BIOCHEMICAL CHARACTERISATION OF COCONUT PALMS IN RELATION TO YIELD

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Biochemical characterisation of coconut palms in relation to yield" 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 or other similar title, of any other University or Society.

Vellanikkara,
November, 1983.

Narayanan Kutty, M.C.

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CERTIFICATE

Certified that this thesis entitled "Biochemical characterisation of coconut palms in relation to yield" is a record of research work done independently by Mr. M.C. Narayanan Kutty 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.

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We, the undersigned members of the Advisory Committee of Mr. Narayanan Kutty, M.C. a candidate for the degree of Master of Science in Horticulture with major in Horticulture, agree that the thesis entitled "Biochemical characterisation of coconut palms in relation to yield" may be submitted by Mr. Narayanan Kutty, M.C. in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

The improvement of crops by agronomic and genetic means involves manipulation of the physiological and biochemical characters of the plant. The likelihood of success of a particular project with such an objective could be guaged only by an appreciation of the various mechanisms at cellular and molecular level. Approach in the same line is necessary to understand the causes of failure or to identify the future possibilities. Biochemical methods are increasingly used to evaluate the crop varieties, changed methods of management and to predict the performance of the plant as such.

The magnitude of resources and amount of time spent towards improving the perennial crops, agronomic or genetic, is much less remmerative when the not-so-sure results are considered. In such cases especially biochemical tools for evaluation will be of immense help. In this instance selection of proper biochemical constituents assumes much importance. The relationship for the selected parameters with various plant performance characteristics must be made known. This must be monitored thence from the seed or seedling stage to the field production stage before such tools could be standardised.

Research programmes with such broad objectives are already underway in many perennial crops. The present study is undertaken in order to characterise the yield components in coconut palm in relation to biochemical and morphological characteristics of the palms. This could be of use in identifying the components associated with better yield and for selecting potential yielders.

Review of Literature

REVIEW OF LITERATURE

As with most of the perennial plants, coconut improvement works take a lot of time and space but a certain amount of both can be saved by way of forming criteria for early selection. Monitoring the biochemical components at the juvenile stage and establishing their relationship with the field performance forms the latest line of work in such cases. Thorough information regarding the basic biochemical nature of the plant is necessary for this.

Crop yield is described as an expression of the physiological activity in the plant system, which in turn is influenced by the amount or activity of the biochemical constituents. Of late, the use of chemical diagnostic techniques are on the increase, to judge the general state of health of the plants and to assess the nutrient needs. The foliar diagnostic techniques standardised for various crops have had commendable impact on economic management of crops. Use of such techniques for improving yields has been reported in coconut also. A brief review of the available information on these aspects are presented in this chapter.

Yield and yield components

Patel (1938) had observed that variation in nut and yield characters may be due to the age of palm, the soil and environmental conditions and the inherent nature of the trees. Considerable data on the effects of season on the different characters of tall variety of palm of the west coast have been gathered as a result of detailed investigations carried out at CPCRI, Kasaragode. For an ordinary W.C.T. type highest yield as well as maximum copra are obtained during summer season. The smallest nuts with lowest yield of copra are obtained during north east monsoon. Effect of season on crop vary with varieties.

Yielding capacity of the palms is to be identified during the early stages of growth. Liyanage and Abeywardane (1958) had pointed out that the yield of second and third year of bearing had a relation to the yielding capacity of the palm at adult stage. The initial yield is thus helpful in spotting out the low yielders and replacing them in the early stages.

Among the various components of yield, Smith (1969) expressed the view that number of nuts per bunch was the most variable component, which was influenced by fertilizer treatments.

In coconut palms it was suggested that yield variations due to weather factors are more pronounced than in other tree crops (Aboywardane, 1971). It was reasoned that the long reproductive cycle of coconut cannot obviate from vagaries of climate in its external manifestations. According to him, although rainfall is the chief factor controlling these yield variations, a quantitative demonstration of this influence leading to a prediction of crops on that basis has been elusive.

Variation in morphological characters and yield

Attempts have been made to establish the degree of relationship that exist between various morphological characters and yield of palms. Patel (1938) reported that the length of stem and number of leaves on the crown, are positively correlated to yield.

The directon of leaf orientation on the crown was stated to be associated with yield of the palm by Davis (1963) who observed that the anticlockwise arrangement of the 2/5 spiral of leaves have superior yielding capacity over clockwise arrangement. But Satyabalan <u>et al.</u> (1964) ruled out such possibility and stated that the 'lefts' have no superior yielding capacity over the 'rights'.

In 1972, Satyabalan reported significant positive correlation for plant height and number of leaves with yield. Positive correlation for stem girth just below the crown, number of leaves present at a given time, the average number of flowers per bunch at the time of opening and yield have been reported by Abeywardane (1976). He also found that there was significant correlation between yield, leaf length and number of leaflets per leaf.

Foliar nutrient status in relation to yield

Ziller and Prevot (1962) suggested critical nutrient levels for coconut palms in the leaves which has attained full maturity. They observed that the nitrogen content of leaves increases from leaf number one to leaf number six and then decreases. Phosphorus and potassium content decreased with age of leaf but calcium and magnesium content increased. Synergistic relation existed between K and Na when the amount of K was below the critical level, but the inverse relationship was true when K was above the critical level. Such relationships were also suggested in between K and Ca, and K and Mg. Indirakutty and Pandalai (1968) observed significant difference between low, medium and high yielders in terms of foliar N, P and K content. They attributed this variation to the ability of the palms to absorb nutrients which in turn is affected by genetically controlled factors operating through its effects on root production or physiology. They also suggested that the critical foliar nutrient levels may vary from soil to soil when trees falling under the same yield group are grown on different soils.

Devi and Pandalai (1968) reported a progressive fall in nitrogen, potash and phosphorus as the yield from the palms decreased. They found little effect for calcium and Boron. They also worked out the following correlation coefficients and regression equations.

N	- 0.90**	Y = 625,.82 x -916.82
P_2O_5	- 0.91**	Y = 656.00 x -288.8
K_2O	- 0.89**	Y = 96.61 x -100.23
CaO	- 0.30	Y = 1100.00 x -983.36
Fe	- 0.90**	Y = 3.52 x -983.78
Mn	- 0.96**	Y = 2.56 x -257.67
Bo	- 0.07	Y = 2.17 x - 81.71

(x = ppm of nutrient in leaf, y = average yield)

The very concept of independent critical level of major nutrients in foliar diagnosis was challenged by Smith (1969) who stated that the ratio between foliar N and K is related to yield.

Thomas (1973) observed relation between yield and N/P, N/K, and Ca/Mg ratios. According to him the level of K had to be interpreted in terms of a balance between K and Ca. With regard to the individual nutrients, he could observe positive correlation with yield only in case of N and Ca. He also opined that to some extent nutrient composition of leaves could reflect the nutrient status of soil.

Significant genotypic variation in foliar nutrient concentrations were observed by Wahid et al. (1981).

Gopi (1981) found significant correlation for yield with nitrogen content of leaf in leaf positions 2, 3, 4, 8, 10, 14, 15 and 26 from the first fully opened leaf. The highest correlation for potassium with yield was obtained from the leaf at position 2. He obtained no significant correlation for leaf phosphorus with yield.

Biochemical components of yield

Identification of biochemical components responsible for crop productivity had been attempted in many crops. Factors such as activity of various enzymes, content of free amino acids, mitochondrial activity, Co_2 assimilation rates etc. have been studied. Srinivasan and Rao (1971) reported increased peroxidase enzyme activity during inflorescence formation in grapevine shoots. According to Hagman _et al._ (1967) enzymatic activities assessed can provide an estimate of the metabolic potential of a genotype, by virtue of which other criteria for early selection can be furnished. The enzymatic activities can also reflect the influence of environment and mineral nutrition on plant function. In situations where the activity of a single enzyme can be related to some particular aspect of development or to some important property of the final product, according Draper (1976), there exists a possibility of using enzyme techniques as a tool for selection of improved genetic material.

Studies relating to enzyme activities and their correlation with growth have been carried out by scientists. Vora and Vyas (1974) found that catalase activity increased concomitantly with active growth. They also put forward an inverse relationship between the activities of catalase and peroxidase and growth in oats. Peroxidase activity increased whenever there was differentiation.

Enzyme analysis as a tool to judge the mineral nutrition status is also being looked into. Barret (1982) suggested enzymatic markers for phosphorus deficiency in wheat. He found that althougn the total phosphatases activity had no consistent relation with P deficiency, the 'fraction B' of phosphatases separated by batch chromatography with cation exchange matrix CM cellulose, where the'fraction B' was absorbed by the matrix contained phosphatases which increased with P deficiency.

Eschbach (1982) based on his studies on biochemical components of yield in oil palm, arrived at the conclusions that although significant differences occur for each parameter among different groups of oil palm, there is no overall relationship between the biochemical characters and yield. He also found that the enzyme activities especially nitrate reductase and acid phosphatase are distinctly influenced by mineral nutrition to such an extent that they could be considered as diagnostic tools.

Studies made on the mitochondrial activity in oil palm have shown that there is significant correlation between such activities measured during nursery stage and field production. Such relations could make it possible to sort out most productive material at very early stage (Kouame and Noiret, 1981).

In coconut palms, investigations with regard to enzyme relations, relationships of other cell components with yield had been attempted by some workers. Heinicke (1923) and Egell and Christ (1927) have shown that catalase activity is related to growth and vigour of the palm. Sadasivan (1951) had found that the endosperm of coconuts contains peroxidase, dehydrogenases, catalase and phosphatase. Nagarajan and Pandalai (1975) studied the influence of agricultural practices on oxidising enzymes of coconut water. They suggested the possible use of selection and adoption of agricultural practices using the information on carbohydrate, fat and protein splitting enzymes in coconut water.

The apparent rate of photosynthes
estimated by Mathew and Ramadasan (1975),
its correlation with annual yield and chl

Characters	r
Rate of apparent photoshynthesis vs annual yield	+ 0.6137**
Rate of apparent photosynthesis vs chlorophyll	+ 0.2233*
Total chlorophyll vs yield	+ 0.2735**

Variation in chlorophyll content among different cvs and hybrids were reported by Mathew and Ramadasan (1973).

Two high yielding hybrids i.e., Dwarf x Tall (DxT) and Tall x Dwarf (TxD) had more chlorophyll compared to W.C.T. and others in the $\frac{N+1}{2}$ or N/2 leaf which had minimum coefficient of variation.

Ramadasan and Mathew (1977) reported variation in starch, reducing sugars and non-reducing sugars in coconut palms. They observed higher total carbohydrate content in the trunk of bearing palms compared to non-bearing palms. The bearing palms had a C:N ratio of 1.0 compared to 0.6 in non-bearing palms. Mathew (1977) described changes in carbohydrate constituents in disease affected palms. Total, reducing and non-reducing sugars were significantly higher in the foliage, while there was a depletion of these constituents from the roots.

Bai and Ramadasan (1978) described variations in starch, reducing and non-reducing sugars during commencement of flowering. The starch content reduced and non-reducing sugars went up.

Analysis of free amino acids (FAA) can throw light to the nitrogen metabolism. Pillai (1964) performed circular and two dimensional chromotography on coconut tissue extract. He identified aspartic acid, serine, glycine, glutamine, threonine, alanine, tyrosine, valine, methionine, leucine, aminobutyric acid, proline, metheonine sulphoxide, aspargine, lysine, cystine, argenine, histidine, and pipecolic acid in different tissues. The salient findings were summed up as

(1) Free amino acid content of nut water increases with maturity while that of kernel decreased.

(2) Petiole, stem, roots and leaves were found to contain lower quantities of FAA.

Balasubramaniam et al. (1974) studied the FAA pattern in bearing and non-bearing palms. They found that non-bearing palms had significantly lower FAA level than that of bearing palms. The pattern they observed were similar to that shown by nitrogen starved young palms. They found that the bearing palms had atleast 50 per cent more FAA content than the non-bearing ones. Amino acids like serine, aspartic acid, glutamic acid and alanine which are important in glycollytic cycle and kreb's cycle were very less in non-bearing palms. Tyrosine was detected only in bearing palms.

Barcelon *et al.* (1983) after studying free amino acid pattern in many palm varieties, correlated it with susceptibility of these palms to lethal yellowing disease and found that there is some correlation between presence of free arginine and the susceptibility of the palm to the disease.

Materials and Methods

MATERIALS AND METHODS

The experimental palms, cv West Coast Tall were selected from the existing plantation at the Agricultural Research Station, Mannuthy (12° 32' North latitude, 74° 20' East longitude, 22.25 m above M.S.L.). Palms were selected based on yield data for the previous five years. The group I consisted twenty palms which gave less than 40 nuts per year on an average. The twenty palms under group II gave 40-80 nuts per year on an average and the twenty palms of group III gave more than 80 nuts per year. The experimental palms are maintained according to the package of practices recommended by the Kerala Agricultural University.

I Yield data

Yield data for previous five years were collected from the register maintained in the research station. During the experimental period yield of nuts was recorded during each harvest.

II Observations on growth characters

Observations on the following as[illegible] recorded from the sixty selected palms.

1. Total number of leaves on the crown

The total count of leaves on the crown were recorded every two months, taking the first fully opened leaf as number one and counting downwards. The average leaf number on the canopy was then calculated.

2. Periodicity of leaf emergence

Observations on the rate of emergence of leaves were recorded at bimonthly intervals and the mean number of days elapsed between emergence of two successive leaves were computed.

3. Length of leaves

The total length of two oldest leaves at the base of the crown was recorded from each palm.

4. Length of petiole

The length of petiole was measured from the proximal end of the rachis to the position of the first leaflet on the rachis.

5. Number of leaflets

The total number of leaflets in the leaves selected for length measurements were counted and recorded.

6. Mean length of leaflets

The mean length of leaflets was calculated from random measurement of length of leaflets from basal, middle and distal parts of the leaves.

7. Girth at collar

The girth of the trunk at the collar region was measured and recorded.

III Chemical analysis

1. Collection of samples

From each palm, samples were collected selecting the 14th leaf from the top excluding the unopened leaf, which was suggested by Ziller and Prevot (1962) as the physiologically mature leaf of the palm. Sampling was done during two periods i.e., during March-April, just prior to the South-West monsoon and during September-October, just towards the close of monsoon.

For the analysis of mineral elements, carbohydrates and phenols, the samples were collected between 0730 h and 1030 h. Three to four leaflets from the middle portion of the leaf were collected and the mid rib was removed. The middle 10-15 cm portion was washed in distilled water and after blotting the water, it was dried in a hot air oven at 80°C, till it attained constant weight. The dried samples were powdered and stored in polythene bottles.

Samples for the estimation of chlorophyll content, catalase and peroxidase activity were collected fresh. In order to arrest the enzymic action and degradation of the biochemical components, the samples were immediately transferred to an ice bucket after covering with polythene wrappers. Before weighing out suitable sample lots in the laboratory, they were washed in distilled water.

2. Analysis of mineral nutrients

a. Total nitrogen

The total nitrogen present in leaf tissues was estimated following the microkjeldahl digestion and distillation method (Jackson, 1958). The nitrogen content estimated thus was expressed as per cent nitrogen on dry weight basis.

b. Phosphorus

Phosphorus was estimated by vanadomolybdate yellow colour method on the extract prepared by digesting powdered leaf samples in 9:2:1 nitric acid: sulphuric acid: perchloric acid mixture. The phosphorus content was expressed as per cent on dry weight basis.

c. Potassium

Potassium content of the leaf sample was determined flame photometrically as suggested by Jackson (1958) in the triacid digests, and was expressed as per cent on dry weight basis.

d. Calcium and magnesium

Content of calcium and magnesium was estimated by Versene titration method using Calcon and Erichrome Black T as indicators, on the wet digested samples mentioned earlier. The contents were expressed as per cent on dry weight basis.

