STANDARDISATION OF INDEX LEAF/LEAVES FOR ASSESSING THE NUTRITIONAL STATUS OF CLOVE IN RELATION TO SOIL FERTILITY

By

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THESIS

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"You will have to work hard and sweat to make the soil produce anything until you go back to the soil from which you were formed"

Genesis. 3 : 19

Dedicated to

MY LOVING PARENTS

DECLARATION

I hereby declare that this thesis entitled "Standardisation of index leaf/leaves for assessing the nutritional status of clove in relation to soil fertility" is a bonafide record of research work done by me during the course of research and that the thesis has not been previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

VELLAYANI,

28th April, 1989.

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CERTIFICATE

Certified that this thesis entitled "Standardisation of index leaf/leaves for assessing the nutritional status of clove in relation to soil fertility" is a record of research work done independently by Sri. D. Gnanadas under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

Clove, *Syzygium aromaticum* Syn. *Eugenia caryophyllus*, is one of the most ancient and valuable species of the orient and holds a unique position in the international spice trade. In India, clove was introduced around 1800 A.D. by the East India Company. The important clove growing regions in India are Nilgiris, Tirunelveli, Kanyakumari and Ramanathapuram districts of Tamil Nadu, Calicut, Kottayam, Quilon and Trivandrum districts of Kerala and South Kanara district of Karnataka. Kerela has the largest area with 596 ha under clove (Anon, 1979).

Since the production in the country is insufficient to meet the domestic demand, cloves worth Rs.15 lakhs are imported annually to India from other countries like Zanzibar and Pemba. It has been estimated that the area under clove has to be increased to about 4000 ha. to meet the internal demand. The long pre-bearing age, lack of scientific knowledge on the culture of the crop and dearth of reliable planting material, seem to have stood in the way of its large scale cultivation.

In India, it is grown in loamy soil rich in humus. Responses to fertilizers have been observed in many of the clove growing countries, such as Indonesia, Zanzibar, Madagascar etc. Though clove is a highly priced spice, not much work has been done in increasing its productivity. Being seed propagated, clove exhibits tremendous plant to plant variation. This variation, at present, is not taken into account while making the fertilizer recommendations. Further, studies on the mineral nutrient requirement of this crop in India is very limited.

Clove, being a perennial crop, soil analysis alone may not provide a comprehensive picture of the fertilizer requirement of the crop. Foliar diagnosis has to be coupled with soil analysis for correct interpretation. In this context, establishment of index leaf/leaves for the essential nutrients would pave way for accounting individual variability and for making scientific fertilizer recommendations so that the production of this elite spice can be maximised.

The present study was initiated in order to shed some light on the above aspects with the following objectives.

1) To assess the fertility status of the clove growing soils and the nutritional status of the clove plants growing on them.

2) To establish the relationship between the soil nutrient content and the corresponding leaf nutrient concentrations.

3) To standardise the index leaf/leaves for assessing the nutritional status of the clove in relation to soil fertility.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Studies on the nutritional aspects of clove in relation to soil fertility are meagre and the foliar content of different essential nutrients has been gaining more attention recently. Literature on these aspects are practically limited. Even in the biggest clove producing countries like Zanzibar, Madagascar and Indonesia, very few or nor work has been carried out on the lines of the present approach. The available references in relation to clove culture and similar aspects related to this study viz., relationships between soil nutrients and leaf concentrations, foliar analysis, soil analysis etc., are summarised in this chapter.

2.1. SOIL ANALYSIS

For the efficient and economic use of fertilizers, it is necessary to assess the requirement of each nutrient for any plant. The diagnostic methods primarily involved are soil analysis and leaf analysis. Soil testing aims at assessing the fertilizer status of soil through quick chemical tests. These tests give information on the potential of the soil to supply nutrients to plants.

Kowal (1959), from the analysis of soils under 14 year old cocoa plants in Nigeria stated that the soil analysis may prove very useful in bringing out the causal factors of other growth problems, which are less obviously related to nutrition.

According to Pushpadas and Ahammed (1980), though routine soil testing gives some idea about the total quantity of available nutrient in the soil, it fails to give adequate information on the rate at which these nutrients would become available to rubber crops. It also does not take into account the availability of organic form of nutrient such as phosphorus. Sometimes the nutrient present in the soil may not become available to the plant because of adverse physico-chemical or biochemical properties of soil which may not be evident from the routine soil testing. Hence these limitations of soil testing could be overcome by the use of leaf analysis.

2.2. FOLIAR ANALYSIS/FOLIAR DIAOGNOSIS

The concept of tissue analysis as a diagnostic technique for mineral deficiency in plants was given a rational and scientific footing (Lagatu and Maume,1926). Plant analysis has now come to be viewed as a satisfactory guide to nutrient status and nutritional requirements for optimal growth and yield of crops rather than an index of soil fertility (Goodall and Gregory, 1947). The nutritional requirement of certain crops particularly temperate and sub-tropical fruit crops, have been formulated using this technique (Smith,1962). General principles of leaf analysis have been thoroughly reviewed by several authors (Thomas, 1945; Goodall and Gregory,1947; and Smith, 1962). This is specifically true with reference to fruit crops (Boynton and Compton, 1945).

Loue (1962), did chemical analysis of cocoa leaf from field plantations in the Ivory Coast and reported that in shaded plantations, a nitrogen concentration of 2.35-2.50 per cent was normal. Normal phosphorus concentration was approximately 0.18 per cent. Potassium was considered deficient when present in proportions of less than 1-2 per cent. Burridge et al. (1964), recorded the highest variations in the concentration of nutrients in the leaves of cocoa. The same trend was also observed in cocoa by Murray and Maliphant (1965). Santana and Igue (1979), also reported that the cocoa leaf nitrogen and potassium tended to decrease with leaf age.

Pushpadas and Ahammed (1980), found that analysis of leaf samples collected from rubber plants observing the correct sampling techniques provided reliable information on the state of the nutrient content of plants at the time of sampling. Based on the leaf analysis, they have given the critical leaf nutrient level for rubber plant as, below 3.00 per cent as low, 3-3.5 per cent as medium, above 3.5 per cent as high for nitrogen; below 0.2 per cent as low, 0.2 to 0.25per cent as medium and above 0.25 per cent as high for phosphorus and below one per cent as low, 1-1.5 per cent as medium and above 1.5 per cent as high for potassium.

Annie (1982), reported that N, P, K, Ca and Mg content of cocoa leaves varied depending on the age of the leaf. In most of the cases, P and K status increased from the second to the third leaf and then decreased to the fourth leaf. Calcium and magnesium content tended to decrease with age. The petioles contained the highest concentration of P, K, Ca and Mg and the lowest concentration of N. The third leaf petiole was suggested as the ideal foliar diagnostic sample for cocoa plant irrespective of soil type.

2.3. SOIL NUTRIENT Vs. LEAF NUTRIENT

Hardy et al. (1935), stated that the relationship that existed between the plant and its environment were not simple, and factors other than nutrient supply might affect the growth and composition of the plant. Schroo (1960), compared the results of soil analysis with those obtained from leaf analysis and used it as a guide to the nutritional demands of young cocoa. He observed closest relationship between soil phosphorus and magnesium with that of leaves and also found that agreement between leaf and soil nitrogen, potassium and calcium was less satisfactory. In an experiment with four year old cocoa plants, Acquaye <u>et al</u>. (1965), observed positive correlations between soil exchangeable K and leaf K. Verliere (1965), also found that the growth rate of cocoa was significantly correlated with soil P.

Wessel (1970), reported that nitrogen content of soil was indicative of the N availability to cocoa plant and that leaf nitrogen could only be used in detecting the deficiency of nitrogen in the soil. He found a positive relationship between soil and leaf phosphorus. He concluded that the soil and leaf analysis are of limited value for assessing the nitrogen requirement of cocoa, but can fairly determine the phosphorus requirement of the crop.

Annie (1982), reported that the foliar diagnosis of cocoa plant indicated a good relationship between the soil nutrient status and leaf nutrient status. She has also observed positive correlation between soil test values and leaf nutrients concentration in the order of Mg followed by Ca, N, K and the least by P.

2.4. POSITION OF LEAF SAMPLING

In foliar diognosis, sampling of the leaves is of prime importance as the position of the leaf is significant in their nutrient status. McDonald (1934) recommended the use of most recently matured leaf for analysis. Hardy <u>et al</u>. (1935) sampled the first hardened shoot leaf of cocoa, but Thomas (1945) pointed out that, in general the older leaf may be preferable since they reflect the stage of internal starvation before the younger ones, because nutrients are drawn most rapidly from the older leaves when new growth is taking place. Murray (1952) sampled 8 to 10 leaves of the second or third leaf from the apex of different matured flushes while Loue (1962) recommended sampling leaves of ranks 2 and 3 from the first fully green sprout from 5 branches, thus yielding 10 leaves per tree in cocoa. Use of second or third fully matured leaf below the apex of shoot in cocoa for sampling was suggested by Acquaye (1964) and Chapman (1964).

