14.33	8.67	13.00
Mean	23.28	19.25	13.00	..	21.00	20.56	13.67	Mean	21.00	20.56	13.97	..

C.D. for marginals - 7.84 C.D. for combinations - 13.58

4.4.6 Soil pH

The change in pH due to continued fertilization of NPK at 0-50 cm depth was determined and the results are presented in Table 109.

No significant difference in soil pH was noted at the various levels of N, P and K and also their combinations. The trend in pH values appeared to be quadratic with a slight increase in pH owing to N_1 level of fertilizer nitrogen followed by a fall in pH ie from 4.97 to 4.92 as the fertilizer nitrogen was doubled from 340 g per tree per year to 680 g per tree per year. The pH was found to decrease at various levels of P though not significant. At zero level of K the soil pH was found to be 5.0 which decreased to 4.7 at K_1 level followed by a slight increase to 5.1 at K_2 level ie. 900 g K per tree per year of fertilization.

The change in pH values of the soil samples collected from a depth ranging from 50-100 cm are given in Table 110.

When soil samples from a depth of 50-100 cm was analysed for pH, differential response to pH was noted. At N_0 level pH was 4.4 which decreased to 4.3 at N_1 level and raised to 4.39 at N_2 level of N. However, it was evident that as the level of nitrogen was increased, the trend in pH was on the decline. In the case of P the trend in soil pH was

Table 109

pH of soil due to continuous NPK fertilization

Year of sampling - 1982 Depth of sampling 0-50 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.90	4.82	4.97	4.89	4.70	4.82	5.17	P_0	4.85	4.63	5.45	4.98
N_1	5.00	5.08	4.83	4.97	5.08	4.73	5.10	P_1	5.13	4.85	4.85	4.94
N_2	5.03	4.93	4.78	4.92	5.18	4.62	4.95	P_2	4.98	4.68	4.92	4.86
Mean	4.98	4.94	4.86	..	4.99	4.72	5.07	Mean	4.99	4.72	5.07	..

C.D. for marginals - 0.30 C.D. for combinations - 0.53

Table 110

pH of soil due to continuous NPK fertilization

Year of sampling-1982 Depth of sampling 50-100cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.58	4.43	4.30	4.44	4.26	4.33	4.72	P_0	4.28	4.30	4.67	4.42
N_1	4.43	4.53	4.20	4.30	4.45	4.37	4.35	P_1	4.37	4.48	4.57	4.47
N_2	4.23	4.45	4.23	4.39	4.32	4.25	4.35	P_2	4.38	4.17	4.18	4.24
Mean	4.42	4.47	4.24	..	4.34	4.32	4.47	Mean	4.34	4.32	4.47	..

C.D. for marginals - 0.24 C.D. for combinations - 0.41

found to be quadratic. At zero level of P the soil pH was 4.4 which was increased to 4.5 at P_1 level, ie. 225 g P per tree per year and depressed to 4.2 at P_2 level ie. 450 g P per tree per year.

The behaviour of K towards soil pH was found to be similar to that of N.

4.4.7 Cation Exchange Capacity

The results of analysis on cation exchange capacity of soil samples collected at 0-50 cm depth from plots fertilized continuously with NPK fertilizers are presented in Table 111.

Significant differences in CEC of soil were noted at various levels of N, P and K and also of their combinations. CEC of soil at zero level of N was 4.8 me/100 g of soil which was raised to 4.9 at N_1 level and again to 4.96 at N_2 level. As the level of N was increased from zero, the CEC was also found to be on the increase. But the main effect of P was found to be in the other way. The CEC was 6.0 me/100 g of soil for zero level of P which decreased to 5.6 at P_1 level and again decreased to 5.1 at P_2 level indicating that higher levels of P produced a negative effect on CEC of the soil. The main effect of K was also found to reduce the CEC of the soil. Of the interaction effects, the response was quadratic in nature at N_0 and N_1 levels of nitrogen in combination with P

At N_0P_0 level the CEC was 4.8 me/100 g of soil which increased to 5.1 at N_0P_1 level and then decreased to 4.5 at N_0P_2 level. The CEC was 4.7 at N_1P_0 level followed by a marked increase of 7.1 at N_1P_1 level and a significant depression at N_1P_2 level. The maximum CEC of 8.4 me/100 g of soil was noted at N_2P_0 level. At N_2P_1 and N_2P_2 levels, CEC was significantly reduced. In general, higher the levels of N in combination with higher levels of P the CEC was found depressed. Highest level of N alone ie 680 g N per tree per year or in combination with P_1 level of P ie. 225 g P per tree per year produced good response to CEC of soil. Higher levels of K in combination with P and N reduced the CEC while K at zero level in combination with various levels of N and P increased the CEC of the soil.

The CEC of soil at depths ranging from 50-100 cm is presented in Table 112.

The CEC of soil at depth ranging from 50-100 cm was found to be similar in nature with soil ~~of~~ depth ranging from 0-50 cm.

4.4.8 Organic carbon

The percentage of organic carbon content of the soil of depths from 0-50 cm and from 50-100 cm are presented in Tables 113 and 114.

Table 111

CEC of soil due to continuous NPK fertilization (m.e/100 g)

Year of sampling - 1982 Depth of sampling 0-50 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.82	5.13	4.59	4.83	5.47	3.85	5.23	P_0	7.21	4.48	6.22	5.97
N_1	4.73	7.13	5.85	5.90	7.56	5.26	4.88	P_1	6.23	4.98	5.32	5.64
N_2	8.37	4.66	4.85	5.96	7.06	4.66	6.16	P_2	6.19	4.32	4.73	5.08
Mean	5.97	5.64	5.08	..	6.68	4.59	5.42	Mean	6.68	4.59	5.42	..

C.D. for marginals - 0.64 C.D. for combinations - 1.11

Table 112

CEC of soil due to continuous NPK fertilization (m.e/100 g)

Year of sampling-1982 Depth of sampling 50-100cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	4.03	4.33	3.83	4.07	4.46	3.28	3.45	P_0	5.58	3.38	5.20	4.88
N_1	4.10	5.08	5.03	4.74	5.60	4.25	4.30	P_1	4.92	4.23	4.43	4.53
N_2	6.53	4.17	4.53	5.08	5.80	4.35	5.28	P_2	5.37	3.73	4.30	4.47
Mean	4.88	4.53	4.47	..	5.29	3.95	4.64	Mean	5.29	3.95	4.64	..

C.D. for marginals - 0.64 C.D. for combinations - 1.11

Table 113

Organic carbon in soil due to continuous NPK fertilization (percentage)

Year of sampling - 1982 Depth of sampling - 0-50 cm.

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.62	0.54	0.51	0.56	0.51	0.53	0.63	P_0	0.52	0.59	0.65	0.58
N_1	0.54	0.56	0.58	0.55	0.51	0.56	0.58	P_1	0.55	0.53	0.51	0.53
N_2	0.58	0.55	0.53	0.56	0.56	0.56	0.54	P_2	0.57	0.52	0.56	0.55
Mean	0.58	0.53	0.55	..	0.53	0.54	0.59	Mean	0.53	0.54	0.59	..

C.D. for marginals - 0.08 C.D. for combinations - 0.01

Table 114

Organic carbon in soil due to continuous NPK fertilization (percentage)

Year of sampling - 1982 Depth of sampling 50-100 cm

	P_0	P_1	P_2	Mean	K_0	K_1	K_2		K_0	K_1	K_2	Mean
N_0	0.41	0.41	0.38	0.40	0.37	0.38	0.46	P_0	0.35	0.44	0.42	0.41
N_1	0.38	0.44	0.41	0.41	0.37	0.43	0.43	P_1	0.47	0.41	0.43	0.42
N_2	0.45	0.43	0.43	0.43	0.43	0.45	0.43	P_2	0.39	0.39	0.43	0.41
Mean	0.41	0.42	0.42	..	0.38	0.42	0.44	Mean	0.38	0.42	0.44	..