3. Analysis of biochemical constituents

a. Soluble sugars

The soluble sugars present in the powdered samples were extracted in alcohol and were estimated by anthrone method (Dubois et al., 1951). These were expressed as per cent on dry weight basis.

b. Starch

The residue left after extraction of soluble fraction of carbohydrates was used for this estimation. The starch fraction was hydrolysed to soluble fractions with 52 per cent perchloric acid at $0^{o}C$ for 20 minutes twice as suggested by Mc-cready *et al.* (1950).and the content was estimated by anthrone method. The conversion factor 0.9 was used to calculate the starch content.

c. Total phenols

The total phenolic constituents were estimated in the water extracts from the powdered samples by the method, suggested by AOAC (1970) with Folins-Dennis reagent. The contents were expressed as per cent on dry weight basis.

d. Free amino acids

The free amino acid fractions in the leaf samples were extracted in aqueous alcohol and were qualitatively separated by paper chromatography with n-butanol: acetic acid: water (4:1:1). The amino acids were identified by nithydrin colour reaction.

e. Total chlorophyll

Chlorophyll in the freshly collected samples was extracted in acetone by macerating 1 g sample in a mortar with acid washed sand. A pinch of $Ca\ CO_3$ was added to avoid pheophytin formation. Chlorophyll estimation was done by recording the differential absorptivity of the filtered extract at 642 and 665 nm as suggested by Starnes and Hadley (1968). The chlorophyll fractions were estimated using the following formulae.

$$\text{Chlorophyll 'a'} = 12.72\,A_{663} - 2.58\,A_{645}$$

$$\text{Chlorophyll 'b'} = 22.87\,A_{645} - 4.67\,A_{663}$$

$$\text{Total chlorophyll} = 8.05\,A_{663} + 20.29\,A_{645}$$

The contents were expressed as mg/g on fresh weight basis.

f. Catalase activity

The catalase enzyme activity of the fresh tissues was estimated by the method suggested by AOAC (1970) on the extracts prepared by comminuting 1 g portions with 20 mg Ca CO_3 and water, and was expressed by the arbitrary units as μ moles of H_2O_2 decomposed per hour per gram of sample.

g. Peroxidase activity

Peroxidase enzyme activity was estimated in the enzyme extracts prepared by blending 1 g fresh sample made into 1-2 cm pieces, in chilled phosphate buffer pH 6.0, by its colour development reaction with Guaiacol (O-methoxyphenol) in presence of 1 per cent H_2O_2 as substrate (Addy and Goodman, 1972).

4. Soil analysis

Soil samples were collected from the basins of each palm to a depth of 50 cm from the surface using a hammer driven soil tube. The samples were collected from 4 points covering 1.5 m radius around the palm. The bulk of sample was reduced by quartering. These were then air dried, sieved to pass through 2 mm seive and stored. The soil pH was measured in the suspension with one part soil in 2.5 parts of water.

The nitrogen content was determined by kjeldahl digestion and distillation method. The available P was extracted using Bray No.1 and was estimated by the stannous reduced chloromolybdic blue colour method in HCl system. The available K was extracted in neutral normal ammonium acetate and was estimated by flame emission spectroscopy.

IV Statistical analysis of the data

The data recorded on various morphological and chemical parameters were analysed as described by Snedecor and Cochran (1967).

Simple linear correlation coefficients were worked out between yield and the characters under study.

Characters which exhibited significant correlation with yield were selected to find out their interrelationships. Yield prediction models were proposed based on the regression analysis of these characters and linear prediction equations were evolved.

The mathematical model of the linear regression equation is

$$Y = b_o + \sum_{i=1}^{n} b_i X_i$$

where b_o, b_i .... b_n are the paramete .... n) being the partial regression c Significance of the regression coefficient by using the student's 't' test. The coefficient of multiple determination (R^2) was calculated to test the adequacy of the fitted model. The direct effect of various characters were calculated by using the statistic β_i

$$\text{where} \quad \beta_i = B_i \times \frac{Sx_i}{S_y}$$

Sx_i = S.D. of X_i, $Sy.$ = S.D. of yield.

Results

RESULTS

This chapter presents the salient findings from the observations recorded during the course of the study, based on general trend and statistical analysis of the data.

3.1. Yield from the experimental palms

The yield data of experimental palms for six years inclusive of the year of investigation have been presented in Tables 1a, 1b and 1c. The classification of palms to low yielding, medium yielding and high yielding groups; was done based on this. The low yielding group of palms on an average produced 26.67 to 36.0 nuts per palm annually. In the medium yield group it ranged from 51.5 to 93.83 nuts per annum. The high yielding palms produced 77.0 to 117.2 nuts on an average, annually.

The yearwise variation in the yielding habit of the three groups has been graphically depicted in Fig.1. The low yielding group presented a narrow range of variation compared to the medium and high yield groups. From 1980-81 onwards, all the three groups showed similar trend. There was a general decrease in yield during 1980-81 period.

Table 1a. Yield of the experimental palms, Group I
(Nuts/palm/year)

Sl. No.	1977-'78	1978-'79	1979-'80	1980-'81	1981-'82	1982-'83	Mean
1	42	36	21	45	26	36	34.33
2	31	13	47	28	41	50	35.00
3	20	26	39	36	43	52	36.00
4	33	18	24	17	35	36	27.17
5	15	19	27	38	31	30	26.67
6	18	35	30	23	40	58	30.67
7	27	19	24	23	38	44	29.17
8	36	29	17	18	42	51	32.17
9	46	33	23	26	46	51	37.50
10	36	31	42	30	29	50	36.33
11	21	17	19	21	15	44	22.83
12	29	47	29	25	51	49	38.33
13	30	29	30	30	50	44	35.50
14	29	19	34	18	27	43	28.33
15	19	27	31	30	26	33	27.67
16	27	19	16	34	41	34	28.50
17	16	21	32	38	33	43	30.50
18	18	19	35	41	36	37	31.00
19	21	37	32	28	23	48	31.50
20	19	27	31	24	38	38	29.50
Mean	27.15	25.05	29.15	27.15	35.55	43.55	31.43

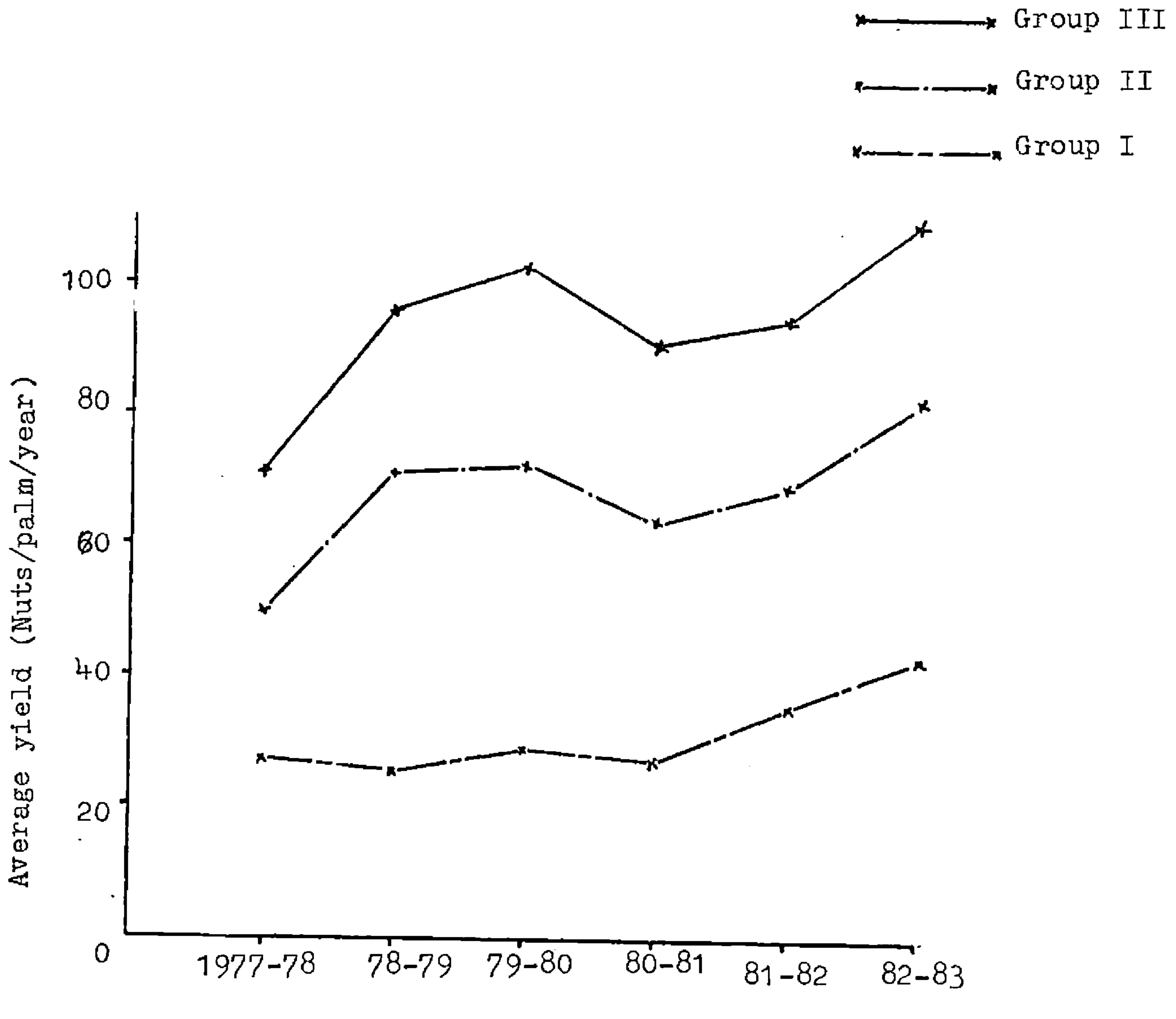
Table 1b. Yield of experimental palms, Group II
(Nuts/palm/year)

Sl. No.	1977-'78	1978-'79	1979-'80	1980-'81	1981-'82	1982-'83	Mean
1	89	73	56	21	44	65	58.00
2	70	39	28	46	65	66	52.33
3	52	39	49	61	63	79	57.17
4	50	48	52	30	72	87	56.50
5	49	89	84	44	67	89	70.33
6	35	44	85	40	78	83	60.83
7	49	58	49	62	53	94	60.83
8	41	72	109	90	53	54	69.83
9	22	62	51	32	67	75	51.50
10	49	55	79	86	78	81	71.33
11	43	88	89	44	101	74	73.17
12	51	64	98	115	67	84	79.83
13	61	143	119	72	98	70	93.83
14	63	72	101	92	60	108	82.67
15	52	84	75	80	90	83	77.83
16	41	80	73	72	102	87	75.83
17	39	104	55	81	50	111	73.33
18	39	58	74	64	51	82	62.33
19	46	90	57	81	50	93	69.50
20	69	62	67	56	69	80	67.17
Mean	50.5	71.2	72.5	63.45	68.9	82.25	68.13

Table 1c. Yield of experimental palms, Group III
(Nuts/palm/year)

Sl. No.	1977-'78	1978-'79	1979-'80	1980-'81	1981-'82	1982-'83	Mean
1	57	92	148	114	73	127	101.83
2	67	80	79	89	112	107	89.00
3	97	118	73	112	108	112	103.33
4	40	54	127	103	116	141	97.67
5	81	70	117	84	78	114	91.33
6	77	111	127	116	134	126	115.17
7	101	95	117	99	81	126	103.17
8	60	119	97	97	60	127	93.33
9	74	83	168	89	99	126	106.50
10	99	157	126	106	76	139	117.17
11	62	89	121	96	91	110	94.83
12	60	83	64	72	108	126	85.50
13	67	98	96	79	112	86	89.67
14	70	76	110	94	84	98	88.67
15	43	98	96	79	126	90	88.67
16	73	105	89	88	101	92	91.33
17	50	100	75	64	82	91	77.00
18	74	98	71	84	95	84	84.33
19	117	102	74	60	63	84	83.33
20	67	87	76	79	90	82	80.17
Mean	71.0	95.75	102.55	90.65	94.45	109.4	93.97

Fig.1 YIELD VARIATIONS IN EXPERIMENTAL PALMS YEARWISE



3.2 Morphological characters

3.2.1 Number of leaves retained by the palm

The average number of leaves retained by the palm was computed from the bimonthly observations collected year round. The data pertaining to this are presented in Tables 2a, 2b and 2c.

Low yielding palms, in general had lesser number of leaves on the crown at any given time. In the twenty palms of this group observed under the study, it ranged between 20 and 33.33. In the medium yield group this range was between 24 and 40.5, while it was 31 to 40.83 in the high yield group of palms. The general trend has been given in Fig.2.

The simple linear correlation coefficient between yield and number of leaves was worked out. It was found that number of leaves had a significant positive linear correlation with yield (r = 0.697**). The partial regression coefficient of number of leaves and yield was found to be positive and significant (Table 19). The path coefficient analysis indicated that number of leaves do not have marked direct effect on yield (Table 20).

When the inter relationships between the number of leaves and other characters were studied, it showed that this character had significant linear correlation with leaf potassium (r = 0.489**) chlorophyll (r = 0.617**) total phenols (r = -0.576**) and leaf nitrogen (r = 0.312*).

3.2.2 Leaf length

The observations on leaf length of the experimental palms are shown in Tables 2a, 2b and 2c and the general trend is represented graphically in Fig.2.

The observations indicated that there is an increase in the average length of leaf corresponding to the increase in yield. In the low yield group the leaf length ranged between 3.86 to 498 metres. It was between 4.61 and 5.98 m in medium yield group and between 4.27 and 6.38 m in high yield group.

There was a significant positive correlation between yield and leaf length and the linear correlation coefficient (r) was worked out as 0.674**. Regression analysis also indicated that the partial regression coefficient is significant (Table 19). The direct effect of leaf length as obtained from the path analysis is shown in Table 20. This shows that a 1 per cent change in leaf length will be followed by about 0.3 per cent change in yield.

The intercorrelations between various morphological and chemical characters was also studied and it was observed that the length of leaf is significantly correlated with leaf number (r = 0.621**) leaf nitrogen and potassium (r = 0.297* and 0.336**) and also with the leaf chlorophyll content and soluble carbohydrates (r = 0.460** and 0.312*). It was also recorded that a significant negative correlation exists for this character with the total phenols present in the leaf (r = -0.455**).

3.2.3 Petiole length

The petiole length recorded from the palms selected for the study is presented in Tables 2a, 2b and 2c. The general trend is shown in Fig.2.

From the data collected, it is observed that there is a considerable difference between the low yield group and the medium yield group while that between the latter and the high yield group is not so. The mean length in low yield group was 1.08 m and 1.27 m and 1.26 m respectively in medium and high yield groups.

The relation between yield and petiole length was found to be linear with the correlation coefficient

0.497**. It was also significantly correlated with the total length of leaves (r = 0.514**), and leaf number (r = 0.451**).

3.2.4 Number of leaflets

Tables 2a to 2c shows the number of leaflets recorded from the experimental palms. In the first group it ranged from 148 to 260. Group II had 208 to 264 leaflets while group III had 213 to 276 leaflets.

The simple linear correlation between number of leaflets and yield was found to be significant (r = 0.507**). It also had similar relation with leaf number, leaf length and peticle length. Among the chemical constituents chlorophyll and leaf potassium posted significant positive correlation while total phenols recorded a negative coefficient (Table 18).

3.2.5 Mean leaflet length

The data on mean leaflet length have been given in Tables 2a, 2b and 2c. In group I, it averaged to 87.16 cm while it was 93.65 cm in group II and 88.77 cm in group III.

Statistical analysis showed that there is no consistent relationship between yield and leaflet length.

3.2.6 Periodicity of leaf emergence

The number of days elapsed between the emergence of two successive leaves in each palm has been computed and given in Tables 2a, 2b and 2c. The relation of this character with yield has been shown in Fig.2. Approximately 30.4 days elapsed between two successive leaf emergence in the low yielders. It was about 28.4 days in medium yielders and 28.3 days in high yielders. Considering this as the leaf production capacity of the palms, it could be observed that the difference between low and medium yielders was considerable.

There was a significant negative correlation between the periodicity of leaf production and yield of palms. It was also observed that similar relationship exists for this character with leaf number, length, petiole length, leaf potassium and leaf chlorophyll. With total phenols and leaflet number it had a positive correlation (Table 18).