Burridge <u>et al</u>. (1964) sampled the recently matured leaf from the lower shaded part of the canopy. Pushpadas and Ahammed (1980) reported that leaf samples from the immature rubber trees and trees under tapping should be collected from the base of the terminal whorl of lower branches. They again suggested that if 30 trees are selected, collect only the middle leaflets from each leaf, if 15 trees, collect the two leaflets from either side and if 10 trees, collect all the three leaflets so that above 120 leaflets would be available in one composite sample.

Josepth (1981) suggested the leaf ranked fifth from the apex as standard leaf for leaf analysis in cocoa. Annie (1982) sampled second, third and fourth rank orders on 10 fan branches from each plant of cocoa and collected 10 leaves per plant from each rank order. Sushama et al. (1984) sampled the first mature leaf of full bearing laterals of pepper vines for the foliar diognosis in a study to standardise the most suitable season in the Cannanore district of Kerala.

2.5. SAMPLING OF SPECIFIC PARTS

Eventhough leaf is the most ideal tissue to sample for analysis for most nutrient elements, it has to be decided as to whether the petiole or the lamina or the whole leaf should be used for the accurate and precise observation.

Thomas (1945), concluded that in cocoa the entire leaf should be used when the purpose is to determine the relationship of mineral nutrition to yields. Chapman and Brown (1980), found that the petiole showed no advantage over the lamina with regard to K estimation in citrus, while Ramig and Vandecaveye (1950) observed that in raspberry, lamina was more sensitive than petiole for diagnosing nitrogen status and petiole was more sensitive than lamina for P, K and Ca. Murray (1952), used the leaf with petiole attached for cocoa. Bould (1961), emphasised the importance of including the petiole in case of soft fruits if sampling errors are to be kept at minimum.

Smyth (1962), suggested that the variations can be avoided by omitting the petiole, if the petioles are large, in the foliar diagnosis of cocoa. Adquaeye (1964) found that the petioles contained the highest concentration of Ca. Mg, P and K and the lowest concentration of N and recommended the use of whole leaf for cocoa foliar analysis. Pushpadas and Ahammed (1980), detached the leaflets from the petiole using a sharp knife or blade when they collected leaf samples for the use of foliar analysis in rubber plants. Annie (1982), used lamina and petiole samples separately for foliar analysis of cocoa and she found that the petiole gave more appropriate diagnosis in cocoa than lamina or whole leaf.

2.6. RELATIONSHIP BETWEEN LEAF CONCENTRATION AND YIELD

A close relationship between leaf composition and yield was noticed by Hardy et al. (1935). They expressed their results as ratios and indicated that high yields are associated with ratios of N/P = 4.66; N/K = 0.89 and K/P = 5.21. Varliere (1965), obtained highly significant correlation between cocoa yield on the one hand and N/P and Ca/K ratios in the leaf leaf on the other hand. Wessel (1965) also reported that leaf P content and the yield of cocoa were having high positive correlations.

Wessel (1971), again in a study in Nigeria, reported that a linear relationship existed between concentrations of P, K and Ca and that of dry matter content. The same trend was also recorded by Salesh (1973), in his study in Indonesia.

2.7. RESPONSE OF CLOVE TO FERTILIZERS

Indonesia which is one of the major clove producing countries in the world, has attempted some experiments on fertilizer responses to clove. Tidbury (1949), conducted an experiment on clove at the bearing stage with ammonium sulphate, potassium sulphate and superphosphate each at 0.9 kg per tree and observed a positive response to ammonium sulphate, half of the response to potassium sulphate and no response to superphosphate.

In an experiment conducted at Madagascar, Dufournet and Rodriguez (1972) applied fertilizers at the following rates to clove planted in 1958; N as urea at 115 kg per ha, (9.449 kg per tree); P_2O_5 as triple superphosphate at 480 kg per ha (1.875 kg per tree) and K_2O as potassium chloride at 150 kg per ha (0.585 kg per tree). The result showed that the control plot gave an yield of 698 kg and 1375 kg per ha in the year 1969 and 1970 respectively. The N, P combination gave 1295 kg and 1729 kg per ha (mean yield of 1512 kg); whereas the NPK combination gave 1191 and 1434 kg per ha (mean yield of 1312 kg). The PK treatment gave 1191 kg and NK treatment 1139 kg per ha.

2.8. CLIMATE AND SOIL REQUIREMENT FOR CLOVE CULTURE

Clove trees grow well in humid tropical climate with an annual rainfall of 150-200 cm and from almost sea level to 1000 metres and a mean temperature range of 20-30°C. Ridley (1922) was of the opinion that sandy soil is unsuitable and water logged condition is still worse. According to Redgrove (1933) if clove is grown in a too moist climate, it will not flower. According to him alternating periods of dry and wet weather as in Zanzibar and Pemba are essential for successful clove cultivation.

A rainfall of 1500-2500 mm or more per year is required with an interruption of a marked dry spell for some months and adequate exposure to sunlight seems to be essential for abundant development of flower buds (Francois 1936) ~~Dufornet, 1968~~). A rainfall exceeding 2500 mm per annum together with insignificant non seasonal periods of drought and little sunlight tends to promote luxuriant vegetative growth. Under these conditions relatively few floral buds develop (Maistre,1964).

In India, clove is grown in loamy soil rich in humus. Deep and rich loams with high humus content and laterite soils are found best suited for the successful cultivation of clove and the plants thrive well if they are periodically irrigated during the earlier years of planting during drought (Shanmugavelu and Madhava Rao, 1977). Deep black loam soil with high humus content found in the forest region is best suited for clove cultivation. It grows satisfactorily on laterite soils, clay loam and rich black soils having good drainage (Anon,1979).

MATERIALS AND METHODS

3. MATERIAL AND METHODS

In this chapter, the details of the experimental sites, the methodology followed for the collection of soil and leaf samples, the procedures adopted for the chemical analysis of soil and leaf samples and the statistical methods followed are furnished below.

3.1. SELECTION OF EXPERIMENTAL SITE

Clove plantations of similar age group (10 years) were selected from four locations for the present investigations. The flushing periods were also more or less same (May-June) in these locations during which time collection of leaf and soil samples were carried out.

District	:	Trivandrum*	Trivandrum*	Trivandrum*	Kanya-kumari**
State	:	Kerala	Kerala	Kerala	Tamil Nadu
Address of the cultivators	:	Mr.Ravindran Nair, Parankan thottam Vithura P.O.	Bishop palace, Trivandrum	College Farm, Agrl. College, Vellayani	M/s.Carmelgiri estate Palkulam PO. Nagercoil
Soil type	:	Forest soil	Laterite	Red soil	Forest soil

Cropping system	:	Clove inter-cropped with coconut	Pure crop	Clove inter-cropped with coconut	Clove inter-cropped with nutmeg

* The mean annual rainfall of Trivandrum district ranges from 2000–3300 mm. June and July are the wettest month. January and February are normally dry months. The mean minimum and maximum temperature of this district ranges from 21.7–33.0°C (Soils of Kerala, 1978; Hand Book of Natural Rubber Production in India,1980).

** The mean annual rainfall of Kanyakumari district is 2000 mm. Both south west and north east monsoons are equally important for thie region. The mean minimum and maximum temperature are 22.0–34.2°C. The elevation of this tract is 700–900 meters from sea level (Agricultural Statistics of Kanyakumari District, 1979).

3.2. SELECTION OF EXPERIMENTAL PLANTS

Since clove trees begin to yield when they are 8-10 years old, plants for this study were selected from the 10-year old plantations, from the four locations.

Twenty trees each under the above age group were selected from Vithura, Pattom and Kulasekharam and 10 trees from Vellayani (as in this tract, enough trees of the same age group were not available). Thus, a total of 70 trees were selected.