C.D. for marginals - 0.07 C.D. for combinations - 0.12

FIG:7 EFFECT OF APPLIED N ON SOIL FACTORS AT TWO DEPTHS

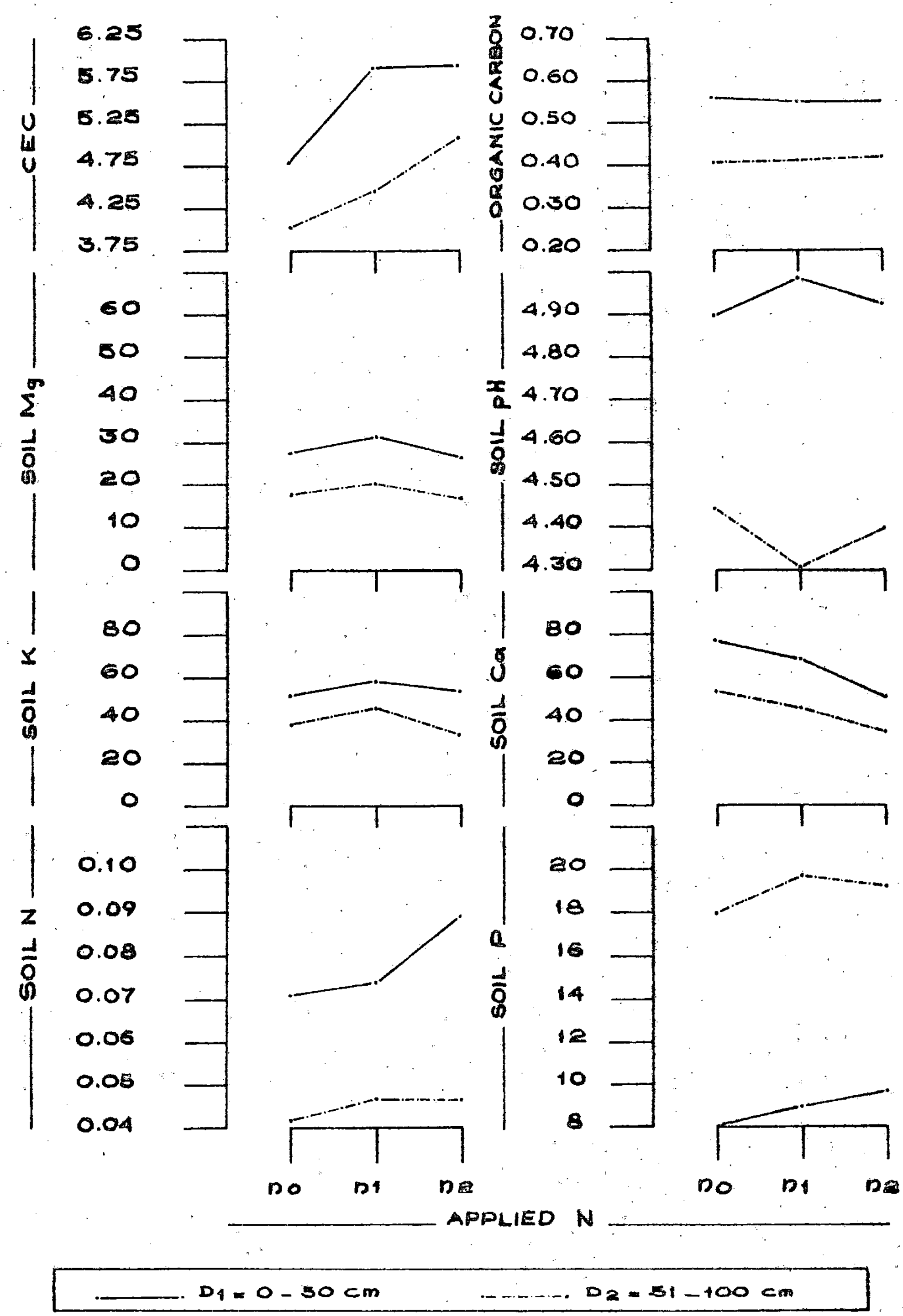


FIG. 8 EFFECT OF APPLIED P ON SOIL FACTORS AT TWO DEPTHS

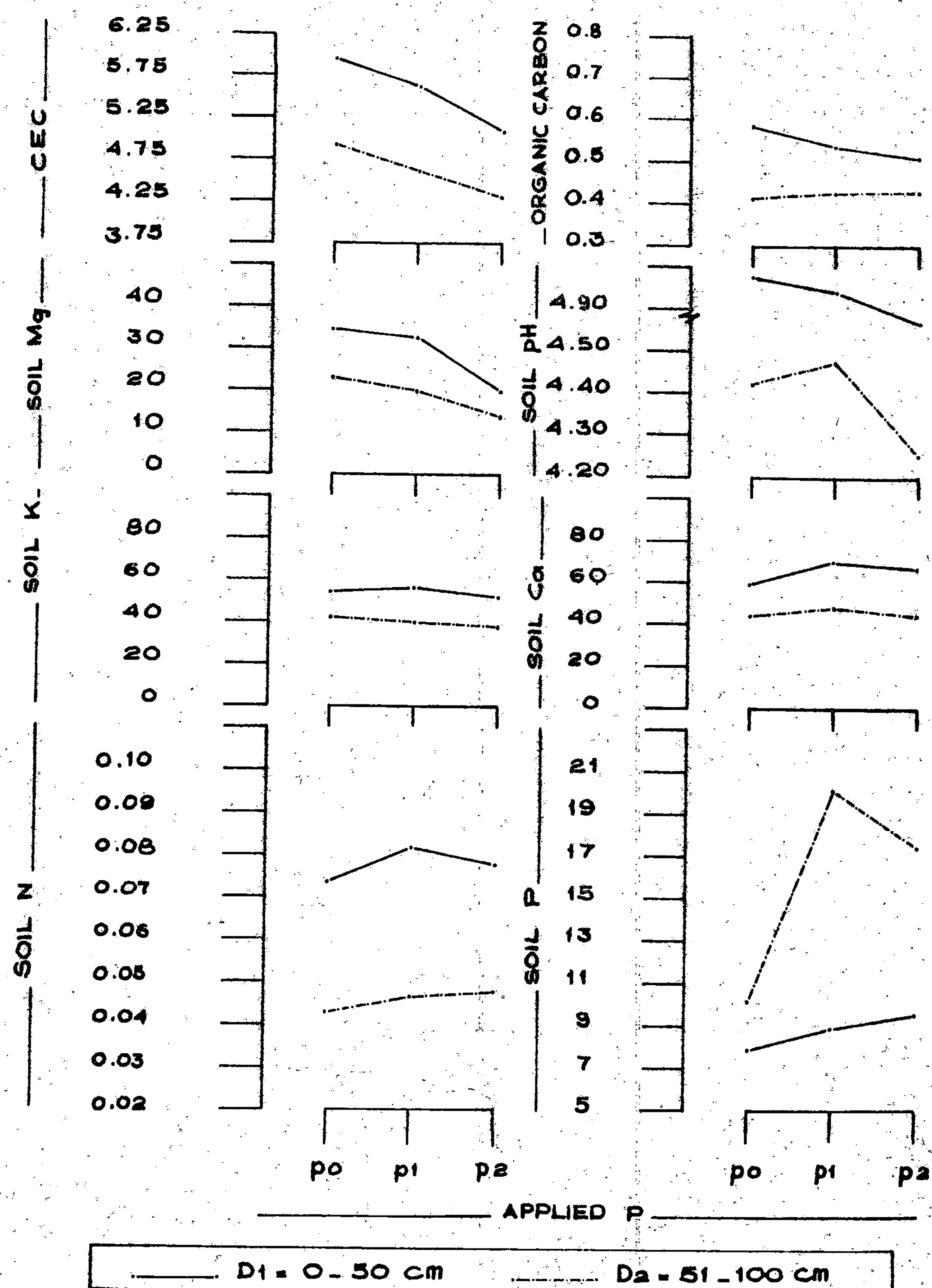
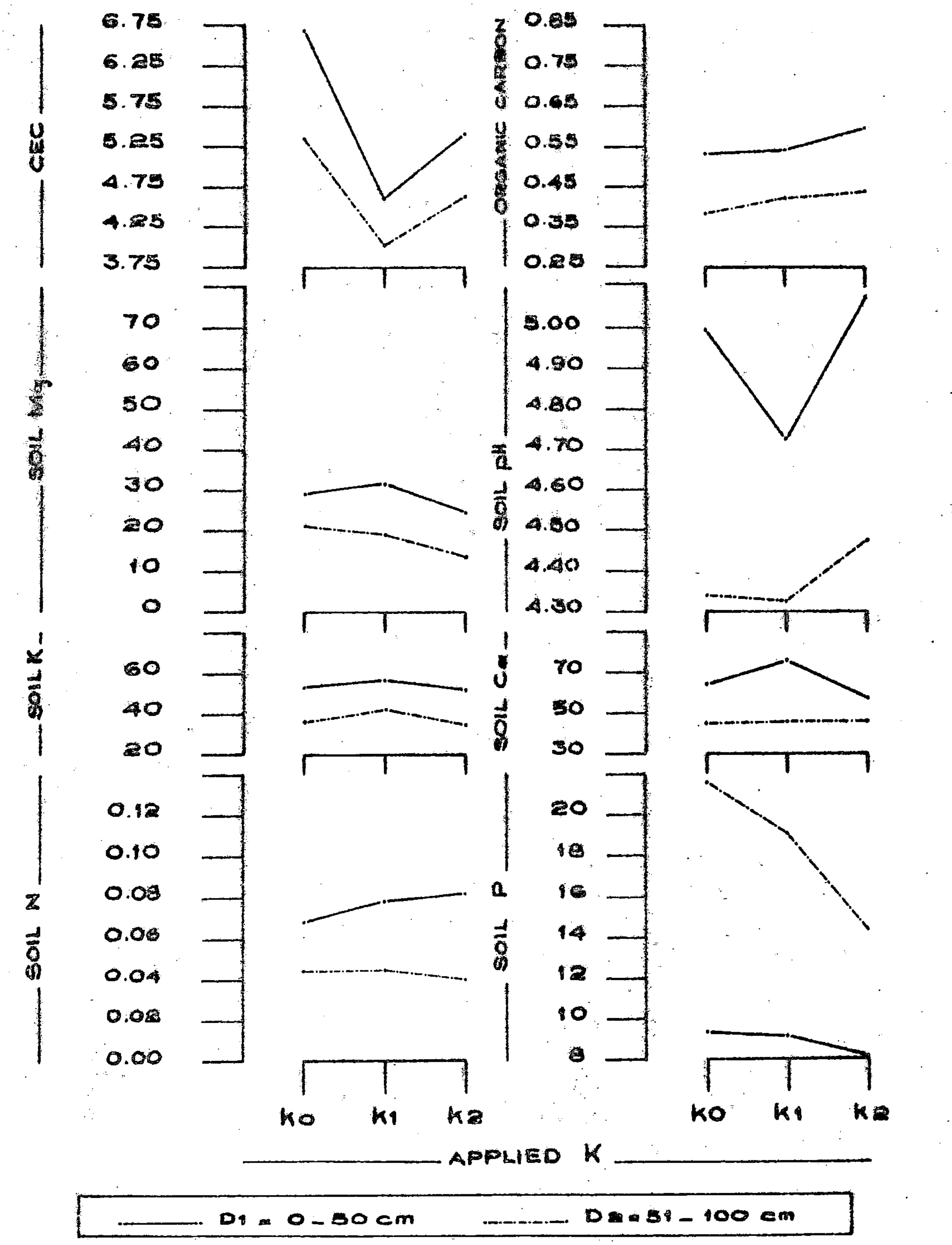


FIG: 9 EFFECT OF APPLIED K ON SOIL FACTORS AT TWO DEPTHS



No significant difference in organic carbon percentage was noticed in soils treated with different levels of N, P and K. Interaction effects were also not found to be significant. The percentage of organic carbon was almost equal at various levels of N, P and K at both depths of sampling.

DISCUSSION

DISCUSSION

The tree most widely grown in the World - the coconut - is found in the whole intertropical zone where its climatic needs are satisfied. By virtue of its geographical distribution the coconut interests a large section of the World population, for whom it represents the sole source of fat.

Whilst research with a view to improving the productivity of this oil plant started more than sixty years ago, it is only in the last couple of decades that considerable progress has been made. This improvement in yields results from the application of a whole series of modern techniques without which no high yields will ever be obtained. Mineral nutrition is one of them. And yet fertilization of coconut is still not a current practice in most of the coconut growing countries. In India a few tens of thousands out of the 1.2 million hectares of coconut groves receive mineral manuring.

The wide extension of high yielding Dwarf x Tall hybrids could revolutionise coconut growing everywhere, but the absence of fertilization will stop them expressing their full potential all the more so in that such high production is inevitably accompanied by a corresponding increase in the uptake of mineral elements from the soil.

The results obtained in a fertilizer experiment on coconut with N, P and K fertilizers continuously ever since its planting in 1964 as an one year old seedlings at the Coconut Research Sub-Station, Balaramapuram, Trivandrum, Kerala are discussed in this chapter.

5.1. Number of fronds produced per palm

From the data presented in Tables from 8 to 23 it is revealed that nitrogen had persistently increased the number of fronds produced per palm during the period of study from 1972 to 1979. The effect of phosphorus was also found to influence the production of fronds in the early stages ie upto 1975, whereas the response was not significant thereafter. In the case of K a mixed trend was observed on the production of fronds. During the first halves of 1976 and 1977 and in 1979 the response of K was not found to be significant. Interaction effects were also not found significant.

The effect of N in increasing the vegetative growth of young palms was also reported by Nambiar and Pandalai in 1959. Mathew and Ramanandan (1964) reported that N had a significant effect on all the growth characters of young palms; in the initial stage, phosphorus increased girth, collar and number of fronds produced, and the effect was reported to be indirect by enhancing the uptake of K, where the application of K increased girth at collar only.

Smith (1964) found significant increase in growth characters of young palms due to application of N. According to Smith (1968) young palms would respond to N even on soils where bearing palms would not normally respond to N, but would respond to K on soils where bearing palms would do. Studies by Nelliat and Muliyar (1971) also found response of young coconut palms of the high yielding types to NPK fertilizers resulting in highly significant increase in all the growth characters. It was found that the Malayan dwarf responded well to N application on early growth, frond production and early yield (Anon, 1972). Studies revealed that the main effect of N and P and the interaction between N and P and that between N and K were significant in increasing frond production in the young palms of the Tall variety grown on a sandy loam soil. However, K had no effect on the growth characters studied (Anon, 1972). Loganathan and Balakrishnamurthi (1979) suggested that inspite of a low status of N in the soil, the higher response of N was probably due to the dominant requirement of this element during the vegetative growth period of the palm.

It is evident from ~~Table~~ Appendix 1a that the initial status of N of the present experimental site was low with respect to N and hence the response to N at higher levels during the early growth stages.

5.2 Length of leaves and number of leaflets

From the data presented in Tables 24 to 55 it was revealed that the length of leaves progressively increased with age. However, there was not much response for nitrogen levels; but a slight increase in length of leaves was observed at both the levels of N viz. 340 g N and 680 g N per tree per year. P application also did not increase the length of leaves to any appreciable extent. However, a linear response to K was evident all through.

The findings of Soon and Wat (1971) that in the coastal clay soils of Malaysia, application of nitrogen significantly increased the length and weight of the frond is not in agreement with the present findings. Significant response of N on length of leaflets was also reported (Anon, 1972). The lack of response for N to the length of leaves in the present study might be possibly due to poor native fertility of the soil; lack of applied nitrogen and due to had distribution of rainfall reducing the nitrification time and the length of activity of the absorbant root system and also of soil conditions unfavourable to the mineralisation of organic matter etc. Though a linear response was noted for K at different levels, it was not significant between the higher levels of applied K viz. 450 g K and 900 g K per tree per year.

5.3 Number of female flowers

The main effects of N, P and K were found to be condusive in enhancing the production of female flowers. A linear response was observed for the main effects of N and K but the response to P was visible only during the early years and later it presented a quadratic expression. The interaction effects of NK and PK were found to be conspicuous. In this connection it is interesting to note that many of the palms that have not received K did not flower at all even after 18 years after planting.

The reports of Menon and Pandalai (1958) that P had a depressing effect on female flower production is in partial agreement only with the findings of the present study, wherein it was observed that P had a beneficial effect in the early years towards female flower production, but later it did not enhance it. According to Smith (1964) the increased production of female flowers was due to the effect of N and the yield increase was due to K. Studies conducted in the Phillippines revealed that the beneficial effect of K was due to the increased leaf area, coupled with improved angle and leaf colour which resulted in better utilization of sunlight and ultimately produced increased number of fronds, inflorescences, female flowers, nut set and weight of nuts.

Summarising the data from fertilizer experiments in SriLanka, Salgado (1968) reported that female flower production was increased by 15 per cent by the application of N. This is in confirmity with the findings in the present study. Taking into account that the effect of P can be observed at a very late stage as reported by Loganathan et al. (1980) the initial increase in female flower production cannot possibly be attributed to the main effect of phosphorus.

Manciot et al. (1980) reported that the element K had a spectacular effect on the number of inflorescences emitted by the tree and the K application triple them. Fremond (1964) reported that N significantly increased the number of female flowers. The application of K resulted in the improvement of all production factors such as fruit setting, number of bunches, number of female flowers per bunch and number of nuts etc. He has further reported that P was not found to have much beneficial effect in increasing the yield of nuts. Smith (1964) found that in Jamaica when the palms were coming to bearing, the early inflorescences usually had either nil or only a few female flowers and this situation persisted on very infertile soils. Under such situations, application of N had increased the female flowers produced which was reflected in the increased yield. The observations in the present study that palms did not receive K have not flowered at all even after the lapse of 18 years of planting clearly emphasises the indispensibility of the nutrients N and K in enhancing the female flower production and thereby the yield.

The finding as reported by Salgado (1968) in SriLanka, that the NP interaction had a positive effect on number of bunches and female flowers per bunch is not in full agreement with the findings of the present study. However, Barrant (1977) observed the beneficial effects of N and NK interactions on yield. This and the findings of Fremond (1964) on the interaction effect of PK fully support the findings in the present study with regard to NK and PK interactions.

5.4 Setting percentage

In the present investigation it was found that the main effect of N was not consistent in increasing the percentage set of nuts. The effect of N was apparent only in alternate years and that too limited with the initial dose of 340 g N per tree per year. Increasing the level of nitrogen from 340 to 680 g per tree per year did not however, influence the nut setting.

P had a depressing effect on percentage set of nuts at the highest level of 450 g P per tree per year, though, of course i-evinced a mild effect at the lower level of 225 g P per tree per year. But the main effect of K was conspicuous and consistent throughout the period in increasing the setting of nuts and thereby increasing the yield. The interaction effects of NP, NK and PK were not found to be significant.

Smith (1964) reported that female flower production and fruit setting provided a field guide to the N and K requirement of the palm. Summarising the contributions by IRHO, Fremond (1964) reported that K resulted in the improvement of all production factors such as fruit setting, number of bunches etc. It was reported in Jamaica that the beneficial effect of N was due to an increased production of bunches ranging from 11.11 to 12.8 per cent and female flower production from 20 to 40 per cent, although there was reduction in fruit setting (Anon, 1968). This is in agreement with the findings in the present study. Salgado (1968) reported that application of K at the rate of 680 g per tree per year increased the setting percentage by 35 per cent over the control. All the above findings upholds the observations in the present study.

5.5 Yield of nuts

The palms from which yields have been recorded for the purpose of this study, have been under continuous fertilization with NPK at graded doses since its planting in 1964. The seedlings planted in 1964 commenced bearing in 1974; but it was found to be uneven and not uniform. An almost uniform bearing was noted in 1976 and hence the yield data from 1976 to 1982 were computed for purposes of analysis in this study. The analytical data are presented in Tables from 70 to 76.

From the results it can be seen that a positive response to applied N was observed during all the years and was progressively increasing over the years upto 1982. The palms which received 680 g N per tree per year yielded on an average more than 226 per cent over the palms that were not supplied with nitrogen during the seven year period from 1976 to 1982. Similarly those palms that received 340 g N per tree per year gave increased yields over 133 per cent than the control plots with no nitrogen. However, the percentage increase in yield of palms supplied with 680 g N per tree per year over those that supplied with 340 g N per tree per year was only 40 per cent, suggesting the operation of the principle of diminishing returns.