3.2.7 Girth of the trunk at collar region

The data pertaining to this have been given in Tables 2a, 2b and 2c. In the low yield group, it ranged

Table 2a. Morphological characters of the experimental palms, Group I

Sl. No.	Mean No. of leaves	Length of leaf (m)	Length of petiole (m)	No. of leaf-lets	Mean length of leaf-lets (cm)	Periodicity of leaf emergence (days)	Girth at collar (cm)
1	22.33	4.38	1.10	182	73.50	40.00	68
2	27.83	4.62	1.13	198	84.00	32.73	64
3	25.67	4.84	1.02	176	98.0	25.71	62
4	24.50	4.52	1.20	214	84.00	30.00	65
5	20.00	4.46	0.85	148	85.00	40.00	53
6	29.17	4.28	1.06	210	85.20	25.71	61
7	21.67	4.74	1.15	192	86.00	40.00	68
8	24.50	4.70	1.14	226	86.00	40.00	64
9	32.50	4.86	1.15	220	84.00	30.00	72
10	31.33	4.32	1.40	208	98.75	32.73	75
11	33.33	4.10	1.20	212	79.00	32.73	71
12	30.67	4.52	1.27	239	78.00	30.00	68
13	28.00	4.72	1.44	250	103.0	30.00	73
14	24.33	4.33	1.09	216	85.00	32.73	57
15	29.33	4.31	1.00	178	73.50	30.00	54
16	22.17	4.58	1.28	186	86.25	30.00	74
17	23.67	3.86	0.79	192	76.00	32.73	56
18	21.50	4.11	0.84	214	98.00	32.73	53
19	34.33	4.91	0.81	260	114.80	30.00	81
20	33.33	4.76	0.84	256	85.2	30.00	84
Mean	27.00	4.49	1.08	208.8	87.16	32.39	66.15

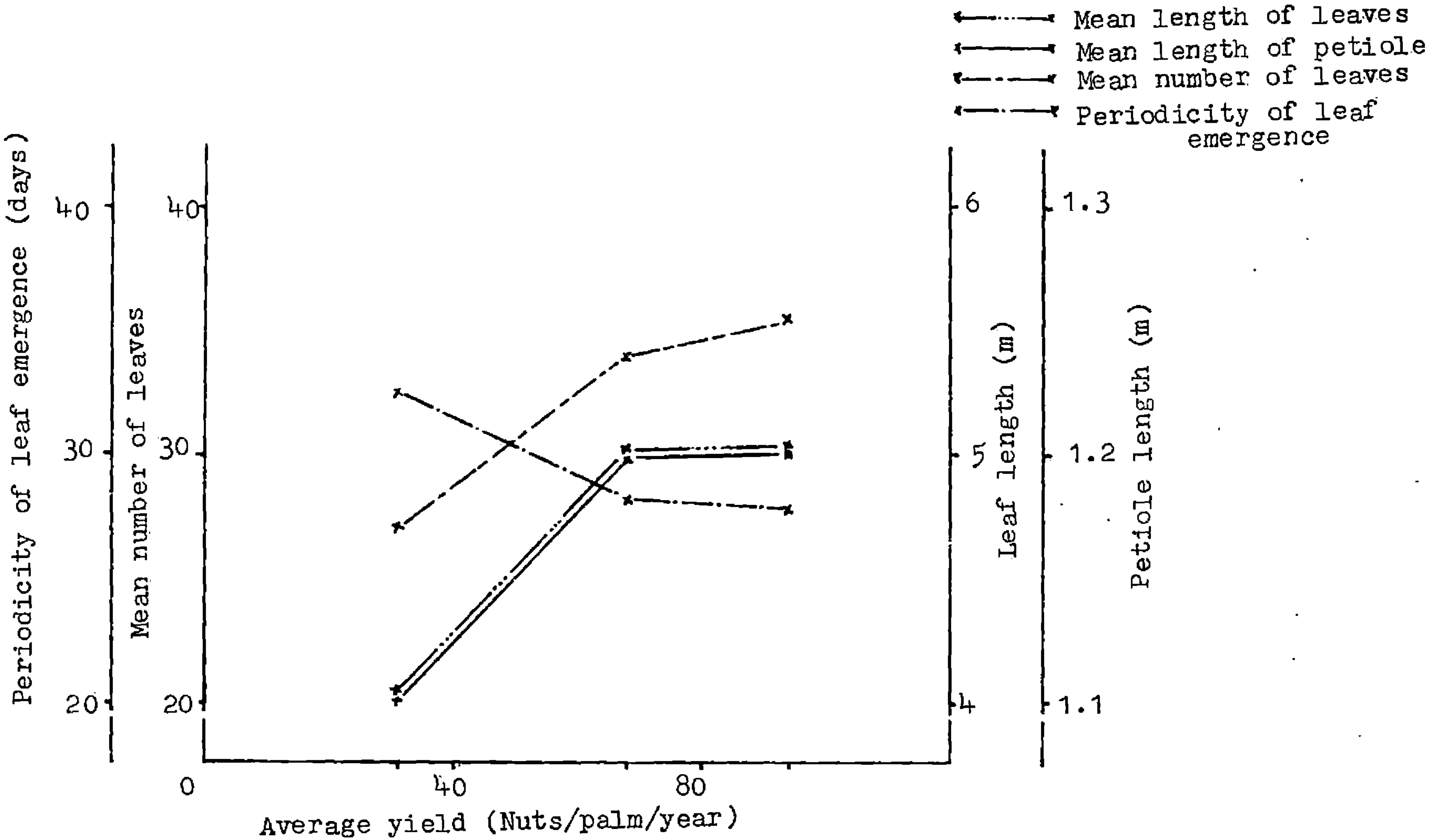
Table 2b. Morphological characters of the experimental palms, Group II

Sl. No.	Mean No. of leaves	Length of leaf (m)	Length of petiole (m)	No. of leaf-lets	Mean length of leaf-lets (cm)	Periodicity of leaf emergence (days)	Girth at collar (cm)
1	24.50	5.38	1.07	244	98.00	32.73	66
2	29.33	5.49	1.16	238	100.00	30.00	72
3	32.67	5.24	1.20	208	85.75	25.71	69
4	36.33	5.59	1.42	228	95.25	25.71	78
5	34.50	5.72	1.11	248	92.75	25.71	66
6	37.67	4.89	1.08	226	98.00	25.71	71
7	39.67	5.29	1.38	230	91.00	30.00	86
8	34.00	5.63	1.37	232	84.00	25.71	81
9	39.50	5.22	1.28	252	100.00	25.71	84
10	37.33	5.98	1.50	264	98.75	30.00	82
11	40.50	5.71	1.35	232	104.60	32.73	87
12	32.17	4.61	1.34	230	88.40	25.71	82
13	38.00	5.65	1.13	230	88.40	25.71	71
14	33.67	5.74	1.37	256	96.00	30.00	81
15	31.50	5.14	1.60	232	94.50	30.00	86
16	34.00	4.67	1.52	248	101.00	25.71	84
17	29.50	4.82	1.03	236	105.00	30.00	75
18	33.50	5.09	1.23	240	88.88	32.73	78
19	35.00	4.78	1.06	248	81.00	32.73	76
20	32.50	4.79	1.24	228	81.75	25.71	70
Mean	34.29	5.27	1.27	237.5	93.65	28.40	77.25

Table 2c. Morphological characters of the experimental palms, Group III

Sl. No.	Mean No. of leaves	Length of leaf (m)	Length of peticle (m)	No. of leaf-lets	Mean length of leaf-lets (cm)	Periodicity of leaf emergence (days)	Girth at collar (cm)
1	40.83	5.10	1.23	232	86.0	25.71	73
2	37.83	5.26	1.14	276	81.3	25.71	77
3	34.50	5.35	1.26	228	102.75	30.00	74
4	34.17	5.59	1.52	246	97.75	25.73	98
5	39.00	5.87	1.40	294	81.75	25.73	90
6	34.83	5.89	1.49	222	87.2	25.73	82
7	39.83	5.40	1.26	236	80.67	25.73	75
8	39.17	5.33	1.27	226	85.75	25.73	70
9	38.50	6.13	1.44	230	100.00	30.00	76
10	37.67	6.38	1.37	230	88.75	25.73	82
11	36.00	5.43	1.38	256	92.20	30.00	84
12	34.83	4.72	0.99	246	90.80	30.00	68
13	32.67	4.73	1.30	240	91.40	30.00	77
14	32.83	5.04	1.23	246	90.80	30.00	69
15	35.83	4.27	1.32	230	90.60	30.00	73
16	31.83	4.87	1.23	238	79.25	30.00	67
17	31.00	4.88	1.09	232	90.00	30.00	70
18	32.83	5.24	1.13	240	104.25	30.00	69
19	32.83	4.99	1.15	232	87.2	30.00	71
20	35.33	4.88	1.11	213	86.00	30.00	73
Mean	35.59	5.26	1.26	237.65	88.77	28.29	75.9

Fig.2 LEAF CHARACTERS IN DIFFERENT YIELD GROUPS



between 53 and 75 cm. In medium yield group it was between 66 and 96 cm and in high yield group it was between 67 and 93 cm. Statistical analysis indicated that the girth of palm had a significant positive correlation with yield (r = 0.508**).

3.3 Chemical constituents

3.3.1 Total nitrogen in the leaf

Foliar nitrogen content of the samples drawn from the experimental palms during March-April and September-October is presented in Table 3. The variation in foliar nitrogen content is also presented graphically in Fig.3 considering the mean values from each yield group.

The variations observed were within a range of 0.975 per cent to 1.97 per cent in the first group. In the group II it ranged between 1.435 per cent and 2.665 per cent while in group III it was between 1.35 per cent and 2.695 per cent. The general observation was that the foliar nitrogen was low during September-October period compared to that during the March-April period.

When the relation between leaf nitrogen content and yield was studied a significant positive linear correlation between these two was observed (r = 0.418**).

Table 3. Nitrogen content of leaf (per cent)

Sl. No.	Yield groups								
	1			2			3		
	Period of sampling		Mean	Period of sampling		Mean	Period of sampling		Mean
	March	September		March	September		March	September	
1	2.24	0.90	1.570	2.80	1.22	2.010	2.80	1.57	2.185
2	1.68	1.57	1.625	1.40	2.02	1.710	1.96	1.63	1.795
3	1.68	1.75	1.715	1.68	1.63	1.655	2.24	1.57	1.905
4	1.90	1.69	1.825	1.96	1.91	1.685	3.36	1.32	2.340
5	1.68	1.18	1.430	1.96	1.41	1.685	1.62	1.22	1.420
6	1.12	1.47	1.295	1.40	1.47	1.435	2.24	2.09	2.165
7	1.40	1.27	1.385	1.62	1.69	1.655	2.58	1.22	1.900
8	2.52	1.09	1.805	3.76	1.57	2.665	2.58	1.87	2.225
9	2.24	1.57	1.875	1.68	1.88	1.780	3.08	1.75	2.415
10	3.02	1.81	1.415	2.24	1.14	1.690	1.68	2.18	1.930
11	1.68	1.37	1.525	2.24	1.57	1.905	2.80	1.52	2.160
12	1.68	1.88	1.780	2.80	1.81	2.305	1.28	1.27	1.275
13	2.64	0.72	1.680	2.24	1.32	1.780	1.40	1.32	1.350
14	2.24	1.32	1.78	1.96	1.52	1.740	1.96	1.59	1.775
15	2.10	1.41	1.755	1.38	1.32	1.350	2.80	1.32	2.060
16	1.68	1.32	1.50	1.96	1.32	1.640	3.08	1.47	2.275
17	2.80	1.14	1.970	2.58	1.37	1.975	2.09	1.76	1.925
18	1.12	0.83	0.975	1.68	2.02	1.850	2.24	1.63	1.935
19	2.24	1.57	1.875	1.68	1.63	1.665	1.96	1.63	1.795
20	1.68		1.270	1.40	1.47	1.435	3.92	1.47	2.695
Mean	1.967		1.65	2.021	1.539	1.78	2.38	1.57	1.975

Foliar nitrogen content also had positive correlation with potassium content in the leaves (r = 286*). Nitrogen had a significant partial linear regression with yield (Table 19). The path coefficient analysis showed that one per cent change in foliar nitrogen level will be followed by 0.15 per cent change in yield.

3.3.2 Phosphorus content in leaf

Data presented in Table 4 relate to the phosphorus status analysed during March-April and September-October in the three yield groups. The phosphorus content was generally higher during September-October seasons. In group I, the mean values ranged from 0.133 per cent to 0.245 per cent while in group II it was between 0.153 per cent and 0.248 per cent. The third group showed phosphorus content ranging from 0.178 per cent to 0.273 per cent.

There was no significant linear correlation for the phosphorus content with yield from the palms. Except for a significant linear correlation exhibited with potassium (r = 0.325*) phosphorus did not show any relationship with other chemical and morphological characters studied.

3.3.3 Potassium content in leaf

The foliar potassium level was found to vary within 0.95 per cent to 1.55 per cent in the low yield group.

In the medium yield group the variation was within a range of 1.275 per cent to 2.025 and in high yield group it was between 1.325 per cent and 2.175 per cent (Table 5, Fig.4). The overall potassium status was low during September-October period. There was a marked difference between the low and medium yield groups in terms of potassium but between medium and high yield groups this difference was not that projected.

Monitoring the relationship between potassium content and yield, it was found that high linear correlation exists between these two (r = 0.614**). The partial regression coefficient for potassium on yield was found significant (Table 19). The direct effect of potassium on yield was found to be 0.289 (Table 20). This indicated that about 0.3 per cent change in yield can be observed with one per cent change in foliar potassium level. Leaf potassium and chlorophyll also exhibited significant correlation (r = 0.36**). There was a negative correlation between total phenols and potassium in leaves (r =-0.469**).

3.3.4 Calcium content in leaf

The calcium content in leaves recorded from the samples is given in Table 6. Mean calcium status ranged from 0.31 per cent to 0.525 per cent in Group I,

Table 4. Phosphorus content of leaf (per cent)

Sl. No.	Yield groups								
	1			2			3		
	Period of sampling		Mean	Period of sampling		Mean	Period of sampling		Mean
	March	September		March	September		March	September	
1	0.152	0.221	0.187	0.245	0.250	0.248	0.152	0.260	0.206
2	0.152	0.221	0.187	0.152	0.231	0.187	0.128	0.270	0.199
3	0.128	0.221	0.175	0.128	0.319	0.224	0.192	0.245	0.219
4	0.084	0.221	0.153	0.084	0.221	0.153	0.108	0.270	0.189
5	0.152	0.295	0.224	0.108	0.201	0.155	0.128	0.344	0.236
6	0.177	0.313	0.245	0.152	0.250	0.201	0.152	0.211	0.182
7	0.128	0.245	0.187	0.084	0.245	0.165	0.084	0.152	0.118
8	0.064	0.221	0.143	0.177	0.245	0.211	0.108	0.245	0.177
9	0.108	0.221	0.165	0.128	0.368	0.248	0.201	0.221	0.211
10	0.128	0.260	0.194	0.085	0.245	0.165	0.152	0.202	0.177
11	0.064	0.201	0.133	0.177	0.221	0.199	0.201	0.344	0.273
12	0.152	0.245	0.199	0.108	0.295	0.202	0.108	0.221	0.165
13	0.084	0.368	0.226	0.108	0.221	0.165	0.128	0.295	0.212
14	0.152	0.245	0.181	0.128	0.295	0.212	0.128	0.245	0.187
15	0.128	0.212	0.170	0.103	0.260	0.182	0.177	0.285	0.231
16	0.128	0.221	0.175	0.084	0.270	0.177	0.177	0.368	0.273
17	0.201	0.221	0.211	0.084	0.344	0.214	0.108	0.295	0.202
18	0.152	0.201	0.177	0.108	0.270	0.189	0.108	0.177	0.143
19	0.177	0.245	0.187	0.178	0.295	0.237	0.221	0.270	0.246
20	0.128	0.221	0.175	0.177	0.221	0.199	0.108	0.295	0.202
Mean	0.132	0.241	0.187	0.135	0.263	0.199	0.143	0.261	0.202

Table 5. Potassium content of leaf (per cent)

Sl. No.	Yield groups								
	1			2			3		
	Period of sampling		Mean	Period of sampling		Mean	Period of sampling		Mean
	March	September		March	September		March	September	
1	1.325	1.150	1.238	1.65	1.90	1.775	1.55	1.65	1.60
2	1.50	1.20	1.35	1.35	1.35	1.35	2.05	1.50	1.775
3	1.20	1.20	1.20	1.65	1.55	1.60	1.725	1.55	1.638
4	1.45	1.25	1.35	1.50	1.30	1.40	1.80	1.75	1.775
5	0.90	1.00	0.95	1.60	1.40	1.50	1.85	1.60	1.725
6	1.35	1.45	1.40	1.75	1.50	1.625	1.70	1.50	1.60
7	1.35	1.10	1.225	1.25	1.60	1.425	1.30	1.35	1.325
8	1.45	1.20	1.325	1.975	1.70	1.838	1.55	1.35	1.45
9	1.35	1.45	1.40	1.80	2.00	1.90	1.85	1.95	1.90
10	1.05	0.95	1.00	1.05	1.50	1.275	1.55	1.95	1.75
11	1.525	1.300	1.41	1.65	1.95	1.80	2.00	1.55	1.775
12	1.60	1.50	1.55	1.95	2.10	2.025	1.65	1.95	1.80
13	1.225	0.70	0.963	1.75	1.90	1.825	1.85	1.45	1.65
14	1.65	1.65	1.65	1.30	1.90	1.60	2.025	1.65	1.838
15	1.60	1.20	1.40	1.95	1.55	1.75	2.10	2.25	2.175
16	1.45	1.30	1.375	1.70	1.25	1.475	1.80	1.45	1.625
17	1.40	1.30	1.350	1.80	1.60	1.70	1.65	1.30	1.475
18	1.50	1.45	1.475	1.55	1.35	1.45	1.60	1.40	1.50
19	1.85	1.15	1.50	2.175	1.30	1.738	1.60	1.60	1.60
20	1.35	1.30	1.30	1.20	1.55	1.525	1.75	1.35	1.55
Mean	1.404	1.24	1.322	1.655	1.603	1.629	1.718	1.605	1.662