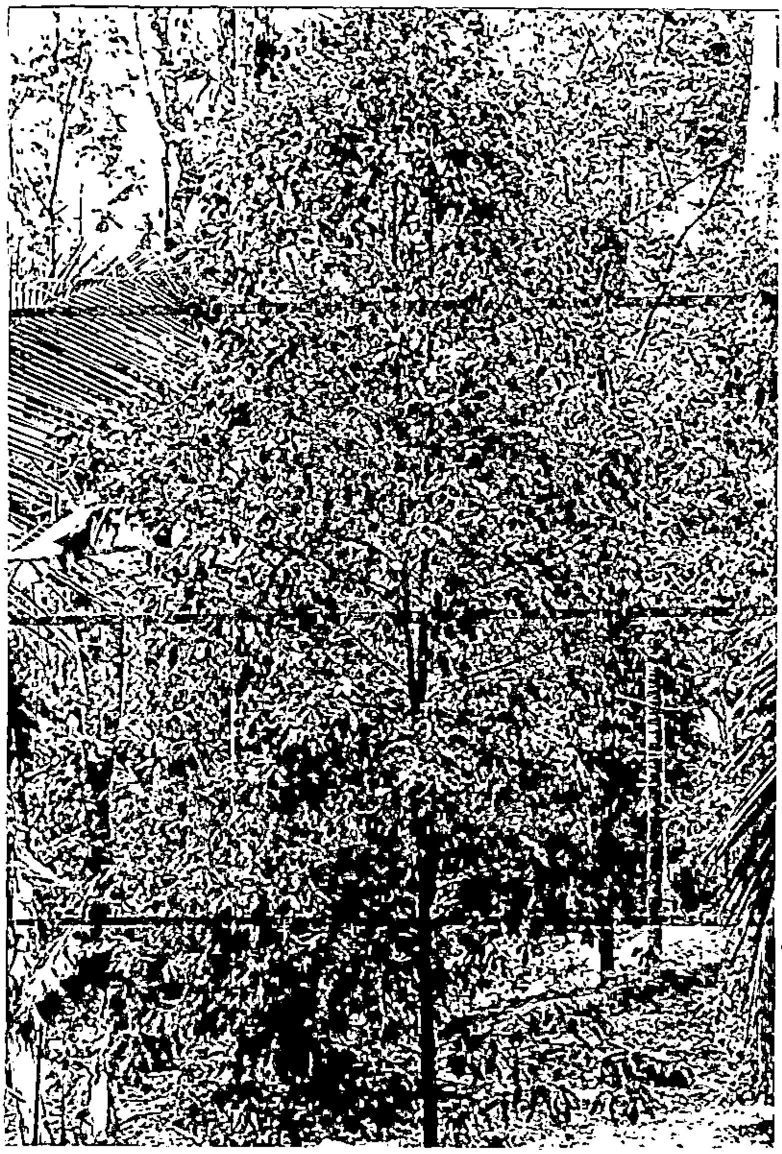
3.3. COLLECTION OF SOIL SAMPLES

For collection of soil samples three zones were marked around the plant, the first zone at 0.5 m radius the second, at 1 m radius and the third at 1.5 m radius from the base of the main trunk. Then surface soil sample to a depth of 30 cm, and at the rate of five soil samples from each zone were collected, composited to draw a representative sample during the flushing period before the application of manure and fertilizers. Thus, 210 soil samples were collected from 70 plants of four experimental sites, and numbered. The collected soil samples were air dried in shade, ground well and seived through a 2 mm nylon sieve. The samples were then stored in polythene bags for chemical analysis.

3.4. COLLECTION OF LEAF SAMPLE (Plate 2)

As in the case of soil collection, leaf samples were collected from each tree for foliar diagnosis during the flushing period. For collection of leaf samples, the canopy of each tree was first equally divided into three regions as top, middle and bottom giving due consideration to the height of the canopy. Then from each region, branchlets oriented towards south, north, east and west were selected and from each branchlet leaves having the same index number viz. whorl-I (first emergence leaf), whorl-II (leaves njust below the first whorl) and whorl-III (leaves just below the second whorl) were collected,pooled and representative leaf samples at the rate of three from each region (whorl-I, II and III) were drawn. Thus totally nine samples from each tree were collected. So a total of 180 leaf samples from the first, second and fourth locations and 90 leaf samples from the 3rd location (Vellayani) were drawn.

The leaf samples collected from each location were cleaned with 0.1 N HCl and rinsed with distilled water a number of times to free them of dusts and other contaminations. Since the petioles of leaves are so small the whole leaf was taken for analysis. Later the dried samples were fed to an ultracentrifugal mill and powdered



TOP

MIDDLE

BOTTOM

Plate 1. **Clove tree indicating different regions viz., top, middle and bottom**

Plate 2. Branchlet of clove plant showing different whorls viz., W_1, W_2 and W_3

well using a 0.5 mm mesh. The samples thus processed were stored in airtight polythene jars and kept for chemical analyses.

3.5. ANALYSIS OF SOIL SAMPLES

3.5.1. Mechanical analysis

The proportion of different particle size fractions viz., coarse sand, fine sand, silt and clay were estimated by the Bouyoucos hydrometer method (Bouyoucos, 1962) after removal of organic matter by hydrogen peroxide treatment.

3.5.2. Electro chemical properties

3.5.2.1. Soil reaction (pH)

The pH of fresh and air dried soil samples was determined in a 1:2.5 soil water suspension using a Perkin Elmer pH meter (Hessee, 1971).

3.5.2.2. Electrical conductivity

The electrical conductivity of the soils was determined by introducing a conductivity cell into the clear supernatent solution of the same soil suspension used for pH measurement using a direct reading ELICO conductivity bridge.

3.5.3. Chemical analysis

3.5.3.1. Organic carbon

Organic carbon was determined by the chromic acid wet digestion method as prescribed by Walkely and Black (1934).

3.5.3.2. Cation exchange capacity (CEC)

CEC was determined by saturating the soil with neutral normal ammonium acetate as proposed by Jackson (1973).

3.5.3.3. Total nitrogen

Total nitrogen of the soil was determined by the microkjeldahl digestion and distillation method (Jackson, 1973).

3.5.3.4. Available nitrogen

Available nitrogen was determined by the alkaline permangnate method (Subbiah and Asija, 1956).

3.5.3.5. Total phosphorus

Total phosphorus content of the soil was precipitated as ammonium phosphomolybdate, from the HCL extract and was estimated volumetrically (Permberton,1945).

3.5.3.6. Available phosphorus

The available phosphorus content was determined by the chlorostannuous reduced phosphomolybdic blue colour method in hydrochloric acid system after extracting the soil with Bray No.1 reagent (Bray and Kurtz, 1945).

3.5.3.7. Total potassium

HCl extract was diluted and fed into an EEL flame photometer and total potassium content of soil was estimated from the standard graph (Stanford and English, 1949).

3.5.3.8. Exchangeable potassium

Exchangeable potassium was determined in the neutral normal ammonium acetate extract of the soil after destroying the organic matter by treatment with aqualregia, using an EEL flame photometer (Stanford and English,1949).

3.5.3.9. Total calcium and magnesium (Piper, 1966)

Total Ca and Mg in soil were determined from the HCl extract using the Perkin Elmer (PE 3030) Atomic absorption spectrophotometer available at the Central Instruments Laboratory of the NARP (SR), at the wave length of 422.7 nm for Ca and 285.2 nm for Mg.

3.5.3.10. Exchangeable Cations (Ca and Mg)

Exchangeable Ca and Mg were determined from neutral normal ammonium acetate extract and the readings were recorded in the Perkin Elmer (PE 3030) Atomic absorption-spectrophotometer available at the Central Instruments Laboratory of the NARP (SR).

3.5.3.11. Total copper, manganese and zinc

The samples were digested with conc. H_2SO_4 and perchloric acid and the extracts were used after filtration and dilution (Holmes,1945) for the determination of total Cu, Mn and Zn by the Perkin Elmer (PE 3030) Atomic absorption spectrophotometer available at the Central Instruments Laboratory of the NARP (SR).

3.5.3.12. Available copper, manganese and zinc
(Lindsay and Norvell, 1969)

Available Cu, Mn and Zn content of the soil were estimated from the DTPA extract, using the Perkin Elmer (PE 3030) Atomic absorption spectrophotometer available at the Central Instruments Laboratory of the NARP (SR).

3.6. ANALYSIS OF LEAF SAMPLES

3.6.1. Total nitrogen

The total nitrogen content present in the leaf samples were analysed by Microkjeldahl method (Humphries, 1956).

Preparation of leaf extract

Triple acid extract was used for the determination of P, K, Ca, Mg, Cu, Mn and Zn in the leaf. (Johnson and Ulrich, 1959). For this 500 mg of the powdered leaf sample was digested with 10 ml of triple acid mixture (nitric, perchloric and sulphuric acids in the ratio of 10.4 : 1). The digest was made upto 10 ml with distilled water, filtered and used for further analysis.

3.6.2. Phosphorus

From an aliquot of the triple acid extract of the plant sample, phosphorus was determined by Vanadomolybdophosphoric yellow colour method in nitric acid system (Jackson, 1973).

3.6.3. Potassium

The triple acid extract was diluted and potassium in the extract was estimated using an EEL flame photometer.

3.6.4. Calcium and magnesium

Calcium and magnesium in the leaf extract was determined in an Atomic absorption spectrophotometer (PE 3030) available at the Central Instruments Laboratory of NARP (SR), after diluting the extract.

3.6.5. Copper, manganese and zinc

The triple acid extract was diluted and copper, manganese and zinc were estimated using the Perkin Elmer (PE 3030) ~~a~~Atomic absorption spectrophotometer.

3.7. COLLECTION OF YIELD DATA

The unopened flower buds (Economic produce) were collected from the experimental trees for two years. The collected buds were dried in shade and the yield data (dry weight) were recorded separately and the results expressed in kg per tree as given in Table 46.

3.8. STATISTICAL ANALYSIS

All the data obtained from the chemical analysis was analysed statistically. The co-efficients of variation were worked out as suggested by Panse and Sukhatme (1967). Simple correlation and regression coefficients were worked out to observe the degree of dependence of variables as suggested by Snedecor and Cochran (1967).

RESULTS

4. RESULTS

The results of the analysis of 210 soil samples and 630 leaf samples collected from representative clove growing soils of Trivandrum and Kanyakumari districts are presented in this chapter. The nutrient status of the soils and leaf samples in relation to their N, P, K, Ca, Mg, Cu, Mn and Zn content was determined. In the case of soil samples both total and available nutrients and their particle size percentages were also determined. The results of analysis are presented in Tables 1 to 37.