Muliyar and Nelliat (1961) observed that the nitrogenous fertilizers significantly increased the number of nuts per palm. Fremond (1967) reported that the IRHO achieved the best correction of N deficiency in Mosambique with yield increase by 30-40 per cent. In Malaya a good response to nitrogenous fertilizers was obtained by Thye et al. (1976). Manciot et al.(1980) observed that nitrogenous fertilizers had a significant effect on the number of nuts per tree per year and the copra per tree, although the copra per nut was significantly depressed. They have further reported that it is in young coconut trees that nitrogen manuring has given the most characteristic results irrespective of whether the cultivars are Talls, Dwarfs or Hybrids. Numerous I.R.H.O. experiments on the nursery and young plantations have shown that nitrogenous fertilizers have a far from negligible role to play. All the above findings are in agreement with the results of the present study in respect of both nitrogen fertilization and age of the palms. It is also worth mentioning that the mean yield of palms that were not receiving nitrogen at all was also on the increase over the years from 1976 to 1982 which may be due to the effect of ageing and climatic factors chiefly rainfall and sunshine.

Applied P also contributed to increase in yields of nuts over the years, but to a limited extent only. The rate of increase in yield was significant only with the initial dose of 225 g P per tree per year over the control palms with no applied P. However, at the highest level of P viz. 450 g per tree per year, the rate of increase in yield was depressed. Pandalai and Marar (1964) reported similar findings in which N and K improved yield of coconut but not P. In several experiments conducted by I.R.H.O. in West Africa, no significant response to P was recorded (Brunin,1970).

The response of K for yield was most conspicuous with applied doses of K, the effect being most prominent in palms that received the initial level of 450 g K per tree per year. The rate of increase in yield of nuts showed a diminishing trend with further increments of K viz. 900 g K per tree per year adhering to the law of diminishing returns. However, the increase in yield due to higher levels of K was steady and linear over the years from 1976 to 1982. The mean annual yield of nuts obtained from the palms that received no potash was 1.06; 4.17; 3.61, 3.28; 5.94; 18.22 and 25.28 for the years 1976, 1977, 1978, 1979, 1980, 1981 and 1982 respectively. In this context it is worth mentioning that though N and P produced visible improvement on the vegetative characteristics and also on yields during the past 18 years after planting in the main field, a majority of the palms which received no potassium failed to flower at all, even when they were given the highest levels of nitrogen and phosphorus. The variations from year to year in the yield of treatment K_0 (zero level) may be ascribed to climatic factors and ageing of the palms. Climatic factors are known to have an important effect on the number of nuts (chiefly influenced by rainfall). Fremond and Gres (1956) have described the visible effects of potash application on the palms, compared to no application of potash by the denser foliage and the lush green colour of the fronds. This increased vigour in the green tissues is reflected on the yields in two ways (1) the number of nuts - potash induces an increase with the rate of application and (2) in the weight of copra per nut. The general flaccidity and drying of leaf tips and the appearance of necrotic patches in the leaflets of older leaves on young palms growing in the plots not supplied with K observed in the present investigation is a clear indication of K deficiency in these plots.

Heth Singh <u>et al</u>.(1961) discussed coconut nutrition and fertilizer requirements in relation to soil conditions existing in SriLanka and found that the main effect which had shown significance was that of K.

Fremond and OuVrier (1971) while confirming the spectacular action of potassic manuring on yield further revealed that the harm done to the trees by a lack of potassium during the early phases of the palm becomes irremediable by later applications. The trees which have received potash manuring from the time of planting always produce more than those which received application of potash at maturity. It was also shown that the residual effect of a double rate every two years being less than the annual application of a single rate. In India Muliyar et al. (1971) consider that the increased yield due to correction of the potash deficiency is essentially due to the increase in the number of nuts and not in the copra content.

Smith (1964) reported that in certain situations in Jamaica where the yield and number of flowers were already high and the only limiting factor was the physiological inability of the palms to hold more nuts, it is often possible to increase the number of nuts and yield further by the application of potash fertilizers. The results of the present study indicate that the application of potassic fertilizer may be helpful in preventing physiological button shedding in many situations in Kerala.

John and Jacob (1959) found that application of 340 g N, 340 g P_2O_5 and 680 g K_2O per palm per year resulted in an increase of 35 per cent in nut production and 44 per cent in copra production over cultivator's practice. When they failed to obtain response to the above dosage, significant yield increases were obtained when the K_2O level was raised to 900 g per palm per year. Raising the levels to 900 g N, 1135 g P_2O_5 and 1135 g K_2O resulted in further increase in yield.

Prudente and Mendoza (1976) reported that on palms fertilized with muriate of potash right from transplanting with N or NP always produced taller and stouter palms, induced initial flowering in less than four years and significantly increased nut and copra production over these trees without KCl. This observation was made in an inland upland area.

The interaction effects of NK and PK were also spectacular in increasing the yield, though the interaction of NP gave slightly inconsistent results. Similar results were reported from SriLanka which showed that the main effects of N, P and K and the interactions of NP, NK and PK were significant with respect to yields (Anon, 1969). Barrant (1977) reported the beneficial effects of N and NK interaction on the yield of Malayan Dwarf palm growing in K deficient soil.

Marar and Pandalai (1961) concluded that the effects of N and K were equal and additive. They quantitatively fixed the effect of N at 10.7 nuts, K at 11.3 nuts and NK at 20.8 nuts per palm per year from a fertilizer trial having two levels of NPK viz. zero and 450 g N, zero and 227 g P_2O_5 and zero and 454 g K_2O per palmper year.

Ollagnier and Ochs (1973) from a study of the interaction effects of N and K concluded that the lack of sinertic effects of N and K on yields is likely to be due to the lower degree of N deficiency and to the slight action of the potash on nitrogen metabolism. All the above reports clearly support the findings revealed in the present study and emphasises the importance of K fertilization to coconut palms.

Response surfaces were also fitted to the annual yield data with respect to applied N, P and K from 1976 to 1982. The partial linear regression (b_0) of yield on no applied fertilizer from the very planting of the seedlings in the main field in 1964 exhibits the effects of ageing and climatic parameters on growth and yield of coconut palms. It may also be due to proliferation of the root system to a wider spectrum in search of nutrients, thereby obtaining the minimum requirements of the palms resulting in sustained increase in yields despite no applied fertilizers.

The partial linear regression (b_1) of yield shows positive response at the initial level of 340 g N per tree per year while at the highest of 680 g N per tree per year the quadratic coefficients (b_{11}) shows negative values which are not significant in any of the years from 1976 to 1982. This indicates that the present highest dose of 680 g N per tree per year is in no way near optimum and there is need for further enhancement of N in the schedule of fertilizer treatments.

The quadratic coefficients (b_{22}) of yields though show negative values, are significant in all the years which shows that there exists a maximum level P. Since the response of P at the highest level viz., 450 g P per tree per year was found to depress the yield, it is to be inferred that the maximum level of P has already been attained and the initial level of 225 g P per tree per year would be sufficient enough in combination with other nutrients to attain sustained higher yields.

The partial linear regression (b_3) of yield exhibited a positive response at the initial level of 450 g K per tree per year. But the quadratic coefficients was found to be significant and negative which indicates that there exists still a maximum level for K to achieve maximum potential yields. However, the response to higher level of 900 g K per tree per year was found to be quadratic though there was increase in yield at reduced rates. This indicates that the present highest dose of 900 g K per tree per year is very near optimum and if at all the dose is increased it need be increased to a little extent only.

The values of coefficient of determination (R^2) explained the fitted response functions satisfactorily and indicate that the responses due to NPK fertilization of yield of nuts were 55, 80, 71, 81, 91, 77 and 75 per cent respectively for 1976, 1977, 1978, 1979, 1980, 1981 and 1982; the rest being attributed to effect of ageing and climatic parameters.

5.6 Weight of unhusked nut and husked nut

The main effects of nitrogen and potash were found to influence the weight of unhusked and husked nuts. It has already been established that applied N and K appreciably increased the yield and yield attributes in coconut. It has also been reported that the addition of K increases the copra weight. The findings at C.P.C.R.I. that nitrogen reduced the size and weight of nuts, potash increased the yield of nuts and also improved considerably all the nut characteristics including quality and quantity of copra and phosphorus with no tangible effects in the nut characters are in full agreement with the nut characters studied in the present investigation.

5.7 Thickness of meat and weight of meat

Applied nitrogen did not influence the thickness of meat in coconut though a slight increase was observed with the starter level of 340 g N per tree per year over the zero level. However, a depressing trend was obtained with the higher level of 680 g N per tree per year. P only decreased the thickness of meat in coconut in the present study. Only the applied K was found to be effective in this respect, although quadratic at the highest level of 900 g K per tree per year.

The result of the present study is in agreement with the findings reported by Fremond (1964) that the application of K resulted in the improvement of all production factors such as fruit setting, number of bunches, number of female flowers per bunch, number of nuts, average copra per nut and ultimately the total copra out turn per palm. The thickness of meat and weight of meat are factors contributing to the yield of copra per nut.

5.8 Weight of copra

It was found that the main effect of nitrogen was significant only at the initial level of 340 g N per tree per year over the zero level in increasing the yield of copra; while the highest level of 680 g N per tree per year depressed it. Applied P also had a depressing effect with regard to weight of copra. Potassic manuring was found to increase the weight of copra considerably, the effect being more conspicuous at the lower level of 450 g K per tree per year than at the highest level of 900 g K per tree per year. The rate of increase in the weight of copra was narrowed between K_1 and K_2 levels.

The I.R.H.O. has often found a depressing action of nitrogen manuring on copra per nut and a close connection to the K levels. For low K contents, ammonium sulphate reduces the number of nuts and the copra per nut, but as soon as the potassic deficiency is corrected the nitrogen favours the number of nuts. Loganathan et al.(1979) reported that copra out turn was influenced both by muriate of potash and sulphate of ammonia. While muriate of potash linearly increased nut per palm, copra weight per palm and copra weight per nut, sulphate of ammonia linearly decreased copra weight per nut.

Manciot et al.(1980) reported that without potash the mean yield for six years was 980kg copra per hectare per year, with the application of 1.5 kg potassium chloride per tree per year the yield increased to 2100 kg copra per hectare per year - the production was more than doubled.

The I.R.H.O. studies have very clearly demonstrated the highly significant correlation between K levels and copra production per tree. However, the study of potassium cannot be dissociated from that of the other cations; as seen here production was lowered by 2 per cent in the N plots, but increased by 20 per cent in the K plots. Zillar and Prevot (1962) observed that addition of 1.5 kg muriate of potash resulted in 62 per cent increase in yield of nuts and

23 per cent increase in copra weight per nut, ie a gross increase of 1.1 to 1.2 tonnes of copra per hectare.

Fremond (1964) found that higher doses of N not only depressed yield of nuts but also reduced the weight of copra per nut. Phosphorus was not found to have much beneficial effect either in increasing yield of nuts or copra content. But in the presence of K, P was found to have beneficial effects on the number of nuts and yield of copra.

Menon and Pandalai (1958) after reviewing the work done in India upto 1958 have reported that N had an adverse effect on copra content, while K had a beneficial effect, but P had no effect on copra weight. According to Salgado (1940) N had a beneficial effect on female flower production, while it had an adverse effect on copra content as a higher number of nuts were required to produce a ton of copra, phosphorus had no effect on the copra content and had a definite depressing effect on female flower production.

Muliar and Nelliat (1971) reported that although application of N increased the yield of nuts by 16.9 per cent, copra yield was increased only by 6 per cent. With K the increase in nut production was 12 per cent while that of copra yield was 22 per cent. Pandalai and Marar (1964) reported that in the seventh year of fertilizing, copra production was lowered by 2.0 per cent in the N plot but increased by 20 per cent in the K plot.

The findings mentioned above emphasise the importance of K on yield of copra and are quite in agreement with the results obtained in the present investigation. It also emphasises the need for a balanced fertilization of coconut palms.

5.9 Thickness of shell and weight of shell

The weight of shell and thickness of shell do contribute to the yield of copra per nut. From the available data it was found that both the characters were influenced by applied N and K though P had a depressing effect. The role of applied N and K in increasing the yield of nuts and yield characteristics have already been illustrated.

5.10 Oil content

The data on the percentage of oil content as influenced by continuous NPK fertilization to coconut are presented in Table 88. From the data it was revealed that the oil content was increased with the initial dose of 340 g N per tree per year while it was found to decline with the highest level of applied N viz. 680 g N per tree per year. However, continuous fertilization with K at all levels substantially increased the oil content in coconut. This finding is in full agreement with the results obtained from trials set out by IRHO at Dabou, where on experimental plots of 125 acres supplied regularly with 2 pounds potassium chloride per tree per year, the out turn of oil ran upto 1786 pounds per acre as against 250 pounds oil per acre for the control plots.

5.11 Weight of fibre

In the present investigation it was found that the application of K fertilizers to coconut had significantly increased the fibre content in the husks; while it was not so with regard to N and P. This finding is in agreement with the results reported by Muliar and Nelliat (1971) that N adversely affected all the nut characters viz. weight of whole nut, weight of husked nut, volume of husked nut, copra weight etc. However, all these charasters were appreciably improved by K nutrition and P had only negligible effect, Fremond (1964) has also reported that the application of K resulted in the improvement of all production factors such as fruit setting, number of bunches, number of female flowers per bunch, number of nuts etc.

5.12 Foliar analysis

The following foliar levels (Fremond *et al.* 1966) are tentatively taken as standard critical levels for purposes of discussion.

Nutrients	Standard critical levels (per cent dry matter)
Nitrogen (N)	1.8 to 2.0
Phosphorus (P)	0.12
Potassium (K)	0.80 - 1.0
Calcium (Ca)	0.30
Magnesium (Mg)	0.20
Sodium (Na)	Upto 0.40

The results of the foliar analysis of coconut palms from the 3^3 NPK fertilizer experiment conducted during the course of the present study in relation to the critical limits of nutrients as arrived in the present study and from published literature and yield of nuts are discussed.

5.12.1 Nitrogen

The critical level for N in the 14th leaf has been fixed as 1.8 to 2.0 per cent of dry matter for tall varieties by Fremond et al. (1966). According to them, below this value the nitrogen nutrition is not assured and may lead to anomalies exhibited by deficiency symptoms and low yield.

The results presented in Table (90) show that the foliar N content range from the lowest value of 1.04 per cent in palms receiving no nitrogen to the highest value of 1.22 per cent in palms receiving 680 g N per tree per year. It may be noted that, inspite of the continued annual application of 680 g N per tree per year the foliar N level was raised only to a small level which is much below the critical level of 1.8 - 2.0 per cent, fixed by I.R.H.O. Neverthless the yield of coconut from the corresponding palms during 1982 were 87 and 184 per annum respectively showing a remarkable increase in yield with only a slight increment in foliar nitrogen levels from 1.04 to 1.22 per cent.