Fig. 3 RELATIONSHIP BETWEEN NITROGEN CONTENT OF LEAF AND YIELD

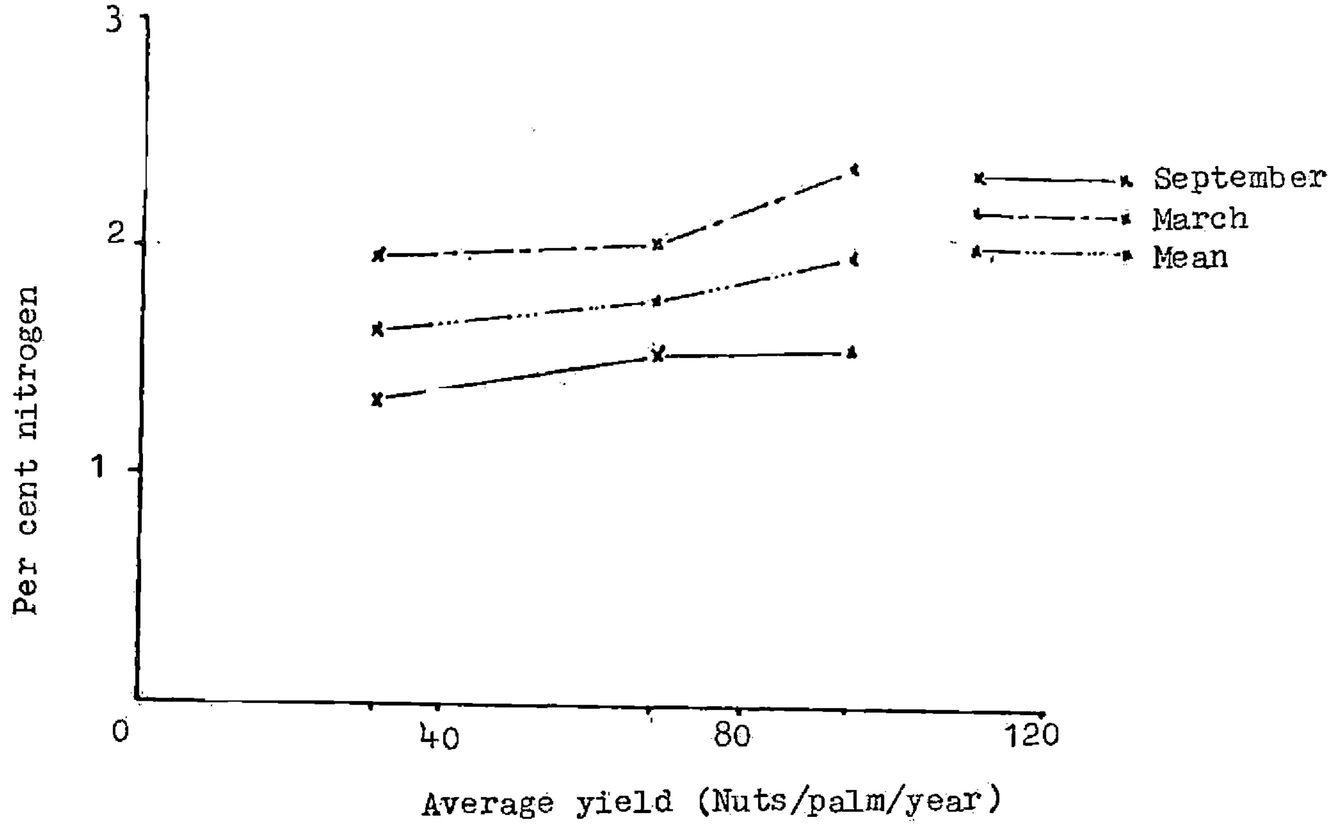
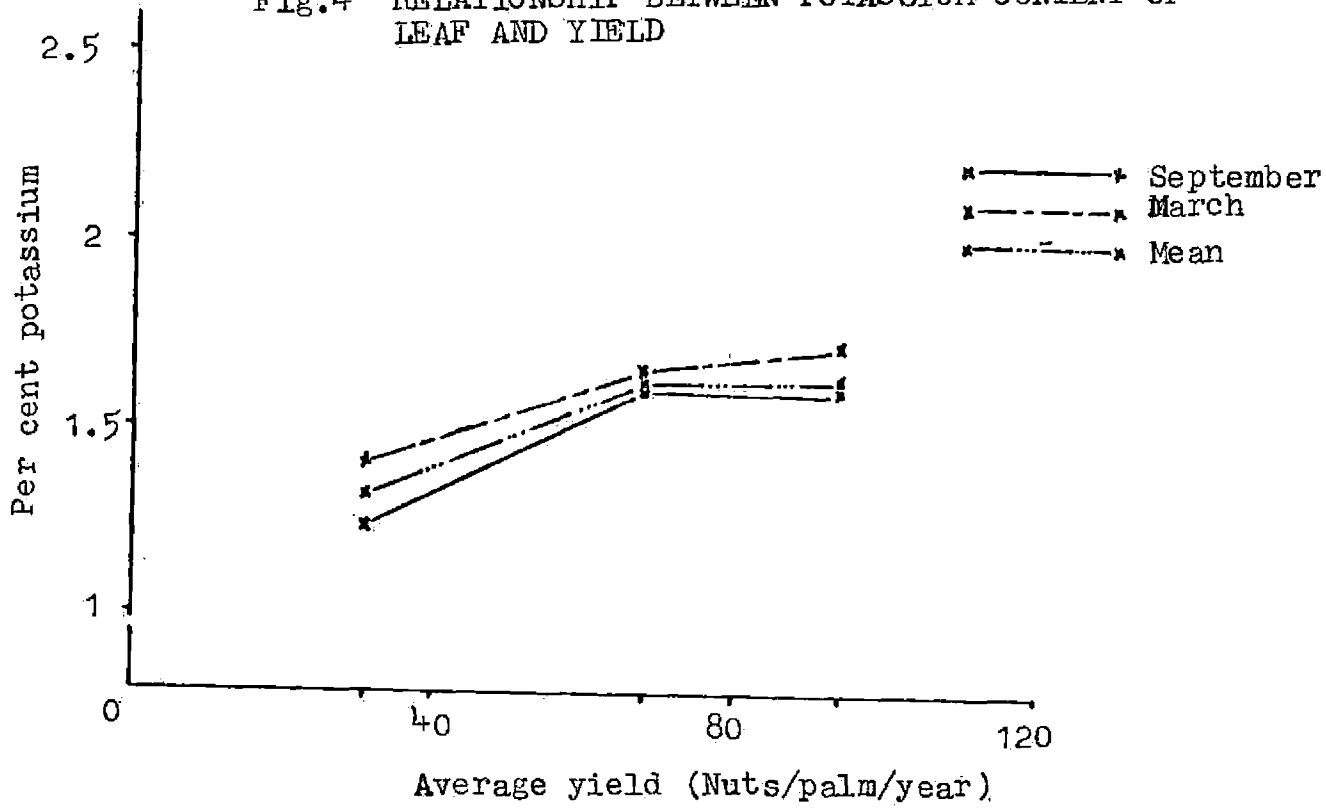


Fig. 4 RELATIONSHIP BETWEEN POTASSIUM CONTENT OF LEAF AND YIELD



0.33 per cent to 0.525 per cent in group II and 0.285 per cent to 0.52 per cent in group III.

There was no consistent trend in calcium content in relation to yield.

3.3.5 Magnesium content in leaf

Table 7 presents the variation in terms of magnesium observed in the experimental palms under three groups. A slightly higher magnesium level was observed during September-October period. Generally it ranged from 0.085 per cent to 0.325 per cent in low yield group, 0.092 per cent to 0.39 per cent in medium yield group and 0.14 per cent to 0.26 per cent in high yield group.

The negative linear correlation observed between magnesium status and yield was not significant.

3.3.6 Nutrient ratios

From the data collected on the nutrient status of the palms, various nutrient ratios were worked out and their relationships with the yield of palms were analysed (Table 8a, 8b and 8c). Among the nutrient ratios studied N/Ca, K/p, K/Ca, K/Mg and K/Ca+Mg showed significant linear correlation with yield of palms (Table 17).

Table 6. Calcium content of leaf (per cent)

Sl. No.	Yield groups								
	1			2			3		
	Period of sampling		Mean	Period of sampling		Mean	Period of sampling		Mean
	March	September		March	September		March	September	
1	0.44	0.42	0.43	0.45	0.36	0.405	0.40	0.27	0.335
2	0.38	0.39	0.385	0.40	0.38	0.39	0.49	0.39	0.44
3	0.32	0.30	0.31	0.42	0.33	0.375	0.45	0.36	0.405
4	0.321	0.48	0.401	0.36	0.42	0.39	0.42	0.39	0.405
5	0.49	0.39	0.44	0.45	0.33	0.39	0.40	0.33	0.365
6	0.32	0.36	0.34	0.85	0.30	0.525	0.28	0.33	0.305
7	0.40	0.33	0.365	0.36	0.45	0.405	0.55	0.33	0.44
8	0.34	0.33	0.335	0.40	0.31	0.355	0.36	0.30	0.33
9	0.36	0.30	0.33	0.52	0.42	0.47	0.44	0.13	0.285
10	0.60	0.52	0.56	0.56	0.36	0.46	0.36	0.27	0.315
11	0.68	0.30	0.49	0.40	0.36	0.38	0.40	0.45	0.425
12	0.28	0.42	0.35	0.36	0.30	0.33	0.32	0.33	0.31
13	0.48	0.42	0.45	0.55	0.27	0.43	0.36	0.27	0.405
14	0.55	0.48	0.515	0.32	0.27	0.295	0.48	0.39	0.435
15	0.55	0.30	0.325	0.36	0.42	0.39	0.44	0.30	0.37
16	0.36	0.34	0.35	0.36	0.36	0.36	0.40	0.51	0.455
17	0.48	0.36	0.42	0.58	0.36	0.47	0.36	0.42	0.39
18	0.44	0.36	0.40	0.28	0.42	0.35	0.56	0.48	0.52
19	0.36	0.55	0.455	0.40	0.42	0.41	0.48	0.51	0.495
20	0.32	0.38	0.35	0.55	0.48	0.515	0.27	0.48	0.375
Mean	0.424	0.387	0.406	0.447	0.366	0.407	0.411	0.362	0.387

Table 7. Magnesium content of leaf (per cent)

Sl. No.	Yield groups								
	1			2			3		
	Period of sampling		Mean	Period of sampling		Mean	Period of sampling		Mean
	March	September		March	September		March	September	
1	0.04	0.13	0.085	0.28	0.24	0.26	0.11	0.18	0.145
2	0.08	0.15	0.12	0.11	0.23	0.17	0.15	0.18	0.165
3	0.16	0.18	0.17	0.19	0.39	0.29	0.10	0.18	0.14
4	0.14	0.14	0.14	0.26	0.28	0.27	0.20	0.22	0.210
5	0.19	0.28	0.235	0.14	0.28	0.21	0.18	0.20	0.19
6	0.12	0.16	0.14	0.14	0.32	0.23	0.19	0.128	0.159
7	0.29	0.10	0.195	0.15	0.16	0.155	0.17	0.27	0.22
8	0.11	0.18	0.145	0.07	0.27	0.17	0.14	0.24	0.19
9	0.20	0.23	0.215	0.27	0.18	0.225	0.13	0.136	0.133
10	0.16	0.09	0 125	0.16	0.36	0.26	0.13	0.312	0.221
11	0.16	0.184	0.172	0.08	0.156	0.118	0.19	0.104	0.147
12	0.28	0.20	0.24	0.18	0.18	0.18	0.15	0.13	0.14
13	0.28	0.28	0.28	0.11	0.28	0.195	0.17	0.144	0.157
14	0.28	0.14	0.21	0.13	0.112	0.121	0.13	0.112	0.141
15	0.14	0.27	0.205	0.08	0.12	0.10	0.12	0.256	0.188
16	0.18	0.18	0.18	0.18	0.21	0.195	0.24	0.28	0.26
17	0.17	0.27	0.22	0.24	0.54	0.39	0.17	0.21	0.19
18	0.06	0.12	0.09	0.08	0.104	0.092	0.20	0.24	0.22
19	0.31	0.33	0.325	0.10	0.18	0.14	0.18	0.23	0.205
20	0.18	0.09	0.135	0.14	0.28	0.21	0.11	0.18	0.15
Mean	0.177	0.186	0.182	0.155	0.244	0.200	0.159	0.197	0.178

Table 8a. Nutrient ratios in leaf, Group I

Sl. No.	N/P	N/K	N/Ca	N/Mg	K/P	K/Ca	K/Mg	K/Ca+Mg	Ca/Mg
1	8.42	1.27	3.65	18.47	6.64	2.88	14.56	2.40	5.38
2	8.71	1.20	4.22	13.54	7.24	3.51	11.25	2.67	3.21
3	9.83	1.43	5.53	10.09	6.88	3.87	7.06	2.50	1.82
4	11.97	1.35	4.56	13.04	8.85	3.37	9.64	2.49	2.88
5	6.34	1.51	3.25	6.09	4.25	2.16	4.04	1.41	1.87
6	5.29	0.93	3.81	9.25	5.71	3.18	10.00	2.92	2.43
7	7.16	1.09	3.66	8.90	6.57	3.36	6.28	2.19	1.87
8	12.67	1.36	5.39	12.45	9.30	3.96	9.14	2.76	2.31
9	11.40	1.34	5.68	8.72	8.51	4.24	6.51	2.57	1.54
10	12.45	2.15	4.31	19.32	5.16	1.79	8.00	1.46	4.48
11	11.51	1.08	3.11	8.87	0.64	2.88	8.20	2.13	2.85
12	8.97	1.15	5.09	7.42	7.81	4.43	6.46	2.63	1.46
13	7.43	1.75	3.73	6.00	4.26	2.14	3.44	1.32	1.61
14	9.83	1.08	3.46	8.48	9.12	3.20	5.89	2.78	2.45
15	10.34	1.25	5.40	8.56	8.25	4.31	6.83	2.64	1.59
16	8.60	1.09	4.29	8.33	7.88	3.93	7.64	2.59	1.94
17	9.34	1.46	4.69	8.96	6.40	3.21	6.14	2.11	1.91
18	5.52	0.66	2.44	10.83	8.36	3.69	16.39	3.01	4.44
19	10.05	1.25	4.12	5.77	8.04	3.30	4.62	1.92	1.40
20	10.28	0.06	9.41	9.41	7.59	.79	9.82	2.73	2.59

Table 8b. Nutrient ratios in leaf, Group II

Sl. No.	N/P	N/K	N/Ca	N/Mg	K/P	K/Ca	K/Mg	K/Ca+Mg	Ca/Mg
1	8.12	1.13	4.96	7.73	7.17	4.38	6.83	2.67	1.56
2	8.17	1.27	4.39	10.06	7.24	3.46	7.94	2.41	2.29
3	7.41	1.03	4.41	5.71	7.16	4.27	5.12	2.42	1.29
4	11.05	1.20	4.32	6.24	9.18	3.59	5.19	2.12	1.44
5	10.91	1.12	4.32	8.02	9.71	3.85	7.14	2.50	1.86
6	7.14	0.88	2.73	6.24	8.09	3.10	7.07	2.15	2.28
7	10.06	1.16	4.09	10.68	8.66	3.52	9.19	2.55	2.61
8	12.63	1.45	7.51	15.68	8.71	5.18	10.81	3.50	2.09
9	7.18	0.94	3.79	7.91	7.66	4.04	8.44	2.73	2.09
10	10.24	1.33	3.67	6.50	7.73	2.77	4.90	1.77	1.77
11	9.57	1.06	5.01	16.14	9.05	4.74	15.25	3.61	3.22
12	10.09	1.14	6.99	12.81	10.05	6.14	11.25	3.97	1.83
13	10.82	0.98	4.14	9.13	11.09	4.24	9.36	2.92	2.21
14	8.23	1.09	5.89	14.38	7.57	5.42	13.22	3.85	2.44
15	7.44	0.71	3.46	13.50	9.64	4.49	17.50	3.57	3.90
16	9.27	1.11	4.56	8.41	8.33	4.10	7.56	2.66	1.85
17	9.23	1.16	4.12	5.06	7.94	3.54	4.36	1.95	1.24
18	9.79	1.28	5.29	20.10	7.67	4.14	15.76	3.28	3.80
19	7.04	0.95	4.04	11.82	7.35	4.24	12.41	3.16	2.93
20	7.21	0.94	2.50	6.83	7.65	2.65	7.26	1.94	2.74