4.1. SOIL ANALYSIS

4.1.1. Mechanical composition of soils

The percentage of course sand fractions at Vellayani was 39.40, which was followed by Pattom (34.40 per cent), then by Vithura (32.20 per cent) and then by Kulasekharam (22.60 per cent).

The percentage of fine sand fraction at Pattom was 31.70, which is followed by Vellayani (27.40 per cent), then by Kulasekharam (22.10 per cent) and by Vithura (20.30 per cent).

TABLE 1. Physico-chemical properties of the representative soils of the four locations

Properties	Location			
	Vithura	Pattom	Vellayani	Kulase-kharam
Textural composition				
Coarse sand (%)	32.20	34.40	39.60	22.60
Fine sand (%)	20.30	31.70	27.40	22.10
Silt (%)	16.60	17.20	18.20	19.20
Clay (%)	24.30	15.80	14.60	28.10
Soil texture	Sandy clay	Sandy clay	Sandy clay	Clay loam
Soil type	Forest soil	Laterite	Red soil	Forest soil
pH	4.7	5.8	4.6	5.5
EC (m.mhos/cm^2)	0.2	0.2	0.3	0.8
Total nitrogen (%)	0.04	0.04	0.02	0.08
Total phosphorus (%)	0.06	0.045	0.05	0.04
Total potassium (%)	0.29	0.30	0.27	0.32
CEC (m.e/100g)	20.6	22.8	18.4	28.2
Total calcium (%)	0.68	0.70	0.58	0.72
Total magnesium (%)	0.42	0.46	0.36	0.48
Total copper (ppm)	870	940	870	960
Total manganese (ppm)	1160	1180	1070	1340
Total zinc (ppm)	940	960	880	980

The silt content of Kulasekharam was 19.20 per cent and that of Vellayani was 18.20 per cent and which is followed by Pattom (17.20 per cent) and then by Vithura (16.60 per cent).

The highest percentage of clay content was observed at Kulasekharam (28.10), which is followed by Vithura (24.30 per cent), then by Pattom (15.80 per cent) and then by Vellayani (14.60 per cent).

Texturally, the soils were sandy clay at Vithura, sandy clay loam at Pattom, sandy clay at Vellayani and clay loam at Kulasekharam.

The types of soils were forest soils at Vithura, laterite soils at Pattom, red soils at Vellayani and forest soils at Kulasekharam.

4.1.2. Soil Reaction (pH)

The pH of soils were recorded as 4.7, 5.8, 4.6 and 5.5 for Vithura, Pattom, Vellayani and Kulasekharam.

4.1.3. Electrical conductivity (EC)

The electrical conductivity of the soils were recorded as 0.2 mS/cm at Vithura and Pattom and as 0.3 mS/cm at Vellayani and 0.8 mS/cm at Kulasekharam.

4.1.4. Cation exchange capacity (CEC)

The CEC was in the order of Kulasekharam (28.2 m.e/100 g), Pattom (22.8 m.e/100 g), Vithura (20.6 m.e/100 g) and Vellayani (18.4 m.e/100 g).

4.1.5. Total nutrient content of soils

The total N content of Vithura and Pattom soils were 0.04 per cent, that of Vellayani soil 0.02 per cent, and that of Kulasekharam 0.08 per cent.

The total P content of the soils of Vithura, Pattom, Vellayani and Kulasekharam were 0.06 per cent, 0.045 per cent, 0.05 per cent and 0.04 per cent respectively.

The total K was in the order of Kulasekharam (0.32 per cent), Pattom (0.30 per cent), Vithura (0.29 per cent) and Vellayani (0.27 per cent).

In the case of calcium, Kulasekharam soils registered the highest value of 0.72 per cent, which is followed by Pattom (0.70 per cent), Vithura (0.68 per cent) and Vellayani (0.58 per cent).

The total Mg content of the soils were in the order of Kulasekharam (0.48 per cent, Pattom (0.46 per cent), Vithura (0.42 per cent) and Vellayani (0.36 per cent).

In the case of micro nutrients, its total content varied from place to place. The total Cu content of Kulasekharam soil was 960 ppm which was followed by Pattom (940 ppm). The Cu content of both Vithura and Vellayani soils were 870 ppm.

The total Mn content of the soils of Vithura, Pattom, Vellayani and Kulasekharam were 1160 ppm, 1180 ppm, 1070 ppm and 1340 ppm respectively.

The total Zn content of the soil was in the order of Kulasekharam (980 ppm), Pattom (960 ppm), Vithura (940 ppm) and Vellayani (880 ppm).

4.1.6. Location wise available nutrient status of soils

The available nutrients (N, P, K, Ca, Mg, Cu, Mn and Zn) of the soils collected from all the locations were determined. The following are the location wise details of available nutrients.

Soil samples collected from three radial distances from each tree were analysed. The mean values of analytical data pertaining to the soils collected from around 20 trees each from Vithura, Pattom and Kulasekharam and 10 trees from Vellayani is presented in Table 2 .

4.1.6.1. Vithura (Table 2)

The available N status for the first half metre distance of surface soil ranged from 0.015 to 0.028 per cent with a mean value of 0.23 per cent. The samples of one metre distance from the tree recorded values between 0.01 to 0.022 per cent with a mean value of 0.018 per cent. The samples collected from one and half metre distance provided an available N content ranging from 0.008 to 0.16 per cent with mean value of 0.01 per cent.

The available P status of soils from half metre distance ranged from 0.0009 to 0.0012 per cent with a mean value of 0.0011 per cent. Samples from one metre distance registered a value of 0.0007 to 0.0012 per cent of available P with a mean value of 0.0010 per cent. The available P content of soils from one and half metre distance ranged between 0.0005 to 0.00012 per cent with a mean value of 0.001 per cent.

The available K content of the samples collected from half metre distance ranged from 0.016 to 0.038 per cent

TABLE 2. Soil fertility status in relation to available nutrients at Vithura

(Mean values for 20 trees)

Sl No.	Nutrient	Sampling distance from the main trunk								
		0.5 metre			1.0 metre			1.5 metre		
		Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
1.	N (%)	0.015	0.028	0.023	0.010	0.022	0.018	0.008	0.016	0.01
2.	P (%)	0.0009	0.0012	0.0011	0.0007	0.0012	0.0010	0.0005	0.0012	0.001
3.	K (%)	0.016	0.038	0.03	0.015	0.032	0.024	0.007	0.028	0.016
4.	Ca (%)	0.005	0.032	0.019	0.002	0.029	0.012	0.002	0.018	0.009
5.	Mg (%)	0.011	0.022	0.017	0.011	0.021	0.015	0.010	0.022	0.015
6.	Cu (ppm)	5.780	26.24	16.736	3.71	18.42	10.821	3.78	28.44	12.26
7.	Mn (ppm)	1.980	27.91	6.194	2.220	15.32	6.341	2.20	10.56	5.83
8.	Zn (ppm)	0.712	19.19	3.498	0.878	8.00	2.656	0.703	8.00	2.27

with a mean value of 0.03 per cent. The samples collected from the one metre distance had an available K content ranging from 0.015 to 0.032 per cent with a mean value of 0.024 per cent. At 1.5 metre distance the values ranged between 0.007 to 0.028 per cent with a mean value of 0.016 per cent.

The exchangeable Ca content ranged from 0.005 to 0.032 per cent with a mean of 0.019 per cent for the soils collected from half metre distance from the main trunk, 0.002 to 0.029 per cent with a mean value of 0.012 per cent at one metre, and it ranged between 0.002 to 0.018 per cent with a mean of 0.009 per cent at the distance of 1.5 metre.

The exchangeable Mg content ranged from 0.011 to 0.022 per cent with a mean of 0.017 per cent for the soils at half metre distance, while the values recorded were 0.011 to 0.021 per cent with a mean value of 0.015 per cent at one metre distance. The soils at 1.5 metre distance had an exchangeable Mg content ranging from 0.01 to 0.022 per cent with a mean value of 0.015 per cent.

The DTPA extractable Cu at the distance of 0.5 metre ranged between 5.78 to 26.24 ppm with a mean value of 16.736 ppm. The corresponding values for the soils at one metre distance were 3.71 to 18.42 ppm (mean

10.821 ppm) and that of soils at 1.5 metre distance were 3.78 to 28.44 ppm (mean 12.26 ppm).

The DTPA extractable Mn ranged between 1.98 ppm and 27.91 ppm with a mean value of 6.194 ppm at the distance of 0.5 metre. The corresponding values for soils at one metre distance were 2.22 ppm to 15.32 ppm (mean 6.34 ppm) and that for soils at 1.5 metre, the values ranged between 2.20 ppm and 10.56 ppm with a mean value of 5.83 ppm.

For DTPA extractable Zn the maximum and minimum values were 0.712 ppm and 19.19 ppm at 0.5 metre distance from the tree (mean 3.498 ppm). At one metre the values ranged between 0.878 ppm and 8.00 ppm (mean value 2.656 ppm) and 1.5 metres the range was between 0.703 ppm and 8.00 ppm with a mean value of 2.27 ppm.