Further the correlation of foliar N and yield of nuts in the present study was positive but not significant (r = 0.2589). The direct effect of Leaf N was also positive though not significant with yield. The response of applied nitrogen to yield is found to be linear indicating that an optimum level of N is not attained with the present levels of N_1 and N_2 viz., 340 g and 680 g N per tree per year, which indicates the need for further increasing the levels of nitrogen. The above findings lead us to infer that the levels of N tried in the present investigation, inspite of the cumulative application of fertilizers over a period of 18 years is still below optimum and is not adequate to exploit the maximum yield potential of the palm. Only when the levels are further raised and application prolonged over a number of years, the foliar nitrogen levels may rise up from the present level of 1.22 per cent as indicated by the regression coefficient (0.12) of N on applied N. A similar positive response of leaf N on yield though not significant has been reported by Loganathan and Balakrishnamurthy (1979). Vonuoxkill (1971) reported that the foliar nitrogen content of palms yielding more than 100 nuts per year in the Phillippines was 1.96 per cent. Indirakutty and Pandalai (1968) in India categorised palms yielding more than 80 nuts as high bearers and reported that the leaf content of N in such palms to be as high as 1.86 per cent. However in the present investigation the average annual yield of nuts was progressively increasing in treatments receiving higher doses of nitrogen. But the leaf content of N was found to be much below the standard critical level fixed by I.R.H.O. One possibility is that the critical levels for foliar N for mature palms in this region could be lower than that fixed by the I.R.H.O.

5.12.2 <u>Phosphorus</u>

Contrary to the findings on foliar N in the study, the leaf contents of P were much higher than the critical levels fixed for P by I.R.H.O. (0.12 per cent), by Vanuoxkull (0.10 per cent), Indirakutty and Pandalai (1968) (0.14 per cent), and others which ranged from 0.19 to 2.0 per cent. Cecil (1969) reported that the P content in leaf of healthy palms of high productivity was 0.198 per cent, which compares well with the present findings. As such it is to be inferred that the present highest level of P viz. 450 g per tree per year would be sufficient enough to maintain the healthiness and productivity of the palms. The comparatively high amount of leaf P might be due to the result of application of phosphatedfertilizer accompanied by a significant increase in the leaf P levels (Manciot et al.1980). The findings of Manciot et al. (1980) that continued application of phosphated fertilizers increase the P content very significantly are in quite agreement with the present findings.

5.12.3 Potassium

The standard critical level for K is fixed at 0.8 to 1.0 per cent of the dry matter for tall varieties (Fremond et al.1966) In the present study foliar analysis of the 14th leaf has shown a percentage range of 1.02 for the palms which received no potash to 1.63 for the ones which received 900 g K per tree per year. It appears that the leaf content of K in palms receiving no potash is slightly above the critical levels suggested by Fremond et al.(1966) and IRHO (0.8 - 1.0 per cent), Anon (1969) in SriLanka (0.87 per cent). However, Vonuoxkull (1971) in the Phillippines reported 1.26 per cent and Indirakutty and Pandalai (1968) in India reported (1.26 per cent) as values for critical levels of leaf K. As such it is to be noted that the palms not supplied with K are very near to the critical level and that they are only slightly deficient in as far as this element is concerned. In this context, attention is again focussed on the observations in the present investigation that though nitrogen and phosphorus produced visible improvement on the vegetative growth characteristics and also on yields during the past eighteen years after planting a majority of the palms which received no potassium failed to flower at all even when they were given the highest levels of nitrogen and phosphorus. Studies on the correlation between leaf K and yield though found to be not significant (r = 0.14) its direct effect was high as compared to other nutrients. The probable reasons for the increasing levels of leaf K with incremental doses of applied K might be due to continued application of high doses of K as reported by Prevot and Fremond (1968) and Loganathan and Krishnamurthy (1979).

The high direct response and the low correlation of leaf K with yield suggest the need to further increase the level of K from 900 g K per tree per year. The linear response of K on yield also reveals this necessity since optimum levels for K has not been reached so far. Vonuoxkull (1971) reported that the leaf content of K was 1.26 per cent for palms yielding more than 100 nuts per year in Phillippines. Indirakutty and Pandalai (1968) reported leaf K percentage as

1.30 for high yielders producing more than 80 nuts per year. In the present study the highest mean yield of 204 nuts per tree per year was recorded from the palms supplied with 900 g K per tree per year. In view of the higher mean yield for K and also of the positive correlation and high direct effect of K with yield there is reason to believe that the absorption and assimilation of K was much higher which was exhibited by a high leaf percentage of K. However, as stated above the dose of K is to be further increased so as to achieve still higher yields in which case probably the leaf content of K may also rise up further from the existing level of 1.63 per cent. It is also suggested that when the potash levels are raised from the present levels, Mg may also be included as one of the treatments as there is negative interaction between K and Mg and that large doses of K are capable of inducing magnesium deficiency (Manciot _et al_. 1980).

5.12.4 Calcium

Calcium was not included as one of the nutrients supplied in the present study. The standard critical level for leaf Ca was fixed at 0.3 per cent (Fremond _et al_.1966). In the present analysis the leaf content of Ca was in the range of 0.028 and 0.180 per cent. The non-inclusion of Ca in the treatment schedule and the continued application of K might have depressed the level of Ca in the leaf. This finding is in agreement with the reports by Manciot et al. (1980). However, it was found that incremental doses of N and P had resulted in a slight increase of leaf Ca. The correlation on leaf Ca with yield was found to be significant (r = 0.3223).

5.12.5 Magnesium

Magnesium was also not included in the fertilizer schedule for this study. Foliar analysis for leaf Mg has shown to vary from 0.12 to 0.13 per cent. The standard critical level of Mg in the leaf is fixed at 0.2 per cent (Fremond et al. 1966) which as compared to the present results is much high. Application of higher levels of N, P or K did not influence leaf Mg in the present study. Manciot et al. (1980) reported that nitrogen fertilizer application often depresses the leaf Mg levels and that application of K always reduces Mg levels in the leaf. The above findings are in confirmity with the results obtained in the present study. The negative correlation (-0.3240) obtained between foliar Mg and K in the present study is in full agreement with the findings reported by Fremond et al.(1966). However, the fact that the direct effect of Mg was positive towards yield of nuts is in par with the findings reported by Cecil (1969). Barrant (1977) reported that the yield increases due to fertilizer applications were not related to any increase or decrease of Ca or Mg content in the leaf.

5.12.6 Sodium

Sodium is not really indispensible but it is known that it can replace K to a certain extent when the latter is in short supply (Manciot et al. 1980). The standard critical level of Na has been taken to be upto 0.40 per cent (Fremond et al.1964 But in the present study the foliar status of Na was 0.14 per cent only. It is revealed that higher levels of applied K depressed the Na content in the leaf which is in full agreement with the findings reported by Manciot et al.(1980). They have further reported that planters in Jawa, India and Columbia apply sodium chloride, as they consider that Na favours coconut yield. There is no scientific proof for this assertion, and it may be thought that as sodium was given in chloride form, it was the chlorine which raised the yield. The negative correlation obtained for K and Na and negative correlation for Na towards yield (-0.1710) obtained in the present study also upholds the findings reported by Manciot et al.(1980).

5.12.7 Direct and indirect effect of foliar nutritients on yield

The correlation of foliar N on yield was found to be 0.26 though its direct contribution was only 0.18. The effect of N was found to have enhanced in combination with other foliar nutrients viz., P, Ca, Mg and Na; however, the leaf K was found to depress the effect of N on yield. Loganathan and Murthy (1979) reported that in the absence of N or P the yield would be low even if the leaf K and Cl are high.

The correlation of foliar P with yield is 0.35 which is due to the sum total effects of P (0.24) and N, Ca, Mg and Na indirectly. The magnitude of correlation is reduced due to the indirect effect via foliar K. This findings is in agreement with the result that the application of potassium fertililizer very often provokes a drop in leaf P(Manciot et al. 1980). They have further reported that there can be wide variations in yield when potassic fertilizers have been applied. In Phillippines the P levels rise considerably while they are more or less constant in Indonesia, Oceanea and Mosambique and drop very significantly in the Ivory Coast (Manciot et al. 1980). This negative relationship is manifested from its correlation with K (-0.07). The presence of Ca in leaves increased the level of P, which is evident from its correlation with Ca(0.30). The indirect effect via Ca is also found to be more than through other foliar nutrients (0.08). A correlation of 0.50 between leaf P and yield was reported from SriLanka and Ivory Coast for P levels below 0.13 per cent (Manciot et al.1980). In the present study the leaf P was 0.2 per cent.

Foliar K was found to have maximum direct effect than other nutrients (0.26), on yield but its correlation with yield was found to be only 0.14. This reduction in the magnitude of correlation is due to indirect effects via N, P, Ca and Mg. The only nutrient which enhanced the effect of K is Na. Coomans (1974) reported that potash levels strongly influenced production. The high direct effect of K observed in the present study stresses this findings. Ziller and Fremond (1961) reported that when K deficiency is a limiting factor in production, this entails a positive correlation between potash content in the leaves, and the number of nuts per tree, whereas the correlation disappears when the deficiency is corrected. In the present study the soil is not deficient in potash and hence the report by Ziller and Fremond et al. (1961) is in conformity with the present observation. The findings reported by Manciot et al. 1980 that the deficient status of the unmanured trees is reflected in a declining trend, and the dose of 1 kg KCl per palm per year appears insufficient to maintain a high level of production holds true in the present investigation also. It was further reported that 1 kg KCl per year was inadequate in so far as the K content rose only very slowly, though it did eventually rise beyond the critical level. This is also true of the findings recorded in the present study.

This slow increase in the K level of the leaf corresponds with the initial growth period of the palm, when the nutrient is being accumulated in the trunk and the crown. Hence the deficient levels at these periods of growth have to offset the storage requirements as well.

Margate *et al.* (1978) observed partial correlation of yield with either leaf K (r = 0.26 at constant Cl), or leaf Cl (r = 0.50 at constant K) and reported that the correlation coefficients were not significant. This is due to the strong correlation of the two nutrients in the leaves. This suggests that the marked response of coconut to muriate of potash application is due both to K and Cl in the fertilizer. The non-significant correlation obtained in the present study might be due to the reason that the leaf Cl was not estimated and as such correlation was worked out for K alone. Had the correlation been worked out both for K and Cl it would have been positive and significant with yield. K and Mg were generally found to have a negative interaction. In the absence of K, Mg has a slight positive action. The effect of K and Mg are not additive but on the contrary the conjunction of Mg with K reduces the effect of K (K - Mg antagonism). This is in par with the findings reported by Loganathan and Balakrishna Murthy (1979). The I.R.H.O. has shown that the principal effect of Mg on yield can be as much as 40 per cent, bu only produced in the presence of KCl. This is also proved true in as much as that the leaf Mg was found to be positively correlated with yield.

According to Ziller and Fremond (1961) although K had no effect on N and P content of the leaves, antagonism towards Ca and Mg and synergism with Na were revealed. Manciot et al. (1980) observed that only K fertilization has a strongly depressive effect on the Na levels in the leaf. The findings in the present investigation are in agreement with the above observations in as much as that the indirect effect of K via Na was positive and K was found to depress the Na content in the leaf.

5.12.8 Effect of applied nutrients (NPK) on foliar nutrient concentration

Multiple regression equations fitted to the data on foliar nutrient contents revealed clearly the rate of change of foliar nutrients with respect to applied doses of N, P and K. The rate of change in foliar N due to applied N and K was positive and significant and exhibited a quadratic response, while a negative relationship was obtained for applied P. The interaction of N with P and K with P increased foliar N while K with N depressed foliar N. The findings reported by Kamala Devi et al.(1974) that the average leaf N and K contents rose with higher application rates of N and K is in agreement with the present findings. The findings of Zillar and Fremond (1961) that the nitrogen levels were strongly influenced by the application of K, also is in confirmity with the present findings.

A positive response to foliar P for applied N and P was noted indicating that with increased levels of N and P the leaf P also increases. Manciot _et al_.(1980) reported that the application of phosphated fertilizers is very often accompanied by a significant increase in the leaf P levels. The close laison of N and P also influences P levels in the leaf. However, applied K exhibited a depressing effect on foliar P. The findings reported by Manciot _et al_.(1980) that at maturity nitrogenous manuring usually raises the P levels and the opposite happens with potassic fertilization, is in full agreement with the present results.

The findings that the regression coefficient of foliar K on applied N and P produced a depressing effect, significant depression being noted for applied N, and that with incremental doses of K, the leaf K also increased significantly are in conformity with the findings reported by Ziller and Fremond (1961), Kamala Devi _et al_. (1971), Prevot _et al_.(1961) and Manciot _et al_.(1980). The interaction effects were found to be negative.

With regard to Ca, the leaf content was enhanced with added N, P and K as also its interactions; but the response was quadratic with higher levels of N, P and K. According to Manciot <u>et</u> <u>al</u>.(1980) the Ca contents in leaves are appreciably increased by nitrogenous or phosphated fertilizers; potassium fertilization tends to depress the levels. This is true of the present findings also.

The Mg levels in the leaf was found to increase with N. This is not in agreement with the findings reported by Manciot <u>et</u> <u>al</u>.(1980) though their findings that Mg rises with applied P confirms to it. The reduced Mg level due to applied K can be attributed to K - Mg antagonism (Manciot <u>et</u> <u>al</u>. 1980).

5.13 <u>Soil analysis</u>

Soil samples from each plot were taken at the different depths viz. 0-50 cm and 50-100 cm and analysed for various characters such as N, P, K, Ca, Mg, organic carbon, cation exchange capacity and soil pH. The results obtained are discussed in this chapter.

5.13.1 <u>Total nitrogen</u>

From the data analysed for N, it was revealed that the nitrogen status of the soil was improved only when the highest dose of 680 g N per tree per year was supplied, whereas the lesser dose of 340 g N per tree per year left behind in the soil only very little nitrogen over the zero level. Foliar analysis data on the other hand showed that the percentage content of nitrogen in the leaf was enhanced with incremental doses of applied N. This shows that the plant uptake of nitrogen was active and also that no significant residual accumulation of nitrogen could be observed in the soil at levels lower than 680 g N per tree per year. Even at the highest level, only a slight increase in the nitrogen reserve of soil could be observed. The yield data and also the correlation studies for N with yield showed that the present dose of N needs an upward revision.