Table 8c. Nutrient ratios in leaf, Group III

Sl. No.	N/P	N/K	N/Ca	N/Mg	K/P	K/Ca	K/Mg	K/Ca+Mg	Ca/Mg
1	10.61	1.37	6.52	10.07	7.77	4.77	11.03	3.33	2.31
2	9.02	1.01	4.08	10.88	8.92	4.03	10.76	2.93	2.67
3	8.72	1.16	4.70	13.61	7.49	4.04	11.69	3.00	2.89
4	12.38	1.32	5.78	11.14	9.39	4.38	8.45	2.88	1.93
5	6.02	0.82	3.89	7.47	7.31	4.73	9.08	3.48	1.92
6	11.93	1.35	7.09	13.62	8.82	5.25	10.06	3.45	1.92
7	16.10	1.43	4.32	8.64	11.23	3.01	6.02	2.01	2.00
8	12.61	1.53	6.74	11.71	8.22	4.39	7.63	2.79	1.74
9	11.45	1.27	8.47	18.16	9.01	6.67	19.29	4.55	2.14
10	10.90	1.10	6.13	8.73	9.89	5.56	7.92	3.27	1.43
11	7.93	1.22	5.08	14.69	6.51	4.18	12.08	3.10	2.89
12	7.75	0.71	4.11	9.11	10.94	5.81	12.86	4.00	2.21
13	6.38	0.82	3.33	8.60	7.80	4.07	10.51	2.94	2.58
14	9.41	0.97	4.08	12.59	9.85	4.22	13.03	3.19	3.09
15	8.92	0.95	5.57	10.96	9.42	5.88	11.57	3.90	1.97
16	8.35	1.40	5.00	8.75	5.96	3.57	6.25	2.27	1.75
17	9.55	1.31	4.94	10.13	7.32	3.78	7.76	2.54	2.05
18	10.05	1.29	3.72	8.80	7.79	2.89	6.82	2.03	2.36
19	9.31	1.12	3.63	8.76	6.52	3.23	7.81	2.29	2.42
20	13.88	1.74	7.19	17.97	7.69	4.13	10.33	2.95	2.50

3.3.7 Soluble sugars in leaf

Table 9 gives the amount of soluble sugars in the samples and Fig.5 shows the general trend between yield groups over the two periods. In the low yielding palms, soluble carbohydrates were found varying between 0.581 per cent and 1.297 per cent in the medium yield group it was from 0.758 to 1.646 per cent and in the high yield group it was from 0.781 per cent to 1.355 per cent. The difference observed between the two periods was not that projected in the high yield group compared to the other two groups.

From the statistical analysis it was concluded that there is a significant correlation between yield of palms and content of soluble sugars in leaves ($r = 0.362^{**}$). With regard to the inter correlations studied, this constituent was found to have significant relationship with total chlorophyll content in leaves also ($r = 0.345^{**}$).

Soluble sugars had a significant linear regression on yield (Table 19). The direct effect of this constituent on yield was not marked (Table 20).

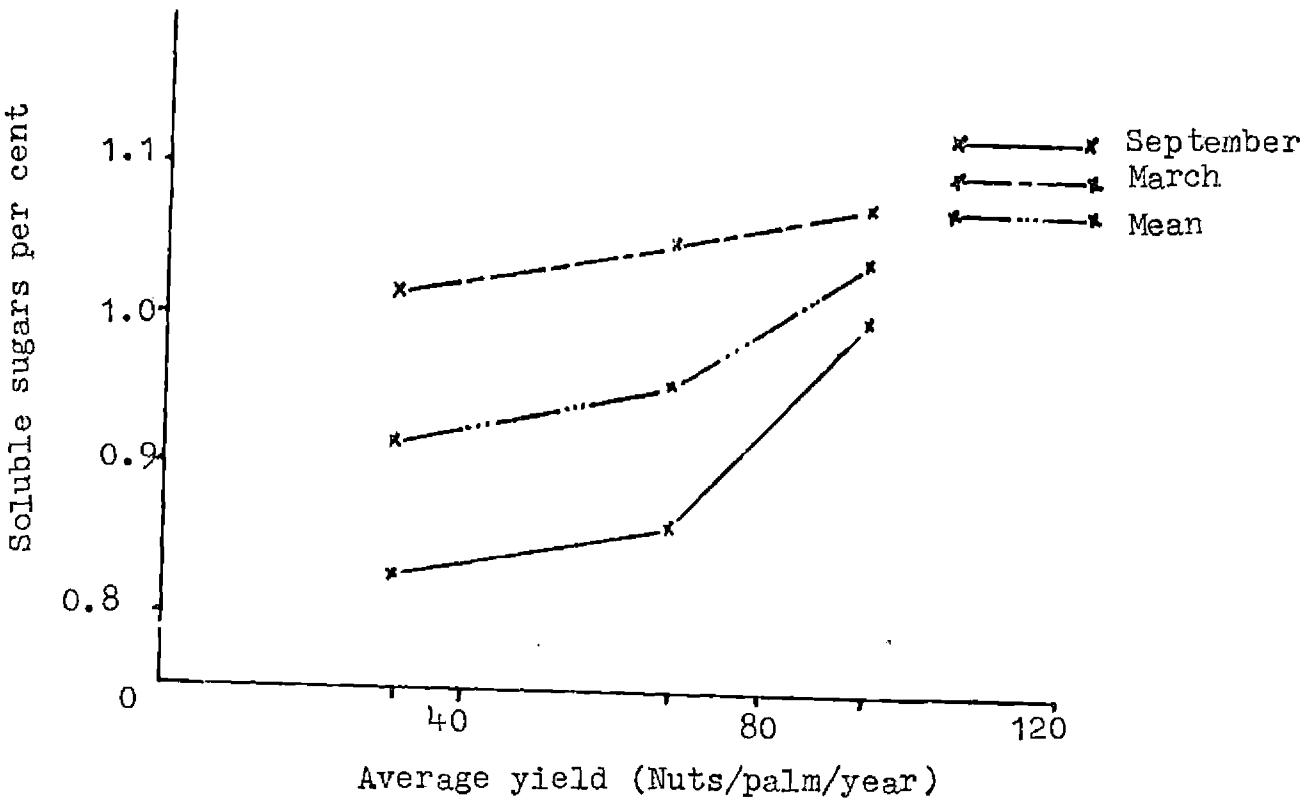
3.3.8 Starch content in leaf

The data pertaining to this are given in Table 10.

Table 9. Soluble sugars in leaf (per cent)

Sl. No.	Yield groups								
	1			2			3		
	Period of sampling		Mean	Period of sampling		Mean	Period of sampling		Mean
	March	September		March	September		March	September	
1	0.878	0.878	0.878	1.445	1.049	1.247	1.088	0.955	1.022
2	0.580	0.581	0.581	1.164	0.703	0.934	0.951	1.038	0.995
3	0.903	0.903	0.903	0.895	0.838	0.867	1.194	1.398	1.296
4	0.986	0.985	0.985	0.726	0.667	0.697	1.281	0.811	1.046
5	0.986	0.985	0.986	0.689	0.884	0.787	1.646	0.768	1.207
6	0.878	0.878	0.878	0.880	1.281	1.081	1.329	0.955	1.142
7	0.957	0.957	0.957	1.130	1.646	1.388	0.878	0.929	0.904
8	0.986	0.783	0.885	1.007	1.381	1.194	1.017	1.130	1.074
9	0.783	0.783	0.783	1.233	0.666	0.950	0.829	1.008	0.919
10	0.623	0.957	0.795	0.811	0.942	0.877	1.681	1.066	1.374
11	1.098	0.722	0.910	1.066	0.704	0.885	1.357	1.353	1.355
12	0.955	0.878	0.917	1.129	0.630	0.880	0.840	0.747	0.794
13	1.445	0.836	1.141	1.098	0.704	0.901	0.981	0.833	0.907
14	1.098	0.666	0.882	1.312	0.320	0.916	0.930	0.632	0.781
15	0.929	0.806	0.868	0.747	0.550	0.649	1.235	1.729	1.483
16	1.663	0.806	1.235	0.811	0.704	0.758	0.806	0.768	0.787
17	0.726	0.852	0.789	0.726	0.630	0.678	1.017	1.130	1.074
18	1.663	0.930	1.297	1.233	1.017	1.120	0.830	0.856	0.843
19	1.098	0.743	0.921	1.129	0.566	0.843	0.830	1.130	0.980
20	1.008	0.492	0.750	1.800	1.049	1.425	0.743	0.833	0.813
Mean	1.013	0.821	0.917	1.050	0.859	0.955	1.073	1.003	1.038

Fig.5 RELATIONSHIP BETWEEN SOLUBLE SUGARS AND YIELD



The mean starch content over the two periods varied from 0.719 per cent to 1.953 per cent in group I 0.665 to 1.441 per cent in group II and 0.719 to 1.285 per cent in group III.

The relationship of this constituent with yield was not found significant in the linear fashion.

3.3.9 Total phenols in leaf

The values for total phenols in leaves estimated as tannins have been given in Table 11. While it ranged 1.78 to 3.75 per cent in low yielders, in the medium yield group it was lesser to a considerable extent putting a range of 0.478 per cent to 2.596 per cent and there was no much change for this in the high yield group where the range was between 1.261 to 2.556 per cent. It is also seen that during September-October period the amount is slightly more compared to March-April period (Fig.6). The total phenols showed a significant negative correlation with yield of palms (r = -0.553**). Its relation with leaf potassium and chlorophyll was also significant (r = -0.469** and -0.485**). The partial regression coefficient for the effect of total phenols on yield was also found to be significant (Table 19). The direct effect of this constituent on yield was found to be very low (Table 20).

Table 10. Starch content in leaf (per cent)

Sl. No.	Yield group 1: Period of sampling – March	Yield group 1: Period of sampling – September	Yield group 1: Mean	Yield group 2: Period of sampling – March	Yield group 2: Period of sampling – September	Yield group 2: Mean	Yield group 3: Period of sampling – March	Yield group 3: Period of sampling – September	Yield group 3: Mean
1	1.485	0.709	1.097	1.260	0.826	1.043	0.756	1.333	1.045
2	0.756	0.958	0.857	1.161	0.466	0.813	1.041	1.369	1.205
3	1.101	0.802	0.957	0.801	1.228	1.015	1.269	0.601	0.934
4	1.041	0.781	0.911	0.825	1.012	0.919	0.825	1.228	1.027
5	0.825	0.709	0.803	0.984	0.826	0.905	1.296	1.261	1.279
6	0.687	0.877	0.782	0.984	1.297	1.141	1.011	1.333	1.172
7	0.957	0.904	0.930	1.368	1.514	1.441	0.984	0.877	0.930
8	1.445	0.757	1.101	1.227	0.826	1.026	0.642	0.958	0.780
9	1.161	0.781	0.971	0.957	1.228	1.091	0.801	1.261	1.031
10	1.131	1.228	1.180	0.621	0.877	0.749	0.801	1.042	0.922
11	1.041	1.369	1.205	0.957	1.012	0.985	0.732	1.261	0.997
12	0.984	0.958	0.971	0.903	0.985	0.944	1.161	0.958	1.060
13	1.227	2.105	1.666	0.708	0.757	0.732	0.792	0.541	0.666
14	0.951	0.622	0.786	0.642	0.802	0.722	1.011	0.426	0.719
15	0.876	0.562	0.719	0.687	0.643	0.665	1.101	0.580	0.840
16	1.071	0.580	0.825	0.708	1.228	0.968	0.621	0.357	0.489
17	0.852	0.601	0.726	0.732	0.960	0.846	0.780	0.643	0.711
18	1.485	0.622	1.053	0.732	0.688	0.710	1.161	1.408	1.285
19	0.093	3.003	1.953	0.792	0.904	0.848	0.930	1.162	1.046
20	0.663	2.390	1.527	0.903	0.733	0.818	0.642	0.853	0.747
Mean	0.992	1.066	1.029	0.898	0.941	0.920	0.918	0.973	0.946

Table 11. Total phenolic compounds in leaf (per cent)

Sl. No.	Yield groups								
	Period of sampling		Mean	Period of sampling		Mean	Period of sampling		Mean
	March	September		March	September		March	September	
1	2.771	2.272	2.522	2.628	1.[illegible]48	2.238	2.113	1.948	2.031
2	3.292	3.387	3.340	2.055	3.015	2.535	1.948	1.550	1.749
3	3.828	2.590	3.209	2.554	2.055	2.305	1.598	2.431	2.015
4	2.055	1.501	1.781	1.504	1.948	1.726	1.550	1.789	1.670
5	3.381	3.292	3.[illegible]0	1.948	1.773	1.861	1.789	1.508	1.649
6	2.554	2.761	2.658	0.722	0.234	0.478	1.789	2.919	2.354
7	3.196	4.109	3.653	1.508	1.646	1.577	1.694	1.694	1.694
8	3.016	3.196	3.106	1.693	0.913	1.030	1.508	1.789	1.649
9	3.387	3.387	3.387	1.598	3.015	2.307	1.173	2.347	1.760
10	2.628	3.387	3.008	1.598	1.550	1.574	2.171	2.835	2.503
11	2.421	2.049	2.235	1.550	1.693	1.622	1.217	3.896	2.556
12	3.600	3.387	3.494	1.948	1.264	1.606	3.197	1.789	2.493
13	1.460	2.760	2.110	2.293	1.842	2.068	2.628	1.217	1.922
14	2.293	2.760	2.527	1.842	1.508	1.675	1.460	1.444	1.452
15	2.628	4.871	3.750	2.421	2.293	2.357	1.099	2.197	1.648
16	2.357	3.790	3.074	2.421	2.771	2.596	2.421	1.460	1.941
17	2.771	3.896	3.334	1.694	2.229	1.961	2.357	2.055	2.206
18	2.490	1.709	2.100	2.230	2.293	2.262	0.924	1.598	1.261
19	1.948	2.771	2.360	2.229	2.230	2.230	1.508	2.431	1.970
20	2.113	2.357	2.235	2.230	2.590	2.410	2.055	1.948	2.002
Mean	2.692	3.008	2.85	1.915	1.937	1.923	1.81	2.042	1.926

3.3.10 Free amino acids (FAA)

The FAA present in the crude leaf extracts were separated chromatographically and were identified by ninhydrin colour reaction. Quantification with the chromatogram was not attempted but it was concluded that the FAA are present only in traces. There was no marked difference between yield groups in the type of amino acids located but for the difference with regard to alanine and tyrosine as indicated in the Table 12.

3.3.11 Chlorophyll content in leaf

In Table 13a, 13b and 13c chlorophyll content of the fresh samples extracted in acetone is presented. It ranged from 1.658 mg/g to 2.645 mg/g in group I. In group II it was from 2.1 mg/g to 3.438 mg/g and in group III it ranged from 2.284 mg/g to 3.831 mg/g. Generally a higher chlorophyll content was recorded during March-April period. The variation between yield groups observed during March-April period was more conspicuous than that observed during September-October (Fig.7).