4.1.6.2. Pattom (Table 3)

The available nutrient status of this location varied appreciably from distance to distance from the tree base.

The available N status of the soils collected from half metre distance of the main trunk ranged from 0.020 to 0.036 per cent with a mean value of 0.027 per cent.

TABLE 3. Soil fertility status in relation to available nutrients at Pattom

(Mean values)

Sl No.	Nutrient	Sampling distance from the main trunk								
		0.5 metre			1.0 metre			1.5 metre		
		Range – Value		Mean	Range – Value		Mean	Range – Value		Mean
		Min.	Max.		Min.	Max.		Min.	Max.	
1.	N (%)	0.020	0.036	0.027	0.008	0.031	0.021	0.008	0.021	0.015
2.	P (%)	0.0009	0.0012	0.0011	0.0009	0.0012	0.0011	0.0009	0.0012	0.0011
3.	K (%)	0.016	0.038	0.030	0.015	0.032	0.024	0.014	0.093	0.031
4.	Ca (%)	0.039	0.164	0.101	0.049	0.162	0.090	0.059	0.098	0.082
5.	Mg (%)	0.011	0.022	0.017	0.011	0.021	0.015	0.010	0.022	0.015
6.	Cu (ppm)	4.42	16.21	9.674	1.770	21.20	5.723	5.54	21.12	10.987
7.	Mn (ppm)	6.28	186.52	62.98	11.94	118.14	64.29	21.72	121.34	73.75
8.	Zn (ppm)	0.864	4.154	2.539	1.006	3.261	2.105	1.007	3.224	2.002

The soils of one metre distance ranged from 0.008 to 0.031 per cent with a mean value of 0.021 per cent. At 1.5 metre distance the value ranged from 0.008 to 0.021 per cent with a mean value of 0.015 per cent.

The available P content of the soil at half metre distance ranged from 0.0009 to 0.0012 per cent with a mean value of 0.001 per cent. The same numerical values were obtained for the soils at one metre distance and also for the soils at 1.5 metre distance.

The available K status of the soils collected from half metre distance varied from 0.016 to 0.038 per cent with a mean value of 0.030 per cent. The values ranged from 0.015 to 0.032 per cent with a mean value of 0.024 for the soils at one metre distance. Soils at one and half metre distance gave a range of 0.014 to 0.093 per cent with a mean of 0.031 per cent.

The exchangeable Ca content of the soils at half metre distance recorded a range value of 0.039 to 0.164 per cent with a mean value of 0.101 per cent. At one metre distance the values ranged from 0.049 to 0.162 per cent with a mean value of 0.090 per cent and at 1.5 metre distance the values ranged between 0.059 per cent and 0.098 per cent with mean value of 0.082 per cent.

The exchangeable Mg content of the soils at 0.5 metre distance recorded a range value from 0.011 ppm to 0.022 ppm with a mean value of 0.017 per cent, and at one metre distance the values ranged from 0.011 to 0.021 per cent with a mean value of 0.015 per cent. At 1.5 metre distance the values ranged from 0.10 to 0.022 per cent with a mean value of 0.015 per cent.

The DTPA extractable Cu at the distance of 0.5 metre ranged between 4.42 ppm and 16.21 ppm with a mean value of 9.674 ppm. The corresponding values for soils at one metre distance ranged from 1.77 ppm to 21.20 ppm (mean 5.723 ppm) and that of the soils at 1.5 metre distance ranged from 5.54 ppm to 21.12 ppm (mean 10.987 ppm).

The DTPA extractable Mn ranged between 6.28 ppm and 186.52 ppm with a mean value of 62.98 ppm. The corresponding values for soils at one metre distance ranged from 11.94 ppm to 118.14 ppm (mean value 64.29 ppm) and that of the soils at 1.5 metre distance the values ranged between 21.72 ppm and 121.34 ppm with a mean value of 73.75 ppm.

For the DTPA extractable Zn, the maximum and minimum values were 0.864 ppm and 4.154 ppm at 0.5 metre distance with a mean value of 2.539 ppm. At one metre, the values ranged between 1.006 ppm and 3.261 ppm (mean 2.105 ppm) and at 1.5 metre the values ranged from 1.007 ppm to 3.224 ppm with a mean value of 2.022 ppm.

4.1.6.3. Vellayani (Table 4)

The available N ranged from 0.012 to 0.018 per cent with a mean value of 0.014 per cent for the soil collected from 0.5 metre distance. A range value of 0.011 to 0.018 per cent with a mean value of 0.013 per cent was registered for the soils of one metre distance. The soils of 1.5 metre distance recorded a range value of 0.01 to 0.018 per cent with a mean value of 0.011 per cent.

The available P status of the soils of 0.5 metre distance ranged from 0.001 to 0.0012 per cent with a mean value of 0.0012 per cent. The same numerical values were obtained for both the soils collected from one metre and 1.5 metre distances.

The available K status of the soils of 0.5 metre distance registered a range value of 0.008 to 0.031 per cent with a mean value of 0.018 per cent. Soils collected from one metre and 1.5 metre from the plant yielded mean value of 0.015 per cent with a range value of 0.004 to 0.021

TABLE 4. Soil fertility status in relation to available nutrients at Vellayani

(Mean values)

Sl No.	Nutrient	Sampling distance from the main trunk: 0.5 metre			1.0 metre			1.5 metre		
		Range – Value		Mean	Range – Value		Mean	Range – Value		Mean
		Min.	Max.		Min.	Max.		Min.	Max.	
1.	N (%)	0.012	0.018	0.014	0.011	0.018	0.013	0.010	0.018	0.011
2.	P (%)	0.001	0.0012	0.0012	0.001	0.0012	0.0012	0.0010	0.0012	0.0012
3.	K (%)	0.008	0.031	0.018	0.004	0.021	0.015	0.004	0.023	0.015
4.	Ca (%)	0.011	0.026	0.019	0.004	0.029	0.014	0.005	0.024	0.011
5.	Mg (%)	0.010	0.012	0.011	0.01	0.012	0.011	0.01	0.012	0.011
6.	Cu (ppm)	0.242	0.92	0.648	0.380	0.862	0.685	0.170	0.944	0.742
7.	Mn (ppm)	10.60	21.45	18.30	8.67	26.00	17.38	13.93	28.00	19.28
8.	Zn (ppm)	0.732	3.232	1.64	0.628	3.231	1.391	0.540	6.714	1.710

per cent for the soils at one metre distance and from 0.004 to 0.023 per cent for the soils at 1.5 metre distance.

The exchangeable Ca content ranged from 0.011 per cent to 0.226 per cênt with a mean of 0.019 per cent for the soil collected from 0.5 metre distance. The corresponding value for the soils at one metre distance were 0.004 per cent to 0.029 per cent (mean 0.014 per cont) and that for soils at 1.5 metre distance the value ranged between 0.005 per cent and 0.024 per cent with a mean of 0.011 per cent.

The exchangeable Mg content ranged from 0.010 to 0.012 per cent with a mean of 0.011 per cent for the soils at 0.5 metre distance, while the values recorded were 0.01 to 0.012 per cent with a mean value of 0.011 per cent at one metre. The soils at 1.5 metre distance had the exchangeable Mg content ranging from 0.01 to 0.012 per cent with a mean value of 0.011 per cent.

The DTPA extractable Cu at 0.5 metre distance ranged from 0.242 to 0.92 ppm with a mean value of 0.648 ppm. The corresponding value for the soils at 1.0 metre distance were 0.380 to 0.862 ppm (mean 0.685 ppm) and that for soils at 1.5 metre distance were 0.170 to 0.944 ppm (mean 0.742 ppm).

The DTPA extractable Mn ranged between 10.60 ppm and 21.45 ppm with a mean value of 18.30 ppm at the distance of 0.5 metre. The corresponding values for the soils at one metre distance were 8.67 ppm to 26.00 ppm (mean 17.38 ppm) and that of soils at 1.5 metre distance the values ranged between 13.93 ppm and 28.00 ppm with a mean value of 19.28 ppm.

In the case of DTPA extractable Zn, the maximum and minimum values were 0.732 and 3.232 ppm at 0.5 metre distance from the tree (mean 1.69 ppm). At one metre the values ranged between 0.628 ppm and 3.231 ppm (mean 1.391 ppm) and at 1.5 metre the range was between 0.54 ppm and 6.714 ppm with a mean value of 1.71 ppm.

4.1.6.4. Kulasekharam (Table-5)

The available N status ranged from 0.012 to 0.018 per cent with a mean value of 0.017 per cent for the soils collected from 0.5 metre distance. Soils of both at one metre and 1.5 metre distances recorded a range value from 0.01 to 0.018 per cent with a mean value of 0.014 per cent.

The available P status of the soils collected from half metre distance registered a range value of 0.0005 to 0.0008 per cent with a mean value of 0.0007 per cent.