The data on soil nitrogen is highly revealing particularly when examined in relation to the climatic parameters of the experimental site. Leaching and volatalisation losses of applied N could have taken place to a significant extent in view of the high intensity of rainfall in both the monsoons and the high temperatures prevailed throughout the year. The fact that the application rate of 680 g N per tree per year could not leave behind a significant residual accumulation of N further indicates the magnitude of the problem in relation to N losses.

The application of P also did not improve the nitrogen status in the soil which is in agreement with the findings reported by Manciot et al. (1980).

Contrary to the effect of N and P on soil nitrogen reserves in the soil, applied K improved soil nitrogen status significantly. However with increased levels of K, the effect was quadratic which shows that the pattern of absorption was shifted from N to K at higher levels of applied K. Pillai and Davies (1963) reported the quantitative sequential of importance of absorption of major nutrients for adult bearing palms as K N Ca Mg P. Similar sequence of absorption was also reported by Ouvrier and Ochs (1978) which is in the order K Cl N Ca Na Mg S P. The above findings are in agreement with the results of the present investigation and lead us to infer that when adequate amounts of K is supplied to the soil, coconut palms prefer to absorb more of K than of N or any other mineral nutrients in the soil. The findings of Ramanandan (1974) that the soil N status was improved when N was added in combination with P and K, and also P when applied along with K are in partial agreement with the present study.

5.13.2 Available phosphorus

It is seen that the application of various levels of NPK fertilizers did not result in any significant reserve, of available P in the soil. However, a marginal decrease in soil P was observed due to NPK fertilization which may be attributed to high absorption of P in the presence of N and K and the possible partial fixation of P in red loam soils which are well known to have high P fixing capacity; especially when the pH is below 5.5. In studies carried out at Purdue University it was found that when ammonium sulphate was mixed with a water soluble phosphatic fertilizer and applied in a band, there was great proliferation of roots in the band and a greatly increased uptake of phosphorus by the plant (Tisdale and Nelson 1975). In the present investigation however, ammonium sulphate was applied in combination with single superphosphate and placed in bands around the palms which resulted in a higher absorption of P by the palms. Foliar analysis for leaf content of P also confirms this. Similar trend was observed in the soil samples from 50-100 cm depths also.

5.13.3 Available K

The available K status in the soil was found to increase with lower levels of applied N, P and K viz. 340 g N, 225 g P and 450 g K per palm per year. With further increase in the levels of applied N, P and K, the soil reserves of K was found to be depressed. This indicates that the absorption of K was of a higher order with the increased levels of applied N, P and K which was also evinced by the foliar content of K. Ramanandan (1974) found that in the case of K, its status in the soil had improved by supplying K alone; which suggests that the K reserves in the soil could be improved only with further additions of K in the soil and the present level tried in this investigation is not sufficient enough to build up the K status in the soil.

Cecil (1981) reported that there was a steady build up of available K in the soil due to the continued application of K fertilizers and the build up was higher with increasing levels of K treatments.

Peterson and Krueger (1980) reported that regular additions or a single addition of a large quantity of K increased the availability of K in the soil substantially, but the residual effect was less for K. The above finding also confirms the present result that the poor build up of soil K is due to comparatively lesser quantities of K applied to the soil.

Based on the ratings of Muhr <u>et al</u>. (1963), Pillai (1975) reported that all the soil groups of Kerala under coconut are generally deficient in available K, with no soil group falling under high rating.

Not much difference in soil K was visible in the soil samples collected from the depth ranging from 50-100 cm.

5.13.4 Calcium

Continuous application of fertilizers in the form of ammonium sulphate, single superphosphate and muriate of potash had resulted in a depletion of soil Ca. The cumulative effect of the application of N in the form of ammonium sulphate has resulted in a shapp decline in the calcium status of the soil. This can be due to the leaching away of Ca under the influence of the residual acidity brought about from the application of ammonium sulphate.

Cecil (1981) reported that the exchangeable calcium content of soil was not influenced by different levels of N, P or K treatments. This is in agreement with the findings in the present study. In view of the continued application of single superphosphate, a slight increase in Ca status of the soil could have been accounted, which could have been nullified by the continued applications of ammonium sulphate. The different levels of applied K did not influence the Ca level in the soil which might be due to K-Ca antagonism especially in the absence of added calcium.

Based on the ratings for exchangeable Ca by Sankaram (1966), Pillai (1975) has reported that all soil groups of Kerala under coconut are having very low Ca status and the differences among different soil groups are not significant. This observation is in agreement with the present finding.

5.13.5 Magnesium

The exchangeable Mg was not influenced either by the application of N, P or K which might be due to K - Mg antagonism especially in the absence of applied Mg. However, the PK interaction was found to have a slight influence on the Mg status in the soil. Similar behaviour of Mg was observed in the lower strata of the soil at depths ranging from 50-100 cm.

5.13.6 Soil pH

The soil pH was not influenced by the different treatment levels of N, P and K. However, increasing the levels of N and P treatments has a slight depressive effect on soil pH. This is probably due to the acidifying effect of ammonium ions present in the ammonium sulphate which was used as the N source in the present study. Cecil (1981) has reported similar acidifying effect of ammonium ions present in factomphos.

5.13.7 Cation exchange capacity

The cation exchange capacity is found to increase with higher levels of N and K, but depressed at higher levels of P. These changes due to continuous application of fertilizers over a long period of time requires further study.

5.13.8 Organic carbon

The organic matter content of the soil was not influenced by the different levels of NPK fertilizers. According to Manciot et al.(1979) the lowest organic carbon value considered ideal for the growth of coconut is 1.0 per cent. Compared to this the organic matter content of the experimental site is below the ideal level and ranged between 0.38 and 0.47 per cent only.

Prall et al.(1959) could not find any significant change in soil organic matter over a 28 year period when no organic manure was added. The above finding is in full agreement with the observation in the present study.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

At the Coconut Research Sub-Station, Balaramapuram, in Trivandrum District of Kerala State, an experiment was laid out as early in 1964 to study the effect of continuous application of N, P and K fertilizer on the growth and yield of West Coast Tall variety of coconut palms. The scope of the experiment was further enlarged to establish critical levels of nutrients in the fronds as related to yield and to determine the cumulative fertility status of the soil. The experiment was laid out in a 3^3 partially confounded factorial design with two replications, confounding NPK_2 in replication 1 and NP_2K_2 in replication 2. The treatments adopted were all the possible combinations of N, P and K at three levels as given below:

N - 0, 340 and 680 g N per palm per year

P - 0, 225 and 450 g P_2O_5 per palm per year

K - 0, 450 and 900 g K_2O per palm per year.

The experimental field was planted with one year old seedlings in 1964 and was continuously fertilized since then. The results of the investigation are summarised below:

1. The annual production of fronds per palm was increased with the incremental levels of N and K. However, the response to P was not significant; so also were the interaction effects.

2. The higher levels of N and P did not increase the length of leaf. A positive response to K was observed throughout the period of study. The interaction effects were inconsistent.

3. The response of N and P was not significant in increasing the number of leaflets, though an increasing trend was noticed with higher levels of N. The effect of K at the higher levels was significant over the zero level but at the higher levels it was on par.

4. The effects of all the major nutrients N, P and K were found to influence the production of female flowers. While the response of N and K was linear, it was quadratic in the case of P. Of the interaction effects, NK and PK interactions were significant althrough the years

5. An apparent increase in setting percentage was observed for N and K. However, the response to P was quadratic.

6. A positive response of N on yield of nuts was observed during all the years. The response of P showed a quadratic expression, while that of K was conspicuous. However, the yield increase was more remarkable with the initial levels of N and K over the zero levels. Among the interactions, NK and PK interactions were significant for all the years.

7. The cumulative yield data for the period from 1976 to 1982 also showed that the yield was increasing in a linear fashion for applied N and K. The most striking of the data is that the palms not supplied with K, gave only a minimum yield of 7.5 nuts, while those palms that received the highest level of K viz. 900 g K per palm per year gave the maximum yield of 405 nuts during the seven year period from 1976 to 1982. The response to applied P was quadratic. The interaction effects of NK and PK were significant.

8. The response surfaces fitted to annual yield data with respect to applied N, P and K from 1976 to 1982 showed that the partial linear regression of yield on N was positive at the initial level of 340 g N per palm per year while at the highest level of 680 g N per palm per year the quadratic coefficient showed negative values which are not significant in any of the years from 1976 to 1982. This indicates that the present highest level of 680 g N per palm per year is in no way near optimum and there is need for further enhancement of N in the fertilizer schedule.

9. The quadratic coefficients of P on yield showed negative values which are significant in all the years. This shows that there exists already a maximum level of P in the fertilizer schedule. Since the response of P at the highest level viz. 450 g P per palm per year was found to depress the yield, it is to be inferred that the maximum level of P has already been achieved and the initial level of 225 g P per tree per year would be quite sufficient in combination with other nutrients to attain sustained higher yields.

10. The partial linear regression of yield on K exhibited a positive response at the higher levels of K_1 and K_2 viz. 450 g K and 900 g K per palm per year. But the quadratic coefficient was found to be negative and significant which indicates that there exists still a maximum level for K to achieve maximum potential yields. However, the response to higher level of 900 g K per palm per year was found to be quadratic though the increase was linear. This indicates that the present highest level of 900 g K per tree per year is very near optimum which suggests further enhancement in the level of K to attain optimum yields.

11. The R^2 (coefficient of determination) values indicate that the response function of N, P & K on yield of coconut were explained respectively 55, 80, 71, 81, 91 77 and 75 per cent for 1976, 1977, 1978, 1979, 1980, 1981 and 1982, the rest being attributed to the effect of ageing and climatic parameters.

12. Post harvest studies revealed that the average weight of unhusked and husked nut was enhanced with N and K though it showed a quadratic expression. The effect of P was found to be negative.

13. The mean thickness and weight of meat were influenced by applied N and K although at the highest levels it was quadratic. The response to P exhibited a negative effect

14. The data on weight of copra revealed that the effects of N and K and also the interaction effects of PK and NPK had significantly influenced the weight of copra. However, the effect of N was quadratic. The response to P was found to be negative, though not significant.

15. The response of N and K to average thickness and weight of shell was significant. However, P had no response.

16. The oil percentage of coconut was significantly improved with applied N and K. The effect of P was found to be negative.

17. The fibre weight of husks was significantly increased by K fertilization while the response of N and P was not significant.

18. The N contents of the leaves was found to be 1.0, 1.1 and 1.2 per cent for N_0, N_1 and N_2 levels of applied N, while it was quadratic for applied K and was not significant for applied P.

19. There was no significant response for N, P or K to leaf phosphorus.

20. The K content in the leaf was steadily increased with incremental levels of K, but not with N or P. Moreover applied N depressed the leaf content of K. The K content in the leaf ranged between 1.0 to 1.6 per cent due to applied K.

21. The response of applied N, P or K did not influence the Ca content in the leaf.

22. The different levels of N, P and K did not influence the Mg content in the leaf.

23. The sodium content in the leaf was also not influenced with applied N, P or K.

24. A quadratic function fitted to describe the effect of NPK fertilization on leaf nutrient concentrations showed that the nitrogen supplied in the form of ammonium sulphate produced a significant positive response on foliar N and a significant negative effect on foliar K. Continued application of phosphorus in the form of single superphosphate resulted in a negative response to foliar N and foliar K. Addition of K in the form of Muriate of potash significantly increased leaf concentrations of N, K and Na but had no effect on P, Ca and Mg.

25. The correlation between yield and leaf N was not significant though a positive trend was observed. Similar results were also observed for leaf K and Mg; but Na was found to have a negative effect on yield.

26. The foliar N content in the present experiment range from 1 to 1.2 per cent for zero level to N_2 level of N viz. 680 g N per palm per year. However, the annual yield of nuts was progressively increasing with higher doses of nitrogen. But the leaf content of N was found to be much below the standard critical level of 1.8 to 2 per cent fixed by I.R.H.O.

27. Contrary to the findings on foliar N, the leaf confent of P was much higher than the critical levels fixed by I.R.H.O. (0.12 per cent) leading to infer that the present highest level of P viz. 450 g P per palm per year would be sufficient enough to maintain the healthiness and productivity of the palm.

28. The standard critical level for K is fixed at 0.8 to 1.0 per cent for tall varieties by I.R.H.O. In the present study the K content in the leaf was 1.02 per cent for zero level of K and 1.63 per cent for 900 g K per palm per year. The leaf content of K in palms receiving no potash is slightly above the critical levels suggested by I.R.H.O. (0.8 to 1.0 per cent). The correlation between leaf K and yield though found to be not significant, its direct effect was high as compared to other nutrients; suggesting the need to further increase the level of K from 900 g per palm per year.

29. The Ca content in the leaf was in the range of 0.028 and 0.180 per cent which is much below the standard critical level of 0.3 per cent, fixed by I.R.H.O. Similar was the case with leaf content of Mg and Na.

30. The correlation between yield and the foliar nutrients have been partitioned into direct and indirect effects of foliar nutrients.

The maximum direct effect was explained by foliar K (0.2692), though its correlation with yield was only 0.1389 which was not significant. This low correlation was due to the negative indirect effect of foliar K via, N,P, Ca and Mg

The direct effect of foliar Ca was 0.2517 while its correlation with yield was 0.3223 which was significant.

The direct effect of foliar Mg was 0.2505 while its correlation with yield was 0.2282.

The direct effect of foliar P was 0.2432 while its correlation with yield was 0.3468 which was significant.

The direct effect of foliar N was 0.1888 while its correlation with yield was 0.2589 which was not significant

The direct effect of foliar Na was negative and negligible and its correlation with yield was also small,

From the above it can be seen that the maximum direct effect was explained by foliar K followed by foliar Ca, Mg, P and N.

31. Soil analysis for nutrient status in the soil was done at two depths, 0 to 50 cm and 50 to 100 cm. The data revealed that continued N and K fertilization at the highest levels alone could improve the N status in the soil over years. The P, K, Ca and Mg status in the soil was not influenced by continued NPK fertilization. So also the pH, CEC and Organic carbon.

Future line of work

1. It is imperative to revise the NPK levels fixed as early in 1964 for the West Coast Tall variety of coconut to exploit the maximum potential yields. Based on the results obtained in the present study, the levels of N and K have to be suitably increased while that of P could be reduced to 225 g per palm per year.

2. Since the direct effect of Ca and Mg were found to be remarkable, their inclusion in the fertilizer schedule for coconut is suggested.