The relation between yield and chlorophyll content was marked with a fairly high degree of linear correlation ($r = 0.637^{**}$). It also had a significant positive correlation with leaf potassium ($r = 0.36^{**}$). Significant partial

Table 12. Free aminoacids in leaf

Sl. No.	Aminoacid	Group I	Group II	Group III
1	DL-Alanine	+	-	-
2	DL-2-amino-n-butyric acid	-	-	-
3	L-Arginine mono chloride	-	-	-
4	DL-Aspartic acid	+	+	+
5	L-Cysteine hydrochloride	-	-	-
6	L-Cystine	+	+	+
7	DL-3,4 dihydroxy phenyl alanine	+	+	+
8	L-glutamic acid	+	+	+
9	Glycine	+	+	+
10	L-Histidine monochloride	-	-	-
11	L-Hydroxyproline	+	+	+
12	L-Leucine	-	-	-
13	DL-iso-leucine	+	+	+
14	DL-nor-leucine	-	-	-
15	L-Lysine monohydrochloride	+	+	+
16	DL-Methionine	-	-	-
17	L-Ornithene monohydrochloride	-	-	-
18	DL-B-Phenyl alanine	-	-	-
19	L-Proline	-	-	-
20	DL-serine	+	+	+
21	DL-Threonine	-	-	-
22	DL-Tryptophan	-	-	-
23	L-Tyrosine	-	+	+
24	DL-Valine	-	-	-

+ = Present

- = Absent

Table 13a. Chlorophyll content mg/g, Group I

Sl. No.	March sampling			September sampling			Mean
	Chlorophyll a	Chlorophyll b	Total	Chlorophyll a	Chlorophyll b	Total	
1	0.850	0.950	1.80	.85	0.97	1.82	1.81
2	1.33	1.58	2.91	.01	0.91	1.92	2.42
3	1.29	1.53	2.82	.29	1.18	2.47	2.65
4	1.37	1.51	2.88	.71	0.82	1.53	2.21
5	0.71	0.69	1.40	.73	0.80	1.53	1.85
6	1.11	1.24	2.35	.23	1.07	2.30	1.97
7	0.78	0.78	1.56	.13	1.24	2.37	1.97
8	0.96	1.14	2.10	.16	1.01	2.17	2.14
9	1.33	1.64	2.97	.08	1.12	2.20	2.59
10	1.14	1.28	2.42	.31	1.04	2.35	2.38
11	1.29	1.52	2.80	.23	1.07	2.30	.55
12	1.24	1.34	2.58	1.07	0.93	1.99	.31
13	0.66	0.75	1.41	1.05	0.86	1.91	.65
14	1.31	1.42	1.73	1.50	1.27	2.83	.27
15	0.82	0.88	1.70	0.80	0.90	1.70	.70
16	1.23	1.38	2.61	1.30	1.13	2.43	.52
17	1.06	1.20	2.26	1.42	1.20	1.62	.94
18	1.72	1.99	3.71	1.23	1.07	2.30	.00
19	0.83	1.03	1.86	1.37	1.24	2.61	2.24
20	0.77	0.90	1.67	1.22	1.11	2.34	2.00
Mean	1.09	1.238	2.297	1.134	1.047	2.134	2.206

Table 13b. Chlorophyll content mg/g, Group II

Sl. No.	March sampling			September sampling			Mean
	Chlorophyll a	Chlorophyll b	Total	Chlrophyll a	Chlorophyll b	Total	
1	0.82	0.92	1.74	1.16	1.30	2.46	2.10
2	1.23	1.45	2.68	1.48	1.57	3.04	2.862
3	1.37	1.50	2.89	1.34	1.11	2.46	2.673
4	1.35	1.45	2.80	1.19	1.04	2.23	2.517
5	1.44	1.78	3.20	1.23	1.15	2.40	2.80
6	1.71	2.12	3.83	1.73	1.32	3.05	3.438
7	1.29	1.53	2.82	1.78	1.46	3.21	3.028
8	1.47	1.90	3.37	0.99	0.84	1.81	2.603
9	1.32	1.67	2.99	1.65	1.17	2.82	2.905
10	1.24	1.67	2.91	1.65	1.45	3.10	3.005
11	1.43	1.84	3.27	1.51	1.24	2.75	3.010
12	1.41	1.64	3.05	1.42	1.17	2.60	2.824
13	1.26	1.49	2.75	1.67	1.30	2.98	2.863
14	1.23	1.45	2.68	1.18	1.50	2.68	2.68
15	0.84	0.68	1.52	1.38	1.19	2.57	2.045
16	1.21	1.37	2.88	1.90	1.18	3.09	2.834
17	1.72	2.01	3.73	1.50	1.34	2.84	3.287
18	1.49	1.76	3.25	1.59	1.58	3.17	3.212
19	1.29	1.53	2.82	1.42	1.20	2.62	2.721
20	1.55	2.05	3.60	1.37	1.22	2.59	3.096
Mean	1.334	1.591	2.925	1.458	1.267	2.725	2.825

Table 13c. Chlorophyll content mg/g. Group III

Sl. No.	March sampling			September sampling			Mean
	Chlorophyll a	Chlorophyll b	Total	Chlorophyll a	Chlorophyll b	Total	
1	1.51	1.60	3.11	1.59	1.47	3.06	3.086
2	1.44	1.76	3.20	1.26	1.15	2.40	2.80
3	1.26	1.48	2.74	1.51	1.24	2.75	2.745
4	1.45	1.70	3.15	1.30	1.08	2.39	2.769
5	1.41	1.59	3.00	1.30	1.13	2.43	2.715
6	1.77	2.11	3.88	1.66	1.34	3.01	3.444
7	1.85	2.53	4.38	1.59	1.47	3.06	3.821
8	1.85	2.53	4.38	1.69	1.58	3.28	3.831
9	1.45	1.71	3.16	1.12	0.95	2.07	2.617
10	1.63	2.27	3.90	1.45	1.31	2.76	3.331
11	1.48	1.83	3.31	1.17	0.93	2.10	2.704
12	1.19	1.52	2.71	1.37	1.50	2.87	2.79
13	1.55	2.05	3.60	1.64	2.03	[illegible]	0.037
14	1.37	1.59	2.96	1.37	1.22	2.09	2.776
15	1.23	1.44	2.67	1.45	1.26	2.71	2.69
16	1.23	1.38	2.61	1.41	1.27	2.68	2.648
17	1.23	1.38	2.61	1.37	1.16	2.50	2.554
18	1.03	1.13	2.16	1.22	1.11	2.34	2.248
19	1.50	2.00	3.50	1.69	1.28	2.97	3.235
20	1.20	1.41	2.61	1.07	0.97	2.03	2.321
Mean	1.432	1.751	3.183	1.402	1.218	2.62	2.902

Fig.6 RELATIONSHIP BETWEEN TOTAL PHENOLS AND YIELD

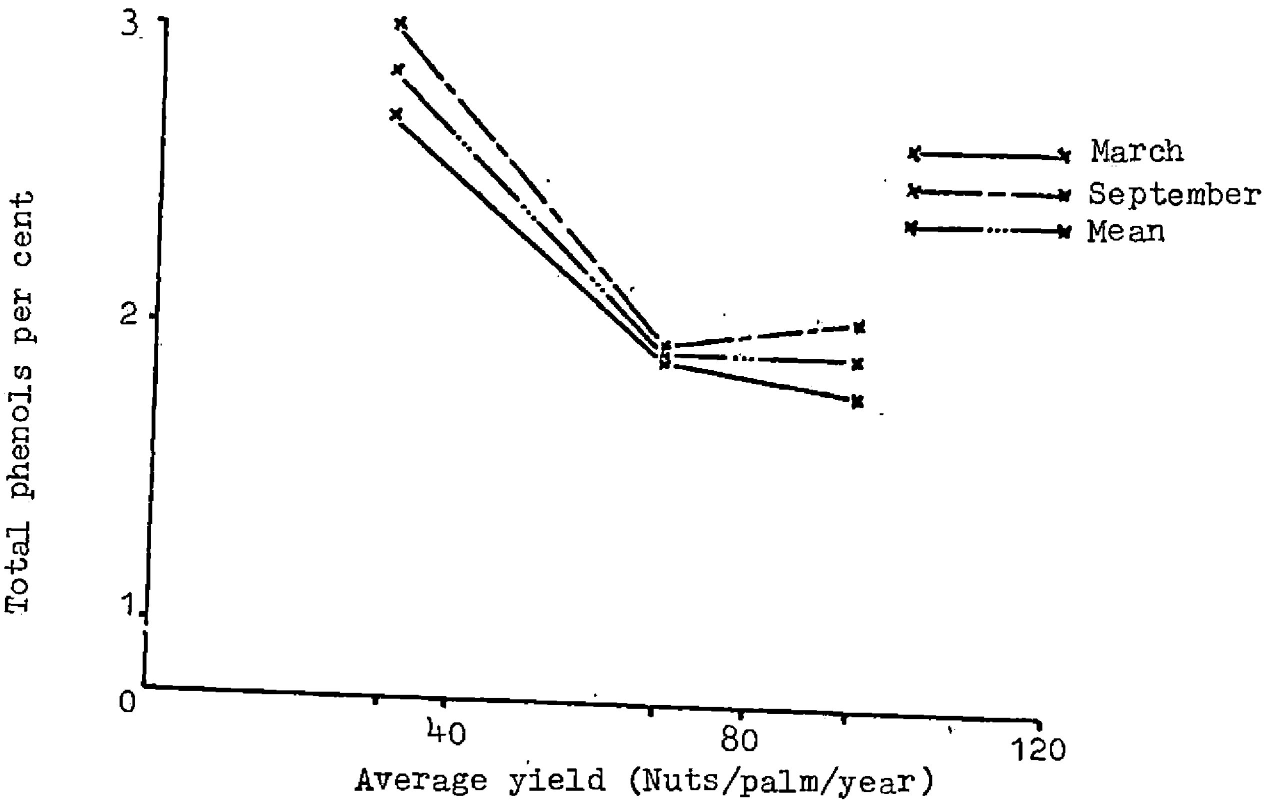
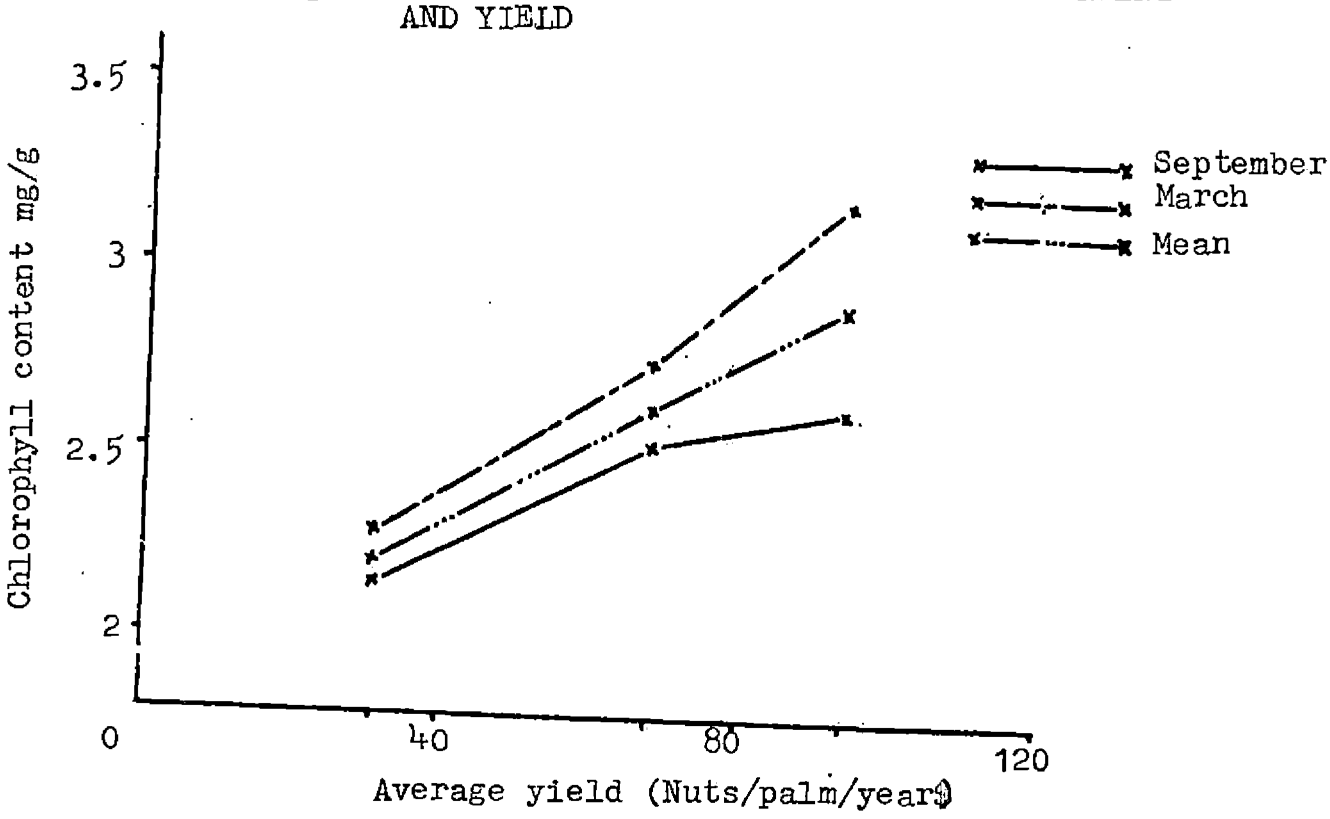


Fig.7 RELATIONSHIP BETWEEN CHLOROPHYLL CONTENT AND YIELD



linear regression was recorded for this constituent on yield (Table 19). The path coefficient analysis indicated that about 0.25 per cent change in yield is possible with one per cent change in chlorophyll content in the leaf.

3.3.12 Catalase activity

Leaf catalase activity in terms of micro moles of H_2O_2 consumed per hour in fresh samples collected from the palms under investigation is presented in Table 14.

It was found that the variation in the activity did not exhibit any consistent trend, and the statistical analysis showed no significant effect for this towards yield of palms. But it was observed that catalase activity has significant correlation with leaf potassium ($r = 0.359^{**}$), phenols ($r = -0.336^{**}$) and starch ($r = 0.406^{**}$).

3.3.13 Peroxidase activity

Leaf peroxidase activity in terms of change in optical density (OD) at 20 second intervals are given in Tables 15a, 15b and 15c.

The average change in OD in the low yield group was between 0.0601 to 0.2508 while it was 0.0713 to 0.2029 in the medium yield group and between 0.0763 to 0.2131

Table 14. Catalase activity in leaves (μ mol H_2O_2 consumed per h)

Sl. No.	Group I	Group II	Group III
1	372.58	345.97	505.65
2	399.19	479.03	496.77
3	345.97	487.90	496.77
4	328.23	390.32	425.81
5	186.29	416.94	239.52
6	452.42	487.90	487.90
7	310.49	496.77	487.90
8	434.68	434.68	248.39
9	159.68	461.29	487.90
10	115.32	266.13	328.23
11	470.16	452.42	168.55
12	452.42	487.90	425.81
13	106.45	470.16	443.55
14	354.84	345.97	363.71
15	156.68	319.35	487.90
16	156.68	443.55	141.94
17	345.97	275.00	159.68
18	434.68	496.77	487.90
19	541.13	283.87	195.16
20	470.16	159.68	399.19

Table 15a. Peroxidase activity in leaf, Group I

Sl. No.	O D at 20 seconds interval							Average change in OD/20 seconds
	40	60	80	100	120	140	160	
1	0.2757	0.4202	0.5686	0.6990	0.8239	0.9586	1.0969	0.1369
2	0.3979	0.6198	0.8539	1.0458	1.2219	1.3979	1.5229	0.1875
3	0.2676	0.4089	0.5528	0.6990	0.8239	0.4586	1.0458	0.1297
4	0.2924	0.4949	0.6990	0.8861	1.0969	1.3010	1.3979	0.1843
5	0.2292	0.3566	0.4815	0.6198	0.7447	0.8539	1.0000	0.1285
6	0.3372	0.5229	0.7213	0.9208	1.0969	1.3010	1.3979	0.1768
7	0.3010	0.4685	0.6383	0.7959	0.9586	1.0969	1.3010	0.1667
8	0.2757	0.4089	0.5376	0.6576	0.7696	0.8860	1.0000	0.1207
9	0.2441	0.3566	0.4559	0.5528	0.6383	0.7213	0.7958	0.0920
10	0.5086	0.7447	0.9586	1.1549	1.3979	1.5229	-	0.1690
11	0.3279	0.4819	0.6198	0.7447	0.8606	1.0000	1.1549	0.1378
12	0.2441	0.3665	0.4815	0.6021	0.6990	0.7959	0.9208	0.1128
13	0.2441	0.3665	0.4815	0.6021	0.6990	0.7959	0.9208	0.1128
14	0.1079	0.1675	0.2366	0.2924	0.3566	0.4089	0.4685	0.0601
15	0.2757	0.4202	0.5086	0.6383	0.7213	0.8239	0.9208	0.1075
16	0.2757	0.4202	0.5086	0.6383	0.7213	0.8239	0.9208	0.1075
17	0.1079	0.1675	0.2366	0.2924	0.3566	0.4089	0.4685	0.0601
18	0.1938	0.3279	0.5086	0.6990	0.9208	1.2219	1.6990	0.2509
19	0.4815	0.6778	0.8539	1.0458	1.3979	1.6990	-	0.2029
20	0.3566	0.5376	0.6778	0.7958	0.9208	1.0458	1.1549	0.1331