TABLE 5. Soil fertility status in relation to available nutrients at Kulasekharam

(Mean values)

Sl No.	Nutrient	Sampling distance from the main trunk								
		0.5 metre			1.0 metre			1.5 metre		
		Range - Value		Mean	Range - Value		Mean	Range - Value		Mean
		Min.	Max.		Min.	Max.		Min.	Max.	
1.	N(%)	0.012	0.018	0.016	0.010	0.018	0.014	0.010	0.018	0.014
2.	P(%)	0.0005	0.0008	0.0007	0.0006	0.0009	0.0007	0.0005	0.0009	0.0007
3.	K(%)	0.022	0.033	0.025	0.018	0.037	0.026	0.020	0.034	0.025
4.	Ca(%)	0.017	0.124	0.081	0.03	0.102	0.070	0.021	0.102	0.085
5.	Mg(%)	0.016	0.024	0.020	0.015	0.023	0.019	0.014	0.022	0.018
6.	Cu(ppm)	1.6	4.0	2.47	0.98	10.26	2.97	1.75	7.22	3.52
7.	Mn(ppm)	8.2	67.0	35.1	40.18	183.32	69.63	33.12	87.16	66.47
8.	Zn(ppm)	2.83	7.62	4.81	2.14	7.61	4.80	2.23	10.11	5.31

The soils of one metre distance and 1.5 metre distance exhibited the same mean value of 0.0007 per cent of available P with a range value from 0.0006 to 0.0009 per cent and from 0.0005 to 0.0009 per cent respectively.

The available K content of the soils collected from half metre distance had a range value of 0.022 to 0.033 per cent with a mean value of 0.025 per cent. A range value of 0.018 to 0.037 was observed for the soils from one metre distance with a mean value of 0.026 per cent. The soils from 1.5 metre distance had available K content between 0.020 and 0.034 per cent with a mean value of 0.025 per cent.

The exchangeable Ca content of the soils at 0.5 metre distance recorded a range value between 0.017 and 0.124 per cent and a mean value of 0.081 per cent. The soils at one metre distance registered a range value between 0.030 per cent and 0.102 per cent with a mean value of 0.070 per cent while the soils collected at 1.5 metre distance recorded minimum and maximum values of 0.014 and 0.022 per cent with a mean value of 0.018 per cent.

The exchangeable Mg content of the soils at half metre distance registered a range value between 0.016 per cent and 0.024 per cent with a mean value of 0.02 per cent, while the soils at one metre distance recorded maximum and minimum values of 0.015 per cent and 0.023 per cent with a mean of 0.019 per cent. The values for soils from 1.5 metre distance, ranged from 0.014 to 0.022 per cent with a mean value of 0.018 per cent.

The DTPA extractable Cu content of the soils at 0.5 metre distance varied from 1.60 ppm to 4.00 ppm with a mean value of 2.42 ppm while the soils at one metre distance varied from 0.98 ppm to 10.26 ppm with a mean value of 2.97 ppm. Soils at 1.5 metre distance registered a range value from 1.75 ppm to 7.22 ppm with a mean value of 3.52 ppm.

The DTPA extractable Mn content of soils at 0.5 metre varied from 8.20ppm to 67 ppm with a mean value of 35.1 ppm and values for the soils collected at one metre distance varied from 33.12 ppm to 87.16 ppm with a mean value of 66.47 ppm. The values for soils at 1.5 metre distance ranged between 33.12 ppm and 87.16 ppm with a mean value of 66.47 ppm.

The DTPA extractable Zn content of the soils at 0.5 metre distance varied from 9.82 ppm to 7.62 ppm with a mean value of 4.81 ppm. Soils collected at one metre distance showed a range value of 2.14 ppm (minimum) and 7.61 ppm (maximum) with a mean value of 4.8 ppm. The soils at 1.5 metre distance registered a range value between 2.23 ppm and 10.11 ppm with a mean value of 5.31 ppm.

4.2. NUTRIENT CONCENTRATIONS IN LEAF SAMPLES

The leaf samples were analysed for their nutrient concentrations with reference to N, P, K, Ca, Mg, Cu, Mn and Zn. The entire canopy was divided into 3 regions viz., top, middle and bottom. Three whorls starting from the tip of branchlets were sampled for analysis (W_1, W_2, W_3). The results indicated appreciable variations within a tree from region to region and also among leaf positions (whorl to whorl). The results obtained for each location are presented below.

4.2.1. Nitrogen

4.2.1.1. Vithura (Table 6)

The nitrogen content of different whorls in all the three regions of the canopy showed wide variation. In the first wholr of leaves in the top portion, the N content ranged from 1.587 to 2.262 per cent with a mean value of 2.133 per cent. Whorl II had a nitrogen content the range value of 1.293 to 2.2 per cent with a mean value of 1.981 per cent. The whorl III had a range value of 1.47 per cent and 2.116 per cent with a mean value of 1.861 per cent. The coefficients of variation for W_1, W_2 and W_3 were 7.757, 11.289 and 10.589 respectively.

TABLE 6. Nitrogen concentration in leaf at Vithura

(Mean values - per cent)

Tree No.	Tree Regions								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	2.234	2.175	1.587	2.822	2.234	2.058	1.882	1.646	1.470
2.	1.882	1.293	1.587	1.528	1.411	1.411	1.764	1.293	1.352
3.	1.587	1.470	1.470	1.528	1.470	1.352	1.705	1.587	1.528
4.	2.234	2.116	2.116	2.175	2.058	2.058	2.293	1.587	1.646
5.	2.058	1.999	1.940	1.999	1.940	1.940	1.881	1.822	1.822
6.	2.175	2.058	1.999	2.116	1.940	1.822	1.940	1.940	1.764
7.	2.258	2.058	1.881	1.940	1.881	1.882	1.822	1.822	1.646
8.	2.234	2.058	1.999	2.116	1.940	1.822	1.940	1.940	1.764
9.	1.999	1.881	1.999	1.881	1.882	1.764	1.822	1.764	1.764
10.	2.058	1.999	1.999	1.940	1.881	1.881	1.881	1.881	1.764
11.	2.202	2.000	1.824	2.200	1.800	1.802	1.982	1.802	1.682
12.	2.220	2.120	1.624	2.002	2.002	1.824	2.202	1.824	1.802
13.	2.220	2.120	1.624	2.002	2.002	1.824	2.202	1.824	1.802
14.	2.211	2.001	1.862	2.220	1.862	1.682	1.982	1.684	1.600
15.	2.121	1.864	1.662	2.001	1.982	1.868	1.940	1.881	1.764
16.	2.206	2.001	1.926	2.001	2.001	2.068	2.002	2.000	1.862
17.	2.244	2.200	2.112	2.202	2.100	2.001	2.240	1.988	1.892
18.	2.118	2.006	2.008	2.218	2.020	2.018	2.008	2.001	1.886
19.	2.242	2.118	2.008	2.118	2.002	1.982	2.242	2.116	2.008
20.	2.262	2.086	2.002	2.246	2.186	2.008	2.216	2.086	2.006
Mean	2.133	1.981	1.861	2.062	1.929	1.859	1.997	1.827	1.744
CV	7.757	11.289	10.589	13.031	10.256	10.453	8.822	10.704	9.677

In the middle region N content in the first whorls ranged from 1.528 to 2.822 per cent with a mean value of 2.062 per cent. The 2nd whorls registered a range value of 1.411 to 2.234 per cent N with a mean of 1.929 per cent. The leaves from the 3rd whorl recorded N content ranging from 1.411 to 2.058 per cent with a mean of 1.859 per cent. In this region the coefficients of variation for W_1, W_2 and W_3 were 13.031, 10.256 and 10.453, respectively.

The N content of the W_1 leaf samples in the bottom region ranged between 1.705 and 2.293 per cent with a mean value of 1.997 per cent while the W_2 leaf samples had a minimum of 1.293 per cent and a maximum of 2.116 per cent with a mean value of 1.827 per cent. The W_3 leaf samples recorded a N content ranging from 1.352 per cent (minimum) to 2.008 per cent (maximum) with a mean value of 1.744 per cent. The coefficients of variation for W_1, W_2 and W_3 samples were 8.822, 10.704 and 9.677, respectively.

4.2.1.2. Pattom (Table 7)

The top region of the trees had appreciable variation in their N content from whorl to whorl as found in Vithura locality. The W_1 samples recorded a range value of 2.234 to 2.6 per cent with a mean value of 2.385 per cent.