3. The standard critical levels of leaf nutrient contents as fixed by I.R.H.O. and others cannot be taken for granted as the critical levels under Kerala conditions as vide variations were noticed in the present study without detrimentally affecting the yield of nuts.

It is therefore suggested that a field experiment may be laid out afresh to include a new fertilizer schedule with still higher levels of N and K and a lower level of P than that of adopted in the present investigation and also incorporating Calcium and Magnesium levels. The treatment combinations for the proposed experiment should be much that it should also be possible to fix up critical levels of plant nutrients in the leaf, as leaf analysis is a very fruitful method for predicting the fertilizer requirements of the palm.

REFERENCE

REFERENCES

Anandan, A.P., Sankarasubramony, R. and Pandalai, K.M.	(1950)	A note on the growth of seedlings in relation to soil fertility. Indian Cocon. J. 3: 205-209.
Anon.	(1941)	Annual Report 1941. Coconut Resea Institute, Ceylon.
Anon.	(1956)	Rapport Annual 1956. Institute of Recherches pourles Nuiles at Gleagineux.
Anon.	(1957)	Improving coconut yields by NPK manuring. World Crops 9: 379-381.
Anon.	(1961)	General directions for coconut leaf analysis (Communicated by IRHO Paris). Proc. First Sessn. FAO Tech. Wlig. Pty. Cocon. Prod. Prot. and Processg. Trivandrum, India.
Anon.	(1964)	NPK manuring means more coconut. Indian Fmg. 14(5): 33.
Anon.	(1967)	Seventh Report of the Research Department 1966-67. The coconut industry board, Jamaica, W.Indies.
Anon.	(1969)	Report of the acting soil chemist. Ceylon Cocon. Q. 20: 45-66.
Anon.	(1969)	Nineth Report of the Research Department: 1968-69. The coconut industry board, Jamaica, W. Indies.
Anon.	(1969)	Potassium deficiency in the coconut palm. Gleagineux 24: 137-138.
Anon.	(1970)	Symptoms of nitrogen, iron and potassium deficiencies in the coconut palm. Fertilite 36: 64-66.

Anon. (1971) Annual Report 1969-70. Central Plantation Crops Research Institute, Kasargode.

Anon. (1972) Annual Report 1971. Central Plantation Crops Research Institute, Kasargode.

Balakrishnan Nambiar, C.K. and Pandalai, K.M. (1959) Preliminary studies on leaf composition of coconut seedlings in relation to nutrient availability in the growth medium. Proc. First Conf. Cocon Res. Workers, Trivandrum, India. p. 161-167.

Bachy, A. (1963) Foliar diagnosis, relation between cations. Oleagineux 18: 381-386.

Barrant, C.I. (1975) The effect of sodium and sodium potassium on yield of "Malayan Dwarf " coconuts growing on a potash deficient clay loam. Prof. Fourth Sessn. F.A.O. Tech. Wlig. Pty. Cocon Prod. Prot and Processing. Kingston, Jamaica.

Barrant, C.I. (1977) 17th report of the Research Dept. The Coconut Industry Board, Jamaica, W.Indies. p. 15-37.

Black, C.A.(Edt.) (1965) Methods of soil analysis Part-II Chemical and Microbiological properties. American Society of Agronomy. Inc. Publisher, Madison, Wisconsin, U.S.A.

Bray, R.H. and Kurta, L.T. (1945) Determination of total organic and available forms of phosphates in soils. Soil Sci. 59: 39-45.

Briones, G.R. (1931) A study on the salt requirements of coconut seedlings grown in pots. Phillipp. Agric. 20: 352-361.

Cecil, S.R. (1969) Nutritional aspect of the coconut palm in health and disease - M.Sc. Thesis, University of Kerala, Trivandrum.

Cecil, S.R., Pillai, N.C., Mathew, A.S. and Kamalakshy Amma. (1978) Effect of application of N, P, K, Ca and Mg on young west coast tall palms in the root wilt affected area. Proc. Phacrosyos 1: 101-113.

Charles, A.E.	(1969)	Report on preliminary observations from a coconut variety trial. Proc. Third Sessn. F.A.O. Tech. Wlig. Pty. Cocon Prod. Prot. Processg. Jagjankanta, Indonesia.
Charles, A.E.	(1968)	Report on the coconut establishment trials on New Guinea. Proc. Third Sessn. F.A.O. Tech. Wlig. Cocon. Prod. Prot. and Processing. Jagjakanta, Indonesia.
Chesnin and Yien	(1951)	Soil Sci. Soc. Ag.Proc. 15: 141.
Child, R.	(1974)	Coconuts Second Ed. Longman Group Ltd., London. p. 335.
Cochran, W.G. and Cox, G.M.	(1957)	Experimental designs Asia Pub. House.
Cooke, F.C.	(1950)	The tapering disease of coconuts. Ceylon Cocon Q. 1: 17-21.
Coomans, P.	(1977)	First experimental results on the fertilization of hybrid coconut in the Ivory Coast, Gleagineux 32: 164-166.
Copeland, E.B.	(1931)	The coconut - Macmillon and Co., Ltd., London.
Das, M.N. and Giri, N.C.	(1979)	Design and analysis of experiments. Wiley Eastern Ltd., pp. 295.
De Silva, M.A.T.	(1967)	Recommended methods of fertilizer application to coconut palm. Ceylon Cocon. Plrs. Rev. 5: 108-114
De Silva, M.A.T., Abeywardena, V., George, G.D. and Balasubramonium.	(1973)	Nutritional studies on initial flowering of coconut (var.typica) 1. Effect of Mg. deficiency and Mg. P relationship. Ceylon Cocon. Q. 24: 107-113.
Dolorne, M.	(1966)	The coconut palm in Dahomey Agronomia Trop. Paris 1-4.
Eckstein, O., Brano, A. and Turrentine, J.W.	(1937)	Potash deficiency symptoms, Ackerbau, M.B.H. Berlin.

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

Foale, M.A. (1968) Seedling growth pattern. Aust. J. Agric. Res. 19: 781-789.

Eremond, Y. (1964) The contribution of I.R.H.O. to the study of mineral nutrition of the coconut palm. Proc. Second Sessn. F.A.O. Tech. Wlig. Pty. Cocon. Prod. Prot. and Processg. Colomba, SriLanka.

Fremond, Y., Zillar, R. and Lamothe, M.N. (1966) The Coconut Palm. International Potash Institute, Borne Switzerla

Fremond, Y. and Ouvrier, M. (1971) Importance to the young coconut palm of mineral nutrition from the time of field planting on a beach sand. Gleagineux 26 (10): 609-618.

George, C.D.V. and Teik, G.L. (1932) The removal of plant nutrients in coconut cultivation. Malay Agric. J. 20: 338-364.

Grunder, C. (1960) The role of potassium in the nutrition of the oil palm. Wld. Crops 12 (ii): 435-437.

Halliday, D.W. and Sylvester, J.B. (1954) Phosphorus fertilizer to plantation crops. Ceylon Cocon. Q. 5: 141-163.

Hoagland, D.R. (1944) Lectures on the inorganic nutrition of plants. Chronice Botanica Walthen, Massachu-sett

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

Jackson, N.L. (1973) Soil Chemical Analysis - Easte Economic Edn. Prentice Hall of India, Pvt. Ltd., New Delhi. p.495.

Jacob, A. and Coyle, V. (1927) Fertilizer requirements of tropical plants and soils. Booklet printed in Germany.

Jacques, C. (1932) Manuring of coconut palms in New Caledonia. Rev. Agric. Nouvelle Caledonia Nov. Dec.

John, C.M. and Jacob, K. (1959) Fertilizer demonstration on coconut in west coast - a review. Proc. First Conf. Cocon. Res. Workers, Trivandrum, India.

Kamaladevi, C.B., Nelliat, E.V. and Pillai, N.G. (1974) Nutritional studies on high yielding coconut genotypes. J. Plant Crops 1. (suppl.): 67-69.

Kanapathy, K. (1971) Preliminary work on foliar analysis as a guide to the manuring of coconuts. Proc. Conf. Cocoa and Cocon. Kuala Lumpur, Paper No. 33.

Kushwah, B.L., Nelliat, V., Markose, V.T. and Sunny, A.F. (1973) Rooting pattern of coconut in sandy loam soil. Indian J. Agron. 18: 71-74.

Lakshmanachar, M.S. (1964) Fertilizer trials in growers' gardens show balanced manuring pays. Cocon. Bull. 17: 371-373.

Loganathan, and Balakrishnamurthy. (1979) Effects of NPK fertilizers on the yield and leaf nutrient concentrations of adult coconut on a lateritic gravelly soil in SriLanka. Ceylon Cocon. Q. 30: 81-9

Magat, S.S. (1979). Soil and leaf analysis in relation to coconut yield. Philipp. J. Cocon. Studies 1(2): 1-9.

Magat, S.S. (1979) The use of leaf analysis in the conduct of coconut field fertilizer trials in the Phillippines. Phillipp. J. Cocon. Studies 4(1): 32-39.

Manciot, R., Ollagnier, M. and Ochs, R. (1979) Mineral nutrition and fertilization of the coconut around the world. Part 1 Oleagineux 34(ii): 499-515.

Manciot, R., Ollagnier, M. and Ochs, R. (1979) Mineral nutrition and fertilization of the coconut around the world. Part II. Gleagineux 34(12): 563-580.

Manciot, R., Ollagnier, M. and Ochs, R. (1980) Mineral nutrition and fertilization of the coconut around the world. Part III Gleagineux 35 (i):13-17.

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

Margete, R.K., Magat, S.S., Alfanja, L.M. and Habane, J.A. (1979) A long term KCl fertilization study of bearing coconuts in an inland-upland area of Davao (Phillippines). Gleagineux 34(5): 235-242.

Markose, V.T. and Sunny, A.F. (1973) Rooting pattern of coconut in sandy loam soil. Indian J. Agron. 18:71-74.

Mathew, C. and Ramadasan, A. (1964) Effect of nitrogen, phosphorus and potassium nutrients on the growth of coconut seedlings. Indian Cocon. J. 17: 114-119.

Menon, K.P.V. (1956) Annual Report of Central Coconut Research Station, Kayamkulam for 1955-'56.

Menon, K.P.V. and Pandalai, K.M. (1958) The coconut palm. A monograph - Indian Central Coconut Committee, Ernakulam.

Muhammed, S.V., Venkateswaran, A.N. and Ramalingam, V. (1969) Response of coconut to fertilizer application in the sandy loam soils of Tanjavur district (Tamil Nadu). Madras agric. J. 56: 221-224.

Muliyar, M.K. and Nelliat, K.V. (1971) Response of coconut palm to NP and K application on the west coast of India. Gleagineux 26(ii): 687-691.

Muhr, G.R., Datta, N.D., Sankarasubramoney, N., Leley, V.K. and Donahue, R.L. (1963) Soil testing in India. Second Ed. United States Agency for International Development Mission to India, New Delhi. p. 118.

Murrey, D.B. and Smith, L.R.N. (1952) Estate fertilizer trials on coconut in Trinidad. Trop. Agric. Trin 21: 180-195.

Nagarajan, M. and Pillai, N.G. (1975) A note on the outstanding growth of coconut seedlings in a photoperiodic experimental nursery and its relation to soil conditions. Madras agric. J. 62(6): 384-388.

Nathanael, W.R.N. (1958) Diagnostic approaches to problems in crop nutrition. Ceylon Cocon. Q. 9 (3-4): 11-29.

Nathanael, W.R.N. (1959) The application of fertilizer to adult coconut palm in relation to theoretical concepts. Fertilite. 35: 11-27.

Nelliat, K.V. and Muliyar, M.K. (1971) Response to different levels of NPK by growing coconut palms of high yielding types. Proc. Intal. Sym. Soil Fert. Evaluation Vol. 1. p. 575-583. New Delhi.

Nelliat, K.V. (1973) NPK nutrition of coconut palm - A review. J. Plant crops I(Suppl.): 70-80.

Nethsinghe, D.A. (1961) Coconut nutrition and fertilizer requirements. Proc. First Sessn. F.A.O. Tech. Wlig. Pty. Cocon. Prod. Prot. and Processg. Trivandrum, India.

Nethsinghe, D.A. (1962) Coconut nutrition and fertilizer requirements. The soil approach. Indian Cocon. J. 15: 131-155.

Nethsinghe, D.A. (1963) Report of the Soil Chemist. Ceylon Cocon Q. 14: 8-20.

Nethsinghe, D.A. (1964) A study of root activity (in soil) of coconut palms using radio active phosphorus. Proc. Second Sessn. F.A.O. Tech. Wlig. Pty. Cocon Prod. Prot and Processg. Colombo, SriLanka.

Nethsinghe, D.A. (1966) Annual Report of Coconut Research Institute, Ceylon for 1965. Ceylon Cocon. Q. 17: 61-72.

Nethsinghe, D.A. (1967) Placement of fertilizers. Ceylon Cocon. Plrs. Rev. 5: 10.

Ollagnier, M., Ochs, R. and Martin, M. (1970) La fumure du plamier a huile dans-la-monds Fertilite 36: 64.

Ollagnier, M., and Ochs, R. (1971) Chlorine a new essential element in oil palm nutrition. Gleagineux 26(1): 1-15.

OuVrier, M. and Ochs, R. (1978) Mineral exploitation of the hybrid coconut PB 121. Gleagineux 33(8-9): 437-443.

Pandalai, K.M. and Krishna Maran. (1964) Fertilizer and cultivation investigations on the coconut in India - response trends. Proc. Symp. Fertt. Indian Soils 1962, Bull. Natn. Inst. Sci. India, 26: 307-321.

Peech et al. (1947) U.S.D.A. Cir.757. p-8. Quoted by N.L. Jackson 1973. Soil Chemical Analysis. Eastern Economic Edn. Prentice - Hall of India Pvt. Ltd., New Delhi.

Pillai, N.K. (1919) Coconut - the Wealth of Travancore. Agric. J. India 14: 608-625.

Pillai, N.G. (1959) Physiological aspects of nutrition in coconut palm, M.Sc. Thesis, University of Kerala, Trivandrum.

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

Pillai, N.G., Wahid, P.A., Kamala Devi, C.B., Ramanandan, P.L., Cecil, S.R., Kamalakshy Amma, P.G., Mathew, A.S. and Balakrishnan Nambiar, C.K. (1975) Mineral nutrition of root (wilt) affected coconut palm. Proc. Fourth Sessn. F.A.O. Tech. Wlig. Pty. Cocon. Prod. Prot and Processg. Kingston. Jamaica.