Table 15b. Peroxidase activity in leaf, Group II

Sl. No.	40	60	80	100	120	140	160	Average change in OD/20 seconds
	O D at 20 seconds interval							
1	0.1249	0.2007	0.2757	0.3463	0.4202	0.4815	0.5528	0.0713
2	0.3372	0.4949	0.6576	0.7959	0.9208	1.0458	1.1549	0.1363
3	0.2840	0.4202	0.5528	0.6778	0.7959	0.8861	1.0000	0.1193
4	0.2840	0.4202	0.5528	0.6778	0.7959	0.9208	1.0000	0.1193
5	0.2840	0.3979	0.5229	0.6198	0.7213	0.8239	0.9208	0.1061
6	0.4815	0.7696	1.0000	1.2219	1.5223	1.6990	-	0.2029
7	0.2441	0.3468	0.4437	0.5376	0.6198	0.6990	0.7696	0.0876
8	0.3279	0.4815	0.6021	0.7447	0.8539	1.0000	1.0969	0.1282
9	0.5528	0.8239	1.0969	1.3979	1.5229	-	-	0.1617
10	0.2757	0.3979	0.4949	0.6021	0.7447	0.7696	0.8539	0.0964
11	0.3010	0.4318	0.5528	0.6778	0.7696	0.8861	1.0000	0.1165
12	0.3872	0.5528	0.7213	0.8539	1.0000	1.1549	1.3979	0.1688
13	0.2292	0.3098	6.3980	0.4815	0.5528	0.6198	0.6990	0.0783
14	0.6021	0.8861	1.1549	1.3979	1.6990	-	-	0.1828
15	0.3979	0.6021	6.7959	1.0000	1.2219	1.3979	-	0.1667
16	0.2841	0.4202	0.5376	0.7447	0.7959	0.9208	1.0000	0.1193
17	0.3979	0.5850	0.7696	0.9586	1.1549	1.3010	1.3979	0.1667
18	0.3010	0.4437	0.5850	0.7447	0.8539	1.0000	1.1544	0.1423
19	0.3979	0.6021	0.7959	1.0000	1.2219	1.3979	-	0.1667
20	0.3010	0.4437	0.5850	0.7447	0.8539	1.0000	1.1549	0.1423

Table 15a. Peroxidase activity in leaf, Group III

Sl. No.	OD at 20 seconds interval							Average change in OD/20 seconds
	40	60	80	100	120	140	160	
1	0.3566	0.5080	0.6778	0.3239	0.9586	1.0969	1.2219	0.1442
2	0.3768	0.5376	0.6576	0.8239	0.9586	1.0458	1.2219	0.1409
3	0.4315	0.6778	0.8861	1.0458	1.3010	1.5229	-	0.1736
4	0.3872	0.6021	0.7959	0.9586	1.1549	1.3979	1.5229	0.1893
5	0.3010	0.4318	0.5376	0.6579	0.7447	0.8539	0.9586	0.1096
6	0.5229	0.7213	0.9208	1.0969	1.3010	1.5229	1.6990	0.1960
7	0.5086	0.7213	0.8861	1.0458	1.2219	1.3979	1.69970	0.1984
8	0.5850	0.8539	1.0969	1.3979	1.6990	-	-	0.1857
9	0.4202	0.6198	0.8239	1.0000	1.1549	1.3979	1.6990	0.2131
10	0.4089	0.5850	0.7447	0.8861	1.0458	1.1549	1.3977	0.1648
11	0.3098	0.4559	0.6021	0.7447	0.9539	0.9586	1.0969	0.1312
12	0.2219	0.3279	0.4318	0.5376	0.6383	0.7447	0.8239	0.1003
13	0.2219	0.3372	0.4437	0.5528	0.6576	0.7447	0.8539	0.1053
14	0.2840	0.4202	0.5376	0.7447	0.7959	0.9208	1.000	0.1193
15	0.2076	0.3098	0.3979	0.4949	0.5686	0.6383	0.7213	0.0856
16	0.3979	0.5850	0.7696	0.9586	1.1549	1.3010	1.3979	0.1667
17	0.1805	0.2596	0.3372	0.4202	0.4949	0.5686	0.6383	0.0763
18	0.3010	0.4318	0.5686	0.6990	0.8239	0.9208	1.0458	0.1241
19	0.3979	0.6021	0.7959	1.0000	1.2219	1.3979	-	0.1667
20	0.2076	0.3098	0.3979	0.4949	0.5686	0.6383	0.7213	0.0856

in the high yield group. Peroxidase activity also did not show any consistent relation with yield or other characters under the study.

3.4 Soil analysis

The soil of the plantation site is well drained laterite with pH ranging from 4.8 to 5.6.

Table 16 gives the data on soil nitrogen, phosphorus and potassium status. The soil nitrogen content varied from 0.028 per cent to 0.252 per cent when the basins of low yielding palms was considered. In the medium yield group it was between 0.084 to 0.616 per cent and in the high yield group it was between 0.112 and 0.448 per cent. The available phosphorus (Bray No.1) ranged between 14-33 ppm in both low and medium yield groups and 18-44 ppm in the high yield group. The available potassium content ranged from 0.016 to 0.032 per cent, 0.01 to 0.036 per cent and 0.01 to 0.04 per cent in low, medium and high yield groups respectively. The nutrient status of soil and plant were compared and it was found that soil and plant nitrogen had a significant positive correlation (r = 0.273*). Soil and plant potassium also had significant correlation (r = 0.39**). There was no linear relationship between soil and plant phosphorus.

Table 16. Content of nitrogen, phosphorus and potassium in soil

Sl. No.	Yield groups								
	1			2			3		
	Total N (%)	Available P (ppm)	Available K (%)	Total N(%)	Available P (ppm)	Available K (%)	Total N(%)	Available P(ppm)	Available K(%)
1	0.14	18	0.017	0.308	28	0.023	0.364	22	0.027
2	0.22	14	0.022	0.196	26	0.011	0.448	18	0.027
3	0.14	16	0.017	0.224	18	0.019	0.336	31	0.026
4	0.056	22	0.021	0.360	24	0.032	0.112	31	0.036
5	0.028	20	0.017	0.140	31	0.036	0.168	18	0.030
6	0.028	16	0.021	0.056	21	0.029	0.364	32	0.028
7	0.168	18	0.022	0.360	27	0.028	0.140	31	0.030
8	0.140	18	0.021	0.364	28	0.028	0.168	32	0.028
9	0.140	20	0.021	0.616	26	0.026	0.36	44	0.027
10	0.168	24	0.016	0.448	26	0.027	0.36	26	0.028
11	0.168	16	0.017	0.364	28	0.026	0.364	28	0.027
12	0.168	14	0.016	0.112	14	0.027	0.364	31	0.025
13	0.252	26	0.032	0.084	20	0.027	0.221	18	0.018
14	0.112	33	0.025	0.168	22	0.036	0.364	44	0.040
15	0.252	26	0.019	0.168	33	0.029	0.392	30	0.023
16	0.112	22	0.032	0.168	23	0.022	0.312	30	0.023
17	0.056	33	0.009	0.196	26	0.022	0.112	22	0.019
18	0.056	30	0.010	0.140	27	0.017	0.224	30	0.026
19	0.252	33	0.032	0.168	40	0.027	0.14	26	0.01
20	0.252	30	0.032	0.14	26	0.010	0.196	28	0.028
Mean	0.145	22.55	0.022	0.239	24.75	0.022	0.279	29.3	0.027

Table 17. Coefficients of correlation (simple linear) between yield (y) morphological and biochemical characteristics.

Character	r	Character	r
		Soluble sugars	0.364**
		Starch	0.120^{NS}
Number of leaves	0.693**	Catalase activity	0.176^{NS}
Length of leaves	0.675**	Peroxidase activity	0.048^{NS}
Length of petiole	0.497**		
Number of leaflets	0.431**	Nutrient ratios	
Length of leaflets	0.094^{NS}		
Periodicity of leaf emergence	0.499**	N/P	0.188^{NS}
		N/K	-0.113^{NS}
Girth of the trunk at collar	0.508**	N/Ca	0.239*
		N/Mg	0.203^{NS}
Leaf nitrogen	0.417**	K/P	0.360**
Phosphorus	0.192^{NS}	K/Ca	0.545**
Potassium	0.614**	K/Mg	0.268*
Calcium	-0.017^{NS}	K/Ca+Mg	0.510**
Magnesium	-0.042^{NS}	Ca/Mg	-0.132^{NS}
Chlorophyll	0.631**		
Total phenols	-0.553**		

* Significant at 5% level

** Significant at 1% level

NS=Not significant

Table 18. Coefficients of intercorrelation between selected characters

Character	Total chlorophyll in leaf	Total phenols in leaf	Soluble sugars in leaf	Total nitrogen in leaf	No. of leaves	Length of leaf	Length of petiole	No. of leaflets	Periodicity of leaf production	Girth at collar
Potassium	0.360**	-0.469**	0.189^{NS}	0.285*	0.489**	0.336**	0.244*	0.384**	-0.398**	0.373**
Total chlorophyll in leaf		-0.485**	0.347**	0.154^{NS}	0.616**	0.460**	0.290*	0.379**	-0.522**	0.382**
Total phenols in leaf			-0.249^{NS}	-0.224^{NS}	-0.576**	-0.455**	-0.313*	-0.539**	0.446**	-0.453**
Soluble sugars in leaf				0.172^{NS}	0.237^{NS}	0.312*	0.234^{NS}	0.091^{NS}	-0.156^{NS}	0.166^{NS}
Total nitrogen in leaf					0.312*	0.294*	0.304*	0.087^{NS}	-0.206^{NS}	0.277*
Number of leaves						0.619**	0.451**	0.441**	-0.631**	0.663**
Length of leaf							0.514**	0.416**	-0.430**	0.608**
Length of petiole								0.303*	-0.338**	0.643**
Number of leaflets									-0.271*	0.565**
Periodicity of leaf production										-0.395**

* Significant at 5% level ** Significant at 1% level NS = Not significant

Table 19. Partial regression coefficients for yield on selected characters.

Sl.No.	Character	Regression coefficient B_i	Standard error SE B_i	t
1	Potassium content in leaf	33.298	1.237	26.909**
2	Total chlorophyll content in leaf	14.399	0.699	20.596**
3	Total phenol content in leaf	- 1.468	0.495	-2.964**
4	Soluble sugar content in leaf	6.432	1.043	6.168**
5	Nitrogen content in leaf	11.798	0.794	14.857**
6	Leaf number	0.634	0.236	2.691**
7	Leaf length	15.220	10.610	24.258**

$R^2 = 0.736$

** Significant at one per cent level

Table 20. Direct and indirect effects of selected characters on yield

Characters	Potassium	Chlorophyll	Total phenols	Soluble sugars	Nitrogen	Leaf number	Leaf length	Total (r)
Potassium	0.289	0.0918	0.0166	0.0117	0.0421	0.0608	0.102	0.614
Chlorophyll	0.104	0.254	0.0172	0.0215	0.0228	0.0764	0.14	0.637
Total phenols	-0.155	-0.123	-0.0355	-0.0154	-0.0331	-0.0715	-0.138	-0.553
Soluble sugars	0.0547	0.0884	0.0088	0.0521	0.0254	0.094	0.0949	0.364
Nitrogen	0.0822	0.0393	0.0019	0.0106	0.148	0.0387	0.0895	0.416
Leaf number	0.141	0.156	0.0204	0.0147	0.0462	0.124	0.188	0.692
Leaf length	0.0971	0.117	0.0161	0.0193	0.0435	0.0768	0.304	0.674

Direct effects are denoted by underlined figures

Discussion

DISCUSSION

Identification of yield components has definite advantage in perennial crop breeding and production. Morphological characters are accounted generally to judge the overall productivity of the plant. Although this can furnish a general assessment, a sound knowledge of causal mechanisms at cellular or molecular level is necessarily warranted for any kind of manipulations. Monitoring the biochemical and physiological mechanisms attain importance at this point.

Identification of biochemical parameters responsible for better plant performance in terms of yield, breeding value, disease resistance etc. is being attempted in various crops. In the following pages the results recorded from the data collected during this study are briefly discussed.

4.1 Yield from the experimental palms

Coconut palms especially the tall typica types take 4-6 years to reach the stage of first bearing. During the initial years, there is much variation in yield with the increase in age. It usually takes another 6-8 years to come to the stage of full bearing. The variations in yield, once the palms attain stabilized yield, mostly confine to a limited range unless they have the alternate or irregular bearing habit. The realisation of good yield from a plantation is thus dependent on systematic selection procedures carried out to ensure the yield potential and also the maintenance practices. A sizable part of the yield from the plantation will be contributed by the high yielders. Murray (1950) found that 9 per cent of the trees in a plantation which came under the high yielding category contributed as much as 21 per cent of the crop.

Observing the yield variations of the three groups of palms under study, it was found that the high and medium yield groups showed a wider range of variation compared to the low yielders. According to Abeywardane (1971) weather parameters have more pronounced effects in coconut yield than in any other crop. The high and medium yielders show a better capacity to utilize the congenial conditions for higher production, while under the unfavourable conditions they can sustain optimal levels of growth and production. The potential ability of the poor yielders being low, increased production need not be obtained even under congenial conditions.

4.2 Morphological characters

4.2.1 Number of leaves retained by the palm

Number of leaves have been marked as an index to the production potential of the palm. The total drymatter production by the palm can mostly be manifested from the production of leaves and nuts, as the annual increment in the length and girth of the trunk is only marginal. Number of leaves and drymatter production are two mutually reciprocating characters one enhancing the other.

From the observations recorded under this study it was found that the high yield group of palms had 40.83 leaves on an average compared to 33.32 in low yielders. A fairly high degree of correlation (r = 0.692**) was recorded between the number of leaves and yield. Path coefficient analysis with selected characters (Table 20) indicated that leaf number contributes to the yield more indirectly than its direct effects on yield. Leaf length was one of the most important parameters contributing to the yield in this respect. The potassium status and chlorophyll content were also found to give substantial contribution. This may substantiate the effect of leaf number on yield in such a way that the net increment in dry matter accumulation realised through the enhanced photosynthetic area and synthesising capacity reflects in nut yield also. The partial linear regression coefficient of leaf number on yield was found to be significant. The correlations mentioned between leaf number and leaf potassium, chlorophyll, total phenols and nitrogen were also found to be significant. This indicates that these constituents can influence the net production of leaves by the palm.

Thus as a recapitulation it can be stated that number of leaves retained by the palm is an indication to its yield potential which inturn results from the indirect influence of this character through the chemical constituents such as potassium, chlorophyll etc. and the number of leaves itself is also influenced by the amount of chemical constituents present. Similar observations were also recorded by Patel (1938), Satyabalan (1972), Mathew and Ramadasan (1975) and Gopi (1981).

4.2.2 Leaf length, petiole length, number of leaflets and length of leaflets

From the observations recorded during the course of experiments it was concluded that the high yielding palms differ significantly with respect to the leaf characters such as leaf length, petiole length, number of leaflets and length of leaflets from the low yielding palms. These parameters can generally enhance the net photosynthesis by increasing the leaf area and by better leaf orientation. The positive correlation for these characters recorded under this study can be viewed as their combined effect on the dry matter production of the palm. The high yielding palms have the inherent capacity to utilise the photosynthates accumulated for the production of nuts by way of improving the sink capacity.

Leaf length was found to be one of the most important parameters contributing towards the yield directly. The path coefficient analysis indicated that a one per cent change in leaf length can cause 0.3 per cent change in yield of nuts. The linear regression for this character on yield was also recorded as significant. Thus leaf length can also give an indication of the yield potential of the palm. Unlike the number of leaves, leaf length had a direct effect on yield. Its indirect effect was most pronounced through the chlorophyll content.

The positive correlation observed between leaf length and other characters like leaf number, potassium content, chlorophyll, nitrogen and soluble sugars, and the negative correlation with total phenols indicate that all these components of yield are inter-related and the manifestation of the production potential of the palm can be done only by giving allowance to these components. The findings are in conformity with the earlier observations recorded by Abeywardene (1976).

4.3 Periodicity of leaf production

The leaf production rate is another indication to the health and vigor of the palm. The observations recorded during the course of this study indicated that the high yielding palms produce leaves more frequently than the low yielders. It took approximately 28 days for a high/medium yielder between two successive leaf emergen while it was about 30 days for the poor yielders. This interval is influenced by the season of the year. During the summer season the recurrent leaf emergence takes even shorter intervals while during the rainy season it takes more. Considering the net number of leaves produced per year, the difference between low and high yielders will not be more than one or two leaves per year. But the number of leaves retained by a high yielder is much more than that in a low yielder indicating that the high yielders not only produce leaves more frequently but are also capable of retaining them for longer period than the low yielders. This can also be influenced by the cultural practices followed.

The leaf production rate and the duration of retention is well marked on the mean leaf stand on the crown. This can give a good indication of the vigour of the palm and thereby its production potential.