TABLE 7. Nitrogen concentration in leaf at Pattom

(Mean value - per cent)

Tree No.	Tree Regions								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	2.923	2.116	2.116	2.234	2.175	2.116	2.175	1.992	1.992
2.	2.450	2.340	2.175	2.340	2.175	2.175	2.175	2.058	1.992
3.	2.350	2.116	2.058	2.116	2.058	2.116	2.175	2.116	2.058
4.	2.410	2.116	2.234	2.116	2.116	2.058	2.175	2.058	1.940
5.	2.293	2.234	2.175	2.175	2.058	1.992	2.058	1.940	1.880
6.	2.234	2.175	2.116	2.058	1.992	1.940	2.116	2.058	1.992
7.	2.293	2.234	2.175	2.234	2.175	2.116	2.175	2.058	1.992
8.	2.475	2.175	2.058	2.116	2.050	2.005	1.992	1.998	1.881
9.	2.234	2.175	2.175	2.116	2.058	2.058	2.058	1.892	1.686
10.	2.293	2.058	2.982	2.058	2.116	1.992	1.992	1.940	1.822
11.	2.421	2.201	2.116	2.301	2.028	2.001	2.224	2.108	2.001
12.	2.401	2.231	2.024	2.323	2.001	1.982	2.248	2.201	1.987
13.	2.368	2.168	2.106	2.301	2.001	2.986	2.420	2.002	1.968
14.	2.520	2.200	2.001	2.382	2.101	2.061	2.268	2.002	2.002
15.	2.600	2.400	2.201	2.464	2.202	2.002	2.325	2.002	1.968
16.	2.464	2.026	2.002	2.363	2.116	2.001	2.168	1.908	1.608
17.	2.358	2.201	2.002	2.202	2.002	1.968	2.200	2.100	1.900
18.	2.456	2.202	2.101	2.026	2.156	2.002	2.101	2.101	1.980
19.	2.368	2.060	2.002	2.460	2.006	2.116	2.026	2.268	2.300
20.	2.424	2.002	2.042	2.062	2.006	1.868	2.074	2.001	1.976
Mean	2.385	2.189	2.093	2.234	2.068	2.025	2.107	2.039	1.946
CV	3.611	3.728	4.317	7.041	3.932	4.217	13.071	4.593	7.122

The W_2 leaf samples recorded a lowest value of 0.026 and a highest value of 2.400 per cent with a mean of 2.189 per cent of N. The W_3 samples registered a N content ranging from 2.001 to 2.234 per cent (mean value 2.093 per cent. The coefficients of variation for the W_1, W_2 and W_3 samples of top region were 3.611, 3.728 and 4.317, respectively.

In the middle region the W_1 had a range value of 2.026 to 2.464 per cent with a mean of 2.234 per cent. The W_2 leaf samples recorded a lowest value of 1.992 per cent and a highest value of 2.202 per cent with a mean of 2.068 per cent of N content. The W_3 samples registered N content ranging from 1.868 per cent to 2.175 per cent with a mean value of 2.025 per cent. At this region the cv values were 7.041, 3.932 and 4.217 for W_1, W_2 and W_3 leaves, respectively.

The W_1 leaf samples of bottom region registered N contents ranging from 1.99 to 2.42 per cent (mean value 2.107 per cent). The W_2 leaf samples had N content ranging from 1.892 to 2.268 with a mean value of 2.039 per cent. The N content ranged from 1.686 to 1.822 per cent (mean value - 1.946 per cent), for the W_3 leaf samples. The cv values for this region were 13.071, 4.593 and 7.122 for W_1, W_2 and W_3, respectively.

4.2.1.3. Vellayani (Table 8)

The N content of the leaf samples collected from the top region of clove plants at Vellayani showed marked variation from whorl to whorl. The W_1 leaf samples exhibited the lowest N content of 1.992 and a highest value of 2.258 per cent with a mean of 2.143. The W_2 and W_3 samples registered more or less the same variation, i.e., from 1.881 to 2.116 per cent with a mean of 1.970 and 1.939 per cent respectively. At this region the cv values for W_1, W_2 and W_3 were 2.457, 4.391 and 4.501, respectively.

In the middle region the W_1 samples had a lowest N content of 1.940 per cent and a highest value of 2.234 per cent with a mean of 2.07 per cent, whereas the W_2 leaf samples showed a range value from 1.822 to 2.200 per cent with a mean of 1.98 per cent. In the case of W_3 leaf sample, the lowest value was 1.764 per cent and the highest value was 2.058 per cent with a mean value of 1.981. The cv values were 4.663, 5.57 and 5.016 for W_1, W_2 and W_3, respectively.

The W_1 leaf samples of bottom region had a N status ranging from 1.94 to 2.16 per cent with a mean of 2.014 per cent. The W_2 leaf samples exhibited a range value from 1.822 to 2.116 per cent with a mean of 1.952.

TABLE 8. Nitrogen concentration of leaf at Vellayani

(Mean value per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	2.175	2.116	2.116	2.175	2.058	1.992	2.116	2.116	1.992
2.	2.258	1.992	1.940	2.116	2.058	2.058	1.940	1.940	1.940
3.	2.058	1.992	1.981	2.116	1.992	1.881	1.992	1.940	1.822
4.	1.992	1.822	1.822	1.940	1.822	1.822	2.058	2.005	1.902
5.	2.202	1.902	1.882	2.002	2.200	1.001	1.992	1.882	1.822
6.	2.234	2.058	1.992	1.234	1.992	1.940	1.992	1.940	1.882
7.	2.116	2.002	2.001	2.116	2.002	2.002	2.000	2.001	1.884
8.	2.008	1.881	1.822	2.058	1.881	1.822	2.001	1.822	1.764
9.	2.175	1.940	1.882	1.940	1.822	1.764	2.058	1.992	1.940
10.	2.216	2.002	2.001	2.039	1.922	1.900	1.992	1.884	1.822
Mean	2.143	1.9707	1.939	2.0745	1.9809	1.918	2.0141	1.952	1.883
CV	2.457	4.391	4.501	4.663	5.557	5.016	3.981	3.555	4.201

The N content of the W_3 leaf samples varied from 1.764 to 1.992 per cent with a mean value of 1.883 per cent. At this region the cv value for W_1, W_2 and W_3 samples were 3.981, 3.555 and 4.201, respectively.

4.2.1.4. Kulasekharam (Table 9)

The mean value of N content of leaf in this region also showed a marked variation from region to region within the plant and also among the three whorls.

A range of values between 2.058 and 2.442 per cent N were recorded in the W_1 leaf samples of top region with a mean of 2.75. In the W_2 and W_3 leaf samples, variations in N content from 1.802 to 2.276 per cent and 1.682 to 2.22 per cent respectively were recorded with mean values of 2.123 and 2.016 per cent. For this region, the cv values were 3.838, 6.843 and 8.325 for W_1, W_2 and W_3 leaves, respectively.

In the middle region the W_1 sample showed a variation from 2.008 to 2.334 per cent nitrogen (mean value of 2.185 per cent) and W_2 samples registered a lowest value of 1.992 and a highest value of 2.274 per cent (mean value 2.092 per cent). The W_3 leaves registered N

TABLE 9. Nitrogen concentration in leaf at Kulasekharam

(Mean values - per cent)

Tree No.	Tree Regions								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	2.392	2.200	2.102	2.234	2.174	2.100	2.058	1.928	1.628
2.	2.305	2.175	1.800	2.175	2.116	1.082	2.116	1.992	1.686
3.	2.175	1.803	1.682	2.116	2.008	1.018	2.116	2.058	1.726
4.	2.294	2.084	2.116	2.234	2.058	2.002	2.058	2.001	1.678
5.	2.410	2.200	2.002	2.175	2.111	2.002	2.175	2.162	2.084
6.	2.175	2.116	2.116	2.176	2.116	1.984	2.212	2.008	1.986
7.	2.058	1.992	1.992	2.116	2.058	2.116	1.992	1.992	1.640
8.	2.175	2.116	2.178	2.175	2.058	2.058	2.116	2.002	1.992
9.	2.293	2.175	2.175	2.234	0.020	1.992	2.175	2.116	2.058
10.	2.234	2.058	1.940	2.058	1.992	1.668	2.116	2.020	1.668
11.	2.310	2.210	2.110	2.334	2.274	2.200	2.158	1.928	1.628
12.	2.405	2.276	1.900	2.275	2.116	1.802	2.226	2.100	1.828
13.	2.176	1.902	1.782	2.226	2.200	2.008	2.226	2.058	1.738
14.	2.284	2.084	2.116	2.234	2.058	2.100	2.226	2.002	1.678
15.	2.442	2.300	2.100	2.176	2.202	2.008	2.276	2.262	2.086
16.	2.317	2.226	2.118	2.178	2.008	1.982	2.202	2.008	1.986
17.	2.168	1.992	1.668	2.116	2.068	2.116	1.909	1.808	1.640
18.	2.175	2.080	2.211	2.118	2.008	2.006	2.008	2.002	1.982
19.	2.383	2.276	2.220	2.244	2.222	2.100	2.168	2.116	2.002
20.	2.234	2.002	1.940	2.008	1.992	1.668	2.116	2.000	1.668
Mean	2.755	2.123	2.016	2.185	2.092	1.936	2.136	2.078	1.819
CV	3.838	6.843	8.325	4.328	0.016	13.423	4.681	11.293	9.767

content ranging from 1.018 to 2.2 per cent with a mean of 1.936 per cent. The cv value for W_1, W_2 and W_3 were 4.328, 4.016 and 13.423, respectively.

In the bottom region the N percentage varied in the W_1, W_2 and W_3 samples from 1.909 to 2.226 (mean value 2.136) from 1.808 to 2.262 (mean 2.078) and from 1.628 to 2.086 (mean 1.819) respectively. The cv values were 4.681, 11.293 and 9.767, respectively.