Piper, C.S. (1966) Soil and plant analysis. Asia Publishing House, Bombay.

Prevot, P. and Fremond, Y. (1961) Manuring of coconut palm in Dahomey. Fertilite 13: 3-12.

Prevot, P. and Bachy, A. (1962) Foliar diagnosis in coconuts. The effect of leaf position and vegetative growth on the content of various elements. Gleagineux. 17: 451-458.

Ramadasan, A. and Lal, S.B. (1966) Exhaust of nutrients from coconut garden - factors affecting production. Cocon. Bull. 20: 173-175.

Ramanandan, P.L. and Pillai, N.G. (1972) Nutrient changes in the soil and leaf tissue due to the addition of NPK fertilizers to the coconut palm. 3rd Internat. Symp. on sub-tropical and tropical Horticulture; Bangalore.

Ramanandan, P.L. and Pillai, N.G. (1974) Effect of continuous cultivation and manuring on the leaf nutrient composition and soil nutrient status of coconut palm. J. Plant Crops 2(2): 1-3.

Rawther, T.S.S., Radha, K. and Mathew, T. (1966) Effect of regular manuring of coconut palm. Cocon. Bull. 20: 195-198.

Romney, D.R.(1965 (1965) Fifth report of the Research Dept. Coconut Industry Board, Jamaica.

Romney, D.R. (1967) Seventh report of the Research Dept. Coconut Industry Board, Jamaica.

Salgado, M.L.M. (1946) Notes on manuring of coconut palms. Coconut Res.Sch. Leaflet No.12.

Salgado, M.L.M. (1948) Recent studies on the manuring of coconuts in Ceylon. Cocon. Res.Sch. Bull No. 6.

Salgado, M.L.M. (1951) The manuring of underplanted seedlings. Ceylon Cocon. Q. 2: 161-164

Salgado, M.L.M. (1952) Potash and its importance in coconut manuring. Ceylon Cocon. Q.3(4): 191-19

Salgado, M.L.M. (1953) Potash deficiency in coconut. Gleagineux 8: 297-298.

Salgado, M.L.M. (1955) The nutrient content of nut water in relation to available soil nutrients as a guide to manuring of the coconut palm. A new diagnostic method. VII Cong. Int. Bot. Coll. Plant Analysis and Fert. Problems p.217-238.

Salgado, M.L.M. and Abeywardena. (1964) Nutritional and physiological studies on coconut water. Part I. Further aspects of the nutrient content of nut water in relation to soil nutrients. Ceylon. Cocon. Q. 15: 95-106.

Santiago, R.M. (1978) Growth of coconut seedlings as influenced by different fertility levels in three soil types. Philipp. J. Cocon. Studies 3(4): 15-28.

Shoemaker, N.B. Mcleon, S.O. and Pratt, P.F. (1961) Buffer methods for determining lime requirement of soils with appreciable amounts of extractable aluminium. Soil Sci. Soc.Am. Proc. 25: 274-277.

Smith, R.W. (1964) (1964) Mineral nutrition of coconut in Jamaica and progress report. Proc. Second Sessn. F.A.O. Tech. Wlig. Pty. Cocon. Prod. Prot. and Processg. Colombo, SriLanka.

Smith, R.W. (1967) Seventh report of the Research Dept. from June 1966 to June 1967. p.25-65 The Coconut Industry Board, Jamaica, West Indies.

Smith, R.W. (1968) Effect of fertilizer on the early growth and yield of Malayan Dwarf coconuts in Jamaica. Proc. Third Sessn. F.A.O. Tech. Wlig. Jogjakantha, Indonesia.

Smith, R.W. (1969) Fertilizer responses by coconut on two contrasting Jamaican Soils. Exptl. Agric. Q. 5: 133-145.

Snedecor, G.W. and Cochran, W.G. (1967) Statistical methods. Oxford and IBH Publishing Cp., Calcutta, Bombay, New Delhi. pp1-585.

Soon, C.P. and Wat, L.K. (1971) Early results from a coconut trial on coastal clay of West Malaysia. Proc. Conf. Cocon and Cocoa, Kaulalumpur.

Subbiah, B.V. and Asija, G.L. (1956) Rapid procedure for the estimation of available nitrogen in Soils. Curr.Sci 25: 259-260.

Telwes, G. (1962) Coconut palm. Green Bullettin. Var Languages LLS Chaft Foreckerban

Thampan, P.K. (1975) Hand Book on coconut palm. Second Printing, 1982.

Thomas, K.M. (1968) NPK requirements of coconut in the back water regions of Kerala. Agric. Res. J. Kerala 6: 84-87.

Tisdale, S.L. and Nelson, W.L. (1975) Soil fertility and fertilizers. Mac Millan Pub. Co., Inc. New York 3rd Edn.1-694-696.

Von Uexkull, H.R. (1971) Manuring of coconut. Proc. Conf. on Cocoa and Cocon. Kualalumpur.

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

Wilshaw, R.G.H. (1941) Results of manurial experiments on coconuts. Malay. Agric. J. 29: 145, 151, 267-272.

Wright, S (1923a) The theory of Path Coefficients. Genetics, 8: 239-255.

Ziller, R., and Fremond, Y. (1961) New results on manuring coconut in the Ivory Coast. Fertilite. 13: 13-26.

Ziller, R. and Prevot, P. (1962) Foliar diagnoses: A method of studying mineral nutrition - its application to the coconut palm. Indian Cocon. J. 15: 156-159.

* Originals not seen.

APPENDICES

APPENDIX - I a

Analytical data of a representative soil profile
Year of sampling - 1964

Name of soil series	Depth in inches	pH	Gravel %	Total nitrogen %	Organic carbon %	Ex.ca. M.E/ 100 gms.	Total CaO %	Total P_2O_5 %	Total K_2O %
	0 - 9	5.4	0.00	0.064	0.255	Trace	0.021	0.020	0.095
Vellayani	9 -21	5.4	0.00	0.032	0.453	,,	0.025	0.025	0.072
	21 -60	5.6	0.00	0.032	0.183	,,	0.021	0.021	0.085

Appendix - I

Number of fronds per palm (Half yearly) - Abstract of ANOVA

Source	df	Mean square									
		June 1972	Dec. 1972	June 1973	Dec. 1973	June 1974	Dec. 1974	June 1975	Dec. 1975	June 1976	Dec. 1976
Blocks	5	0.262	0.392	0.646	0.595	0.149	1.470**	0.398	0.930	0.257	0.400
N	2	0.971	5.767**	6.856**	4.338**	1.480	3.660**	3.196**	3.330*	2.040**	5.894**
P	2	4.602**	8.028**	4.932**	4.133**	2.360**	3.100**	0.930*	5.350**	0.080	0.801
NP	4	0.654	2.032	0.833	1.608	0.273	0.680	0.700	1.050	1.447**	0.076
K	2	8.833**	21.231**	24.798**	12.213**	5.150**	5.930**	6.245**	8.290**	0.474	6.999**
NK	4	0.187	1.709	0.172	0.663	0.821	0.726	1.553**	1.200*	0.451	0.550
PK	4	0.983*	2.430	1.895*	1.012	0.540	0.440	0.946*	1.070	1.227*	0.737
NPK	2	0.652	0.926	0.929	0.498	0.170	0.061	0.269	0.020	0.054	0.171
NP^2K	2	0.045	0.754	0.308	0.462	2.060*	0.925	0.436	0.090	0.320	0.209
NPK^2 +	2	0.378	0.956	0.221	0.070	0.023	0.019	0.050	0.426	0.217	0.147
NP^2K^2 +	2	0.058	1.500	0.378	0.387	1.497	0.199	0.521	0.105	0.102	0.077
Error	22	0.319	0.863	0.492	0.522	0.465	0.354	0.267	0.384	0.318	0.243

+ Confounded effects

* 5 per cent level

** 1 per cent level

	S.E. per plot	0.399	0.657	0.496	0.510	0.482	0.420	0.365	0.438	0.399	0.348

Appendix - I (Contd.)

Number of fronds per palm (Half yearly) - Abstract of ANOVA

Source	df	Mean square					
		June 1977	Dec. 1977	June 1978	Dec. 1978	June 1979	Dec. 1979
Blocks	5	0.164	1.303*	0.467	0.889	0.175	6.379
N	2	4.960*	5.509**	4.800**	2.198*	0.484	3.283*
P	2	0.004	0.864	0.564	0.244	0.517	0.175
NP	4	1.357	0.520	0.786	0.471	0.361	0.561
K	2	1.375	7.662*	5.330**	3.764**	1.199	6.315*
NK	4	0.145	0.691	0.204	0.680	0.829	0.492
PK	4	2.072	1.549	1.003	0.555	0.333	0.579
NPK	2	0.828	0.256	0.432	0.026	0.259	0.447
NP^2K	2	0.806	0.072	0.099	0.247	0.476	0.795
NPK^2 +	2	0.082	0.409	0.473	0.318	0.425	0.021
NP^2K^2 +	2	0.067	0.339	0.288	0.137	0.141	0.145
Error	22	0.6880	0.3998	0.4274	0.3805	0.6972	0.4953
S.E. per plot		0.586	0.447	0.462	0.436	0.590	0.497

\+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - II

Length of fronds (Half yearly) - Abstract of ANOVA

Source	df	Mean square							
		June 1972	Dec. 1972	June 1973	Dec. 1973	June 1974	Dec. 1974	June 1975	Dec. 1975
Blocks	5	381.18	619.57	9094.61	2944.92	1888.00	4294.39	1517.64	912.75
N	2	398.26	2031.38	2446.45	9897.12	5903.62	9054.32*	3213.03	78.71
P	2	13203.76**	14559.91**	60.82	11014.42*	8394.55**	3280.92	2164.22	4293.54
NP	4	2105.62	4350.82*	4961.04	9861.01	4613.08	6541.67	2347.14	891.86
K	2	101319.36**	119399.57**	106028.05**	52015.89**	67741.03**	73117.33**	57076.98**	53344.82
NK	4	1179.98	5246.15*	11173.74	4531.98	2838.73	1760.75	238.99	1685.39
PK	4	6822.76*	9593.36**	22753.41*	2290.82	1374.38	5051.75	1531.51	1522.88
NPK	2	1633.94	287.66	16981.99	4096.60	1523.60	585.98	198.36	48.55
NP^2K	2	261.70	4175.95	1944.58	2358.87	641.74	2247.87	6137.63	2300.50
NPK^2 +	2	4289.49	1959.88	12431.95	515.23	1098.72	1469.23	895.11	417.75
NP^2K^2 +	2	5500.37	1429.21	1859.65	1092.93	806.59	101.69	3211.23	570.85
Error	22	2259.26	1284.62	6652.41	3115.69	1817.66	2508.33	2697.76	2205.9
S.E. per plot		33.61	25.34	57.67	39.46	30.14	35.41	36.72	33.21

\+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - II (Contd.)

Length of fronds (Half yearly) - Abstract of ANOVA

Source	df	Mean square							
		June 1976	Dec. 1976	June 1977	Dec. 1977	June 1978	Dec. 1978	June 1979	Dec. 1979
Blocks	5	1152.13	2019.25	3378.53	2873.39	2125.86	1185.21	7850.30	3074.66
N	2	1536.35	1771.58	1082.48	20922.68	583.44	383.65	817.80	685.00
P	2	1477.77	6917.24*	3752.55	18902.08	43.48	484.48	437.33	477.76
NP	4	1881.87	447.41	1724.59	2857.10	3439.83	2990.70	1905.97	621.09
K	2	42038.93**	77329.35**	53928.96**	85973.05**	88561.79**	51015.74**	63393.77**	68488.33**
NK	4	1254.06	5026.12*	3003.42	15417.11	3968.45	4411.37	4170.14	2005.18
PK	4	2734.34	5319.55*	5176.84*	16734.38	9961.20 *	2367.68	2429.73	1558.71
NPK	2	91.32	273.41	226.37	7058.38	1174.56	1039.73	4933.81	770.61
NP^2K	2	650.21	1407.55	469.13	5474.28	181.99	734.22	1518.45	2480.46
NPK^2 +	2	439.67	1031.08	1726.18	26748.98	178.48	1568.69	4119.26	115.66
NP^2K^2 +	2	720.71	1139.58	919.61	642.57	20364.56**	4202.19	513.74	2672.14
Error	22	1184.58	1459.20	1475.83	6614.65	2973.99	2139.07	2847.85	1498.93
S.E. per plot		24.33	27.01	27.16	57.50	38.56	32.70	37.73	27.37

\+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - III

Number of leaflets (Half yearly) Abstract of ANOVA

Source	df	Mean square June 1972	Dec. 1972	June 1973	Dec. 1973	June 1974	Dec. 1974	June 1975	Dec. 1975
Blocks	5	1706.59	271.84	446.92	737.16**	402.72*	600.31**	151.77	399.56
N	2	784.85	403.22	777.62	523.21*	560.97*	973.98**	258.99	125.70
P	2	374.46	548.04*	618.60	202.00	118.69	949.30**	233.81	639.36
NP	4	1550.10	376.03*	128.06 *	237.72	321.45	370.83	104.43	379.84
K	2	9656.38**	5810.14**	635.11	870.55**	1530.67**	3969.13**	1028.63**	193.32
NK	4	1496.27	232.04	490.37	175.07	91.05	84.13	58.14	430.52
PK	4	1443.57	254.33	97.38	75.24	92.81	307.79	167.69	124.65
NPK	2	2003.05	61.03	54.43	21.72	51.93	565.75*	138.89	342.76
NP^2K	2	1597.01	78.51	86.98	160.18	73.58	61.05	68.36	77.68
NPK^2 +	2	3685.50	470.51*	96.68	238.62	113.12	15.24	81.53	25.18
NP^2K^2 +	2	74.26	145.57	242.41	66.18	94.08	39.83	58.09	67.07
Error	22	1952.26	131.06	226.83	113.40	116.06	137.88	90.05	268.23
S.E. per plot		31.24	8.09	10.64	7.53	7.61	8.30	6.71	11.58

+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - III (Contd.)