4.4 Girth at collar

The observations indicated that the yield of palms are correlated significantly with the collar girth of the palms. The vegetative growth in terms of development of the columnar trunk takes about 4-5 years to initiate. The girth of the developing trunk depends on the fertility and varietal nature. It undergoes minimum change once the maximum has been attained, unless there is serious malnutrition or disease infection. The girth of mature palm at the collar region is a resultant of the vegetative growth attained by the palm during the previous season. This can thus give a good indication of the possible yields as well. Its positive relationship with yield is further stressed by the significant positive correlation observed with all the yield components studied. Similar finding was reported earlier by Narayana and John (1942).

4.5 Chemical constituents

4.5.1 Total nitrogen content in the leaf

The total nitrogen in the leaf lamina showed significant differences among the three yield groups. The increase in foliar nitrogen level observed in medium and high yielders could be attributed to the difference in the ability of palms to absorb the nutrient element from soil which results from genetically controlled factors operating through their effects on root production and physiology. The root producing capacity of poor yielders has been found to be low compared to high yielding palms, resulting in the reduced uptake of nutrients. Variations towards both sides were observed in the foliar nitrogen level, from the critical level of nitrogen proposed by Ziller and Prevot (1962) in the 14th leaf.

The foliar nitrogen level exhibited a significant linear regression on yield of nuts from the palms. The path analysis has indicated that the direct effect of nitrogen on yield is most pronounced. A one per cent change in foliar nitrogen can cause 0.15 per cent change in yield of nuts from the palms. The significant correlation observed between yield and foliar nitrogen level of the palms was mostly due to this effect. Smith (1969) had observed that foliar nitrogen has a close association with the female flower production in the palms. The rate of production of flower bunches also was reported to have close relation with foliar nitrogen level. Thus low level of nitrogen in the leaf lamina can be reflected in the realised yield from the palms. It was also observed that during monsoon season the nitrogen level falls. Reduced uptake of nitrogen with the onset of monsoon had earlier been noted by Wahid *et al.* (1981).

4.5.2 Phosphorus content in the leaf

Phosphorus level in the lamina of the leaf did not exhibit any linear relationship with the yield of the palms. The observed levels of phosphorus were much higher than the critical levels proposed earlier by Ziller and Prevot (1962) for optimal level of production. In such a situation foliar phosphorus level could not have limited the production even in the low yielding palms. There had been earlier reports that the content of phosphorus in leaf does not influence the yield (Indirakutty and Pandalai, 1968; Gopi, 1981). It is also generally accepted that phosphorus application can be skipped depending on the soil phosphorus reserves in the case of coconut palms. But a contradictory finding was also reported by Thomas (1973) who found that significant difference in foliar phosphorus levels exists between yield groups.

4.5.3 Potassium content in the leaf

The results obtained from the experiment indicate that there is a definite relationship between leaf potassium status and yield. Among the primary nutrients it was this element which showed maximum correlation with yield. From Fig.4 it is evident that the difference in potassium status between the low and medium yield groups is quite conspicuous. This may indicate that in the low yield groups potassium remains as the major limiting factor. The medium and high yield groups did not show much difference indicating that the potential production of the medium yielders are not limited by this nutrient.

Potassium had a significant linear regression on yield. The path coefficient analysis indicated that the direct effect of potassium is important. About 0.3 per cent shift in yield is found possible with one per cent change in the potassium status.

The positive relationship exhibited between leaf potassium level and other yield components like leaf number, length, leaflet number, leaf chlorophyll, nitrogen etc., could explain its ultimate effect on the yield of nuts from the palms.

Fremond *et al*. (1966) considered coconut as a luxuriant feeder of potassium, which has prominent role in flower production and nut development. Salgado (1955 stressed the metabolic importance of potassium for chlorophyll production. Most of the absorbed potassium goes to the production of nuts (Pillai and Davis, 1963). Recently, Taffin and Quencez (1980) suggested that the extraordinary response for KCl by the palms is not due to the effect potassium alone, but due to the effect of chlorine also. But the present study indicates that among the nutrients studied potassium has maximum direct effect on yield. Thus potassium does show definite influence on yield of nuts from the palms.

4.5.4 Calcium content in the leaf

Calcium status of the leaves in most of the cases were well below the critical level of this element proposed by IRHO. There were also instances where calcium content was more than the critical level recorded. Coconut is reckoned as a lime loving tree and higher levels of calcium is not uncommon. But from the observations, it may be concluded that there is no significant linear relationship for the foliar level of this element with yield.

Potassium and calcium levels have shown a ...gative correlation between them. Although this was not significant it may indicate that there can be a certain degree of antagonism between the two. It was also observed that K/Ca ratio has a significant correlation with yield. This indicates that it is the balance between potassium and calcium that is important than the amount of calcium alone. Pillai et al. (1973) had reported that coconut roots have low CEC and thus have more affinity towards monovalent cations which results in the antagonism between monovalent and divalent cations.

4.5.5 Magnesium content in the leaf

The foliar magnesium level exhibited a negative linear correlation with the yield of nuts from the palms, but this relationship was not significant. In this case also the K/Mg ratio had shown significant positive relationship with yield of the palms. It was also observed that the ratio between monovalent potassium and divalent calcium + magnesium possesses fairly high correlation with yield. From these observations it can be deduced that for better yields a balanced state of nutrient elements should be attained in the palms. Similar observations were recorded by Thomas (1973).

4.5.6 Soluble sugars in the leaf

The observations recorded on soluble sugar content of the leaf lamina indicated that the high yield group palms have fairly high percentage of this constituent compared to the low yield group. This being the immediate product of photosynthesis the higher percentage observed in the high and medium yielding palms confirms the point that they are having a better synthesising capacity. This results from the larger photosynthetic surface and higher chlorophyll content possessed by them. The difference in soluble sugar content observed during September-October period shows that the synthetic processes take place at a lower intensity during this period. The fall in photosynthetic rate judged through the fall in accumulation of soluble sugars was very low for the high yielding palms, which may be due to their comparitively better efficiency in utilizing the resources for synthetic processes.

The direct effect shown by this constituent on yield was not that marked. This being the primary product of the synthetic process, it must undergo various metabolic changes and has to play many metabolic roles, before the overall effect is manifested in the nut yield, it is possible, that soluble sugars in leaf shows no direct effect on yield.

The soluble sugars in the leaf had shown significant positive correlation with its chlorophyll content. Since the accumulation of photosynthate has a direct bearing on the efficiency with which the pigments function, such a positive relationship can exist. The observations are in conformity with the earlier reports by Ramadasan and Mathew (1979).

4.5.7 Starch content in the leaf

The variation in starch content between the different yield groups was not statistically significant. From the observations it can be deduced that the high yielding palms had a slightly low level of starch in the leaf lamina compared to the low yielders. This may indicate better ability of these palms to translocate the photosynthates to the sinks. The low yielders have low sink capacity resulting in the accumulation of photosynthates.

4.5.8 Total phenols in the leaf

There was a distinct indication that the amount of phenolic constituents reduced as the nut yield from the palm increased. The amount of these constituents had negative correlation with most of the yield components also. The phenolic constituents also had shown a significant linear regression on yield. The path analysis revealed that the direct effect of phenolic constituents on yield is less pronounced. The indirect effects through the leaf length, leaf potassium and leaf chlorophyll content were mainly responsible for the high negative correlation between this constituent and yield.

The function of phenolic constituents in the plant is more regulatory than production. The negative correlation between yield and this component shows that the partition of metabolites for production and regulation function is carried out more efficiently in high yielding palms. In the low yielding palms a major portion of the synthates goes for the regulatory and defence functions as the metabolic activities as a whole proceed at a low rate.

4.5.9 Free amino acids (FAA) in the leaf

The free amino acid fractions present in the coconut leaf were identified as shown in Table 12.

It was observed that free amino acids are present only in traces. The data collected from the present investigation could not furnish enough details so as to characterise the three yield groups according to the amount of free amino acids present in them. The free amino acid alanine was identified only from the low yielding palms, while tyrosine was identified only from medium and high yield groups.

It has been reported that deficiency or poor balance between nitrogen, phosphorus and potassium can result in increased levels of FAA due to the unsatisfactory incorporation of amino acids with proteins. Conclusive deductions are possible only after quantification of the different aminoacids in order to support such a view.

4.5.10 Chlorophyll content in the leaf

The results obtained from this study showed that there is a marked difference between the yield groups with respect to the total chlorophyll content. Chlorophyll pigments being the site of the synthetic processes its amount could influence the net photosynthesis. A sun loving plant like coconut can perform with full efficiency when the actual site of synthesis is not limiting. The comparatively high chlorophyll content recorded during the summer season shows that the palms could cope with the demand for increased production during this period.

This also shows that the palms could adjust the metabolic activities for utilising the increased availability of sunlight.

The linear regression of chlorophyll on yield was significant. The direct effect of chlorophyll on yield was found to be 0.254 per cent. It also had indirect effects on yield through the leaf potassium and leaf length. The high degree of correlation observed for chlorophyll with yield, to the most part, was shared by these three factors.

4.5.11 Catalase activity

The catalase enzyme activity in the leaf lamina presented erratic variation among the different yield groups. The data collected on this aspect could not indicate any definite trend, nor does it exhibit any definite relationship with yield of nuts from the palms. Thus characterising the low, medium and high yield groups based on the activity of catalase enzyme present in the lamina of leaf at position 14, was not possible. However, catalase activity showed positive relationship with leaf potassium levels, loaf starch content and a negative correlation with phenols. This may indicate that increased catalase activity can indirectly influence the yield of the palms.

There had been earlier reports of the association between catalase activity and vigour of the plant (Ezell and Christ, 1927). Vora and Vyas (1974) also suggested that active growth and catalase activity are associated. But the results from the present study do not fall in line with these suggestions.

4.5.12 Peroxidase activity

The peroxidase activity in leaf lamina also did not indicate any consistent trend with the change in yield characteristics of the palms. The inter-relationships between the peroxidase enzyme activity and other constituents under study also was not indicating any conclusive deductions possible. Although peroxidases are known to influence multitude of metabolic functions like regulation of indigenous auxin levels, ethylene biosynthesis, disease resistance etc.it may be concluded that the activity of this enzyme cannot be considered as a marker character to judge the yield potential of the palms.

4.5.13 Yield prediction models

From the different yield components studied it was concluded that leaf number, leaf length, petiole length, leaflet number, periodicity of leaf emergence and girth had significant influence on yield, among the morphological features. Leaf nitrogen content, leaf potassium, chlorophyll, total phenols and soluble sugars also had shown significant correlation with yield. Based on the multiple regression analysis it was concluded that expected yield of nuts from the palms could be predicted using the above 11 characters to the tune of 74 per cent efficiency (R^2 = 0.747**) with the model given below.

$$Y = -254.84 + 33.2\,K + 14.1\,C - 0.978\,P + 4.872\,S + 10.953\,N + 0.97\,L.N + 14.643\,L.L + 25.204\,L.P + 0.0463\,LLN + 0.32\,f - 0.555\,G.$$

(K = potassium, C = chlorophyll, P = phenols, S = sugars, N = nitrogen, L.N = number of leaves, LL = length of leaves, L.P = length of petiole, LLN = number of leaf lets, f = periodicity of leaf emergence and G = girth)

Another linear regression equation was worked out retaining only seven apparently prominent characters i.e., leaf potassium, chlorophyll, total phenols, soluble sugars, nitrogen, number of leaves and leaf length and it was found that yield prediction can be done with almost same level of accuracy (R^2 = 0.736**).

The difference in the value of coefficient of multiple determination comes to 0.011. Thus it is evident that the contribution of four characters viz., petiole length, number of leaflets, periodicity of leaf emergence and girth is quite negligible (1.1%). Thus yield prediction can be done using the simpler linear function as given below.

$$Y = -144.575 + 32.298\ K + 14.399\ C - 1.468\ P + 6.432\ S + 17.798\ N + 0.634\ LN + 15.219\ L.L.$$

The above mathematical model can be efficienly used for forecasting the expected average yield of coconut palms with known values of the morphological and chemical parameters.

Summary

SUMMARY

The study was undertaken to characterise coconut palms in relation to yield, based on various morphological and biochemical characteristics. Sixty palms, cv West Coast Tall were selected and were grouped as low, medium and high yield groups each group comprising of twenty palms. Morphological observations and chemical analyses were conducted during the study.

1. The low, medium and high yield groups of coconut palms differed significantly interms of their morphological characteristics such as number of leaves length of leaves, length of petioles, number of leaflets per leaf, periodicity of leaf emergence and collar girth. The number of leaves which was judged as an indication of the yielding capacity, influenced yield indirectly through the chemical components especially chlorophyll and potassium. High yielding palms produced leaves more frequently and also retained them for longer period. The length of leaf had a direct effect on yield. The overall effect shown by these characters was presumed to have resulted from the net increase in drymatter production due to increased photosynthetic area.

2. The nitrogen level in the 14th leaf lamina exhibited significant difference between the three yield groups. Nitrogen had a direct effect on the yield of nuts from the palm.

3. The phosphorus content in leaf neither showed any remarkable variation between the yield groups, nor did it exhibit any linear relationship with yield.

4. Leaf potassium exhibited high degree of correlation with yield. The difference between low and high yielders was conspicuous. The direct effect of this nutrient on yield was marked.

5. Variation in calcium content of leaf was not significant between the low, medium and high yield groups.

6. Magnesium content in leaf did not show any definite pattern of variation between the yield groups.

7. The nutrient ratios especially N/Ca, K/P, K/Ca, K/Mg and K/Ca + Mg had significant influence on yield of nuts from palms. It was concluded that a balance between various nutrients is highly essential for better production.

8. Soluble sugars in the leaf had a significant positive correlation with yield. The extent of reduction

in the content of this constituent was less in the high yielding palms during September-October period compared to low yielding palms.

9. Starch content of leaves did not show any significant relationship with yield.

10. Total phenolic compounds present in the leaf had a negative correlation with yield of nuts from the palms. Similar relationship was shown with other yield components also. Its ultimate effect on yield was due to the indirect effects through the leaf chlorophyll and leaf potassium.

11. The free amino acids present in the leaf laminae were identified. Alanine was detected from low yielders while tyrosine was detected from medium and high yielders. There was no other qualitative difference between the yield groups.

12. Leaf chlorophyll was found to have positive correlation with yield. It was also related to the potassium status of the leaf. Chlorophyll content of leaf increased during summer season.

13. The catalase enzyme activity measured in the extracts of leaf lamina failed to give indication of any

relationship with yield. It was however significantly correlated to leaf potassium and starch content.

14. Peroxidase enzyme activity in leaf also did not exhibit any consistent relationship with yield.

15. Linear regression model which could predict the yield of nuts from the palms with 74 per cent accuracy was proposed using seven selected characters.

16. The results indicated that characterisation of yield groups based on biochemical components is possible. Those characters which can indicate the yield potential and precocity at the seedling levels itself is to be identified by adopting long term experiments.

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* Originals not seen

BIOCHEMICAL CHARACTERISATION OF COCONUT PALMS IN RELATION TO YIELD

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ABSTRACT OF THESIS

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ABSTRACT

An investigation on the morphological and chemical components of yield in coconut palms was conducted at the College of Horticulture, Vellanikkara during 1981-83, in order to characterise the yield of palms based on these characters. Sixty palms of the cultivar West Cost Tall (W.C.T.) were selected from the existing plantation at Agricultural Research Station, Mannuthy comprising twenty palms each under low, medium and high yield groups (<40, 40-80 and >80 nuts/palm/year respectively).

Observations on morphological characters such as number of leaves, length of leaf, length of petiole, number of leaflets, length of leaflets, periodicity of leaf emergence and girth at collar were recorded at bimonthly intervals. Analysis of leaf samples from the leaf position 14 were taken up to estimate the contents of nitrogen, phosphorus, potassium, calcium, magnesium, soluble sugars, starch, total phenols, free amino acids, total chlorophyll, catalase activity and peroxidase activity during March-April and September-October seasons.

There was a significant positive correlation for number of leaves, length of leaves, number of leaflets,

length of leaflets and girth at collar with the mean annual yield. The periodicity of leaf emergence had a negative correlation with yield.

Among the mineral nutrients, nitrogen and potassium had significant positive correlation with yield. Phosphorus, calcium and magnesium failed to show any linear relationship. The nutrient ratios viz., N/Ca, K/P, K/Ca, K/Mg and K/Ca + Mg also exhibited significant positive correlation with yield.

The biochemical components such as soluble sugars and total chlorophyll content in the leaf lamina had significant positive correlation with yield. Total phenolic compounds present in the leaf lamina had a significant negative correlation with yield. Starch content in the leaf did not show such relations. The free amino acids present in traces in the leaf were identified. Leaf catalase and peroxidase activity exhibited no definite pattern of variation in relation to yield.