Number of leaflets (Half yearly) Abstract of ANOVA

Source	df	Mean square							
		June 1976	Dec. 1976	June 1977	Dec. 1977	June 1978	Dec. 1978	June 1979	Dec. 1979
Blocks	5	198.96	145.53	63.64	308.28	243.94	101.50	45.58	43.62
N	2	153.76	54.95	99.17	217.76	9.93	16.13	22.76	6.08
P	2	43.98	114.30	67.26	223.06	48.64	92.96	55.20	10.96
NP	4	158.87	292.38	44.69	182.36	70.36	96.34	39.77	58.43
K	2	3549.35**	3706.16 **	2819.90**	2927.29**	4158.66**	2790.02**	2405.40**	2248.99 **
NK	4	61.76	143.67	101.59	179.84	71.12	311.49*	114.65	160.81
PK	4	158.43	353.01*	145.86	643.66**	109.65	233.78	233.13*	121.40
NPK	2	156.44	82.66	15.38	9.79	104.75	55.69	9.43	150.01
NP^2K	2	29.97	13.73	27.04	84.48	26.64	80.45	1.18	6.21
NPK^2 +	2	158.29	40.48	77.01	177.28	29.22	193.45	18.39	11.88
NP^2K^2 +	2	149.63	290.83	23.10	325.28	182.32	75.61	17.16	18.12
Error	22	108.56	112.74	65.47	127.31	127.14	88.91	43.92	79.42
S.E. per plot		7.36	7.50	5.72	7.97	7.97	6.66	4.68	6.30

+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - IV

Number of female flowers (Yearly) Abstract of ANOVA

Source	df	Mean square							
		Dec. 1972	Dec. 1973	Dec. 1974	Dec. 1975	Dec. 1976	Dec. 1977	Dec. 1978	Dec. 1979
Blocks	5	99.37	526.17	227.74	215.82	266.83	1101.59	1012.95	1473.25
N	2	1423.06**	1261.42*	3624.63**	12071.87**	4712.34**	13149.75**	7149.02**	22583.42**
P	2	1683.42**	2530.48**	4701.25**	8991.78**	2855.66	5386.62**	8128.12**	5023.74**
NP	4	355.65	328.57	378.30	960.22	353.83	1213.35*	665.52	1290.86*
K	2	3221.03**	5403.28**	8962.55**	23909.86**	10454.73**	22825.34**	23032.86**	41240.03**
NK	4	566.00*	425.00	1223.00*	3516.00*	1599.00*	3480.00**	2014.00**	5528.00**
PK	4	764.45*	1359.21*	1882.33**	4065.51*	2174.12*	2825.60**	2418.49**	3198.75**
NPK	2	1178.53**	222.93	764.92	1560.46	592.58	425.62	466.47	1283.18*
NP^2K	2	59.05	235.70	155.32	755.24	75.25	55.68	11.91	432.37
NPK^2+	2	47.63	173.77	92.19	432.54	284.38	276.47	79.20	1585.90*
NP^2K^2 +	2	50.48	588.91	223.11	9.28	95.09	840.81	1528.91*	1552.82*
Error	22	170.00	335.00	290.00	535.00	238.00	311.00	264.00	312.00
S.E. per plot		9.21	12.94	12.04	16.35	10.90	12.47	11.48	12.49

+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - V

Setting percentage (Yearly) Abstract of ANOVA
(After angular transformation)

Source	df	Mean square					
		Dec. 1974	Dec. 1975	Dec. 1976	Dec. 1977	Dec. 1978	Dec. 1979
Blocks	5	10.93	95.64	57.79	232.75	34.72	229.93
N	2	430.41*	369.06*	43.27	371.36*	102.63	294.55*
P	2	633.97*	202.85*	58.83	21.39	4.03	434.72*
NP	4	27.11	39.03	69.93	120.09	87.92	106.93
K	2	1588.62 *	1734.25 *	2308.17 **	720.13*	1434.79 **	2667.33 *
NK	4	124.10	89.97	39.45	46.73	31.10	35.25
PK	4	175.00	156.09*	91.89	126.17	169.77 *	144.71
NPK	2	60.08	2.76	21.01	11.02	18.99	114.61
NP^2K	2	94.36	132.68	5.70	320.88*	5.63	22.29
NPK^2 +	2	176.23	77.47	4.85	22.51	42.61	83.99
NP^2K^2+	2	44.99	49.98	19.07	14.33	60.41	42.64
Error	22	54.32	34.17	64.15	62.61	33.53	62.35
S.E. per plot		5.21	5.84	5.66	5.59	4.09	5.58

+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - VI

Yield of nuts (Yearly) Abstract of ANOVA

Source	df	Mean square 1976	1977	1978	1979	1980	1981	1982
Blocks	5	909.57	1755.67	1636.33	3682.42	2348.59	3971.65	11065.45
N	2	11746.12**	28337.89**	20889.79**	61470.21**	45014.11**	37753.41**	42458.61**
P	2	7241.19**	11710.12**	11114.37**	18720.03**	6985.59**	2703.40	4249.65**
NP	4	1175.03	1886.98	2768.66	5382.74*	3339.73**	1661.18	8160.92**
K	2	23638.73**	56482.75**	52740.56**	100429.05**	81397.63**	109799.57**	169138.40**
NK	4	3878.00**	8153.00**	5443.00**	16940.00**	11212.00**	10232.00**	16318.00**
PK	4	4217.79**	6190.14**	4295.95*	7596.06**	5204.52**	893.70	4022.92**
NPK	2	245.12	2449.99	1128.37	2319.40	1566.46	2103.37	1584.31
NP^2K	2	1292.37	329.68	574.31	1257.84	1579.81	815.53	3369.65**
NPK^2 +	2	152.33	266.28	550.78	2353.34	1082.28	6706.53*	5586.99**
NP^2K^2 +	2	805.59	1502.34	2080.66	4611.37*	2629.15	2888.06	14205.78**
Error	22	747.00	1370.00	1118.00	1042.00	637.00	1655.00	517.00
S.E. per plot		19.32	26.17	23.64	22.83	17.84	28.76	16.07

+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - VII

Cumulative yield of nuts from 1976 to 1982
(per palm)

Source	df	MSS
Blocks	5	6138.48
N	2	104284.74 **
P	2	25355.67 **
NP	4	7856.00
K	2	245868.68 **
NK	4	29793.78 **
PK	4	13687.92*
NPK	2	4387.20
NP^2K	2	2760.78
NPK^2 +	2	6695.45
NP^2K^2 +	2	547.33
Error	22	3004.92
S.E. per plot		38.76

+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - VIII

ANOVA

Source	df	Mean square			
		Weight of unhusked nut.	Weight of husked nut.	Thickness of meat	Weight of meat
Blocks	5	0.318	55080.16	0.341	30633.16
N	2	0.373 *	76359.45 *	0.206	44451.45 *
P	2	0.072	13450.49	0.026	7656.99
NP	4	0.120	14483.24	0.079	7465.24
K	2	4.455 **	861075.84 *	3.912**	473712.64**
NK	4	0.196	22820.00	0.163	11440.00
PK	4	0.304*	52544.70*	0.249*	28476.48*
NPK	2	0.184	37732.47	0.147	23626.48
NP^2K	2	0.006	1356.99	0.002	1047.99
NPK^2 +	2	0.176	37737.47	0.235*	21032.98
NP^2K^2 +	2	0.458*	73546.46*	0.412 *	38738.45*
Error	22	0.0719	15214.00	0.0761	9239.00
S.E. per plot		0.18	87.21	0.19	67.96

+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - IX

Weight of copra

ANOVA

Source	df	Mean square
Blocks	5	5246.43*
N	2	7336.84**
P	2	1434.06
NP	4	1576.49
K	2	64193.29**
NK	4	1294.00
PK	4	3381.87*
NPK	2	3431.49*
NP^2K	2	402.53
NPK^2 +	2	3588.56*
NP^2K^2 +	2	6935.49**
Error	22	1007.00
S.E. per plot		22.43

+ Confounded effects

* 5 per cent level ** 1 per cent level

Appendix - X

ANOVA

Source	df	Thickness of shell	Weight of shell	Weight of fibre	Oil percentage
Blocks	5	0.026	4007.56	24461.58	746.17*
N	2	0.050*	4310.46*	8779.99	642.47
P	2	0.005	880.59	7288.99	135.53
NP	4	0.005	1211.64	5965.25	160.72
K	2	0.343*	57445.06**	181949.76**	7637.28**
NK	4	0.017*	2084.00	17264.00*	430.00
PK	4	0.018*	3702.77*	11704.24*	744.80*
NPK	2	0.006	1674.84	12728.49	64.62
NP^2K	2	0.0004	117.18	2227.49	14.59
NPK^2 +	2	0.010	3389.96*	13449.49	429.41
NP^2K^2 +	2	0.049*	5548.99**	20153.47*	949.59*
Error	22	0.0039	819.00	4001.00	187.00
S.E. per plot		0.04	20.23	44.72	9.66

\+ Confounded effects

* 5 per cent level

** 1 per cent level

Appendix - XI

ANOVA

Source	df	Mean square					
		Foliar nitrogen	Foliar phosphorus	Foliar potash	Foliar calcium	Foliar magnesium	Foliar sodium
Blocks	5	0.0056	0.0005	0.0903	0.0169	0.0009	0.0007
N	2	0.1656*	0.0005	1.1970	0.0100	0.0006	0.0025
P	2	0.0176	0.0013	0.1939	0.0087	0.0009	0.0010
NP	4	0.0199	0.0018	0.0442	0.0192	0.0009	0.0032
K	2	0.0481*	0.0015	1.6796*	0.0217	0.0007	0.0253*
NK	4	0.0113	0.0015	0.0187	0.0138	0.0022	0.0009
PK	4	0.0068	0.0002	0.0988	0.0151	0.0003	0.0029
NPK	2	0.0786*	0.0009	0.0582	0.0211	0.0003	0.0008
NP^2K	2	0.0221	0.0008	0.0487	0.0118	0.0006	0.0018
NPK^2 +	2	0.0356	0.0005	0.1298	0.0318	0.0003	0.0000001
NP^2K^2 +	2	0.0021	0.0012	0.0533	0.0002	0.0001	0.0066
Error	22	0.01064	0.00071	0.10808	0.01605	0.00063	0.001832
S.E. per plot		0.0729	0.0188	0.2325	0.0896	0.0178	0.0303

\+ Confounded effects * 5 per cent level ** 1 per cent level

Appendix - XII
ANOVA

Source	df	Mean square							
		Soil nitrogen		Soil phosphorus		Soil potash		Soil calcium	
		0-50 cm	50-100 cm	0-50 cm	50-100 cm	0-50 cm	50-100 cm	0-50 cm	50-100 cm
Blocks	5	0.0002	0.00015	4.72	12.284	234.07	186.73	1471.85	573.73
N	2	0.0017**	0.00012	7.77	15.295	279.62	640.35*	3186.57	1440.41
P	2	0.0003	0.00008	11.85	30.758	140.74	110.69	718.51	162.97
NP	4	0.0001	0.00008	18.43	98.575	132.41	45.51	4159.49	1740.40
K	2	0.0011*	0.00032	8.08	124.854	90.74	246.29	1295.25	1.58
NK	4	0.0001	0.00044	16.10	101.534	57.40	142.88	1240.39	775.41
PK	4	0.0004	0.00006	4.56	162.811*	76.85	59.55	1052.54	696.91
NPK	2	0.0005	0.00020	16.82	16.533	7.40	111.91	423.73	436.95
NP^2K	2	0.00002	0.00096	11.53	112.138	24.07	28.35	142.13	139.45
NPK^2 +	2	0.0003	0.000004	3.59	42.098	137.03	0.03	1023.84	851.36
NP^2K^2 +	2	0.0002	0.00003	16.79	150.847	48.15	11.44	2564.58	1431.37
Error	22	0.00022	0.0001617	21.1788	41.2030	191.4141	129.003	1215.2988	633.6510
S.E. per plot		0.0105	0.0089	3.25	4.538	9.78	8.03	24.65	17.79

+ Confounded effects

* 5 per cent level

Appendix - XIII

ANOVA

Source	df	Mean square							
		Soil magnesium		Soil pH		Cation Exchange capacity		Organic carbon	
		0-50 cm	50-100 cm	0-50 cm	50-100 cm	0-50 cm	50-100 cm	0-50 cm	50-100 cm
Blocks	5	136.01	105.03	0.163	0.207	6.728	2.529	0.0089	0.0250
N	2	124.07	39.25	0.028	0.082	7.289*	4.767	0.0003	0.0046
P	2	1169.91*	482.75*	0.065	0.254	3.665*	0.937	0.0118	0.0008
NP	4	85.18	107.75	0.081	0.068	15.848*	5.509	0.0057	0.0020
K	2	231.02	278.78	0.602	0.124	19.901*	8.070	0.0213	0.0131
NK	4	825.46*	317.53	0.248	0.131	2.949	0.661	0.0057	0.0059
PK	4	800.46*	254.12	0.390	0.153	1.018	0.784	0.0048	0.0062
NPK	2	669.90*	264.06	0.334	0.054	5.851*	2.644	0.0423	0.0324
NP^2K	2	242.13	89.12	0.009	0.102	0.732	0.526	0.0226	0.0044
NPK^2 +	2	100.93	91.70	0.189	0.107	7.031	3.021	0.0006	0.0067
NP^2K^2 +	2	844.44*	247.86	0.018	0.356	5.359	0.708	0.0098	0.0165
Error	22	125.0842	128.6561	0.1927	0.12059	0.872	0.559	0.0139	0.01167
S.E. per plot		7.90	8.02	0.310	0.245	0.660	0.528	0.0834	0.0764

+ Confounded effects

* 5 per cent level

ABSTRACT

At the Coconut Research sub-Station, Balaramapuram in Trivandrum District of Kerala State on experiment was laid out in 1964 to assess the growth characters, yield attributes and yield of coconut variety West Coast Tall. The study was further enlarged to include the critical levels of leaf nutrient concentration as related to yield and the soil fertility status due to continued NPK fertilization. The treatments consisted of three levels of N, P and K (N - 0, 340 and 680 g; P - 0, 225 and 450 g and K - 0, 450 and 900 g per palm per year). The experiment was laid out in a 3^3 partially confounded factorial design with two replications.

Application of N enhanced the growth characters viz., production of fronds, production of female flowers, percentage fruit set, yield of nuts, weight of nuts, mean thickness and weight of meat, weight of copra and oil percentage. However, the effect of N was found to be quadratic at the highest level applied.

Application of P although improved the female flower production, its effect was negative towards copra weight and oil percentage. For the remaining characters studied, the initial level of 225 g per tree per year was found to be adequate.