4.2.2. Phosphorus

4.2.2.1. Vithura (Table 10)

The phosphorus status at the top region of the tree showed a remarkable variation with reference the three whorls studied. The W_1 samples at the top region registered a lowest value of 0.140 per cent and a highest value of 0.280 (mean 0.270 per cent). For the W_2 and W_3 samples, the P content varied from 0.012 to 0.24 per cent (mean 0.173) and from 0.110 to 0.270 per cent (mean 0.165), respectively. The cv values for W_1, W_2 and W_3 leaves were 16.110, 23.655 and 26.417, respectively.

In the middle region the P status varied among the W_1, W_2 and W_3 samples from 0.160 to 0.260 per cent (mean 0.213), 0.120 to 0.260 per cent (mean 0.180) and 0.110 to 0.210 per cent (mean 0.160), respectively. The cv

TABLE 10. Phosphorus concentrations in leaf at Vithura

(Mean value - per cent)

Tree No.	Tree Regions								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.16	0.14	0.12	0.18	0.15	0.11	0.26	0.19	0.12
2.	0.18	0.14	0.13	0.20	0.14	0.16	0.20	0.19	0.22
3.	0.18	0.13	0.20	0.20	0.13	0.13	0.21	0.12	0.11
4.	0.14	0.12	0.13	0.18	0.12	0.12	0.20	0.16	0.12
5.	0.16	0.14	0.12	0.18	0.14	0.16	0.18	0.14	0.14
6.	0.18	0.14	0.12	0.16	0.16	0.14	0.20	0.18	0.18
7.	0.21	0.20	0.18	0.20	0.18	0.16	0.20	0.18	0.14
8.	0.16	0.14	0.12	0.18	0.16	0.12	0.18	0.12	0.11
9.	0.14	0.12	0.11	0.16	0.14	0.12	0.18	0.12	0.11
10.	0.20	0.18	0.16	0.20	0.14	0.12	0.16	0.14	0.12
11.	0.21	0.21	0.21	0.21	0.21	0.19	0.26	0.18	0.18
12.	0.22	0.18	0.16	0.23	0.20	0.21	0.26	0.20	0.16
13.	0.24	0.20	0.16	0.23	0.21	0.19	0.24	0.21	0.19
14.	0.25	0.21	0.20	0.22	0.18	0.16	0.26	0.25	0.15
15.	0.26	0.24	0.27	0.23	0.27	0.21	0.22	0.21	0.18
16.	0.24	0.20	0.21	0.22	0.22	0.18	0.26	0.24	0.22
17.	0.23	0.21	0.18	0.26	0.21	0.19	0.26	0.22	0.21
18.	0.28	0.20	0.21	0.26	0.21	0.18	0.26	0.19	0.16
19.	0.26	0.24	0.20	0.24	0.26	0.18	0.26	0.23	0.18
20.	0.24	0.21	0.20	0.26	0.21	0.18	0.26	0.21	0.16
Mean	0.207	0.173	0.165	0.213	0.180	0.160	0.382	0.179	0.169
CV	16.110	23.655	26.417	16.315	22.484	19.957	15.389	20.327	27.281

values were 16.315, 22.484 and 19.957 for W_1, W_2 and W_3 samples, respectively.

In the bottom region the W_1, W_2 and W_3 samples registered values ranging from 0.180 to 0.260 per cent (mean 0.382), from 0.110 to 0.250 per cent (mean 0.179) and from 0.110 to 0.220 per cent (mean 0.165) with cv values of 15.389, 20.327 and 27.281, respectively.

4.2.2.2. Pattom (Table 11)

In the top region of the trees P status of W_1, W_2 and W_3 samples varied from 0.210 to 0.280 per cent (mean 0.251) from 0.162, 0.240 per cent (mean 0.196) and from 0.140 to 0.240 per cent (mean 0.179) with cv values of 12.511, 11.634 and 15.065, respectively.

In the middle region the W_1 samples had a variation from 0.200 to 0.280 per cent with a mean value of 0.241. The W_2 and W_3 samples recorded P content from 0.140 to 0.260 per cent (mean values 0.194) and from 0.120 to 0.250 per cent (mean 0.170), respectively. At this region the W_1, W_2 and W_3 samples had the cv values of 9.414, 17.131 and 19.252, respectively.

The P concentration

~~In~~ the bottom region W_1, W_2 and W_3 samples, the P concentration varied from 0.220 to 0.280 per cent (mean

TABLE 11. Phosphorus concentration in leaf at Pattom

(Mean value - per cent)

Tree No.	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.25	0.18	0.14	0.24	0.18	0.16	0.22	0.16	0.16
2.	0.26	0.21	0.16	0.24	0.20	0.21	0.24	0.20	0.18
3.	0.26	0.18	0.18	0.23	0.14	0.12	0.26	0.21	0.17
4.	0.28	0.22	0.20	0.22	0.18	0.16	0.24	0.18	0.16
5.	0.24	0.18	0.16	0.20	0.16	0.12	0.22	0.21	0.18
6.	0.24	0.16	0.15	0.22	0.20	0.18	0.26	0.21	0.20
7.	0.26	0.19	0.17	0.24	0.16	0.19	0.26	0.21	0.16
8.	0.24	0.16	0.15	0.21	0.18	0.14	0.28	0.16	0.12
9.	0.23	0.18	0.21	0.21	0.16	0.15	0.28	0.18	0.16
10.	0.25	0.21	0.20	0.24	0.16	0.12	0.26	0.16	0.18
11.	0.28	0.21	0.20	0.26	0.24	0.20	0.28	0.26	0.20
12.	0.24	0.18	0.15	0.27	0.21	0.18	0.27	0.20	0.19
13.	0.26	0.22	0.20	0.28	0.22	0.21	0.26	0.22	0.20
14.	0.24	0.18	0.16	0.26	0.22	0.21	0.26	0.26	0.18
15.	0.25	0.20	0.18	0.24	0.18	0.16	0.25	0.22	0.21
16.	0.27	0.22	0.24	0.24	0.21	0.20	0.26	0.24	0.20
17.	0.21	0.17	0.15	0.22	0.16	0.12	0.26	0.16	0.12
18.	0.24	0.22	0.20	0.26	0.24	0.20	0.26	0.22	0.20
19.	0.26	0.21	0.18	0.27	0.26	0.25	0.25	0.22	0.20
20.	0.27	0.24	0.21	0.26	0.22	0.20	0.28	0.24	0.21
Mean	0.251	0.196	0.179	0.241	0.194	0.170	0.258	0.208	0.181
CV	12.511	11.634	15.065	9.414	17.131	19.252	6.859	16.180	16.794

Tree Regions: Top, Middle, Bottom

0.258), 0.160 to 0.260 per cent (mean 0.208) and from 0.120 to 0.210 per cent (mean 0.181) respectively. The corresponding cv values were 6.859, 16.180 and 16.794, respectively for W_1, W_2 and W_3.

4.2.2.3. Vellayani (Table 12)

In the top region of the trees the W_1 samples had a P content ranging from 0.110 to 0.160 per cent with a mean value of 0.132. The P status of W_2 and W_3 samples varied from 0.080 to 0.160 per cent (mean 0.116) and from 0.080 to 0.120 per cent (mean 0.090), respectively. The cv values for W_1, W_2 and W_3 leaves were 16.524, 19.147 and 18.885, respectively.

In the middle region the P status of W_1, W_2 and W_3 samples ranged from 0.080 to 0.160 per cent (mean 0.117) from 0.080 to 0.120 per cent (mean 0.100) and from 0.040 to 0.110 per cent (mean 0.084) respectively. The cv values for the three whorls were recorded as 17.117, 17.638 and 22.587, respectively.

The bottom region of the tree also showed a variation in P status from whorl to whorl ranging from 0.080 to 0.240 per cent (mean 0.165) for the first whorl, from 0.060 to 0.120 per cent (mean 0.100) for the 2nd whorl and from 0.060 to 0.120 per cent (mean 0.090) for

TABLE 12. Phosphorus concentrations in leaf at Vellayani

(Mean value per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.15	0.10	0.08	0.16	0.12	0.11	0.24	0.12	0.08
2.	0.12	0.16	0.08	0.12	0.10	0.08	0.20	0.10	0.11
3.	0.14	0.12	0.10	0.12	0.11	0.10	0.12	0.11	0.10
4.	0.16	0.14	0.12	0.12	0.10	0.08	0.14	0.12	0.10
5.	0.12	0.10	0.08	0.11	0.10	0.08	0.10	0.08	0.06
6.	0.14	0.12	0.11	0.12	0.11	0.08	0.21	0.08	0.08
7.	0.11	0.08	0.06	0.08	0.06	0.04	0.20	0.11	0.12
8.	0.12	0.11	0.09	0.12	0.11	0.09	0.13	0.11	0.09
9.	0.14	0.12	0.09	0.12	0.11	0.10	0.22	0.11	0.09
10.	0.12	0.11	0.09	0.10	0.08	0.08	0.08	0.06	0.06
Mean	0.132	0.116	0.09	0.117	0.100	0.084	0.165	0.100	0.09
CV	16.524	19.147	18.885	17.117	17.638	22.587	12.267	19.999	22.129

the third whorl, with cv values of 12.267, 19.999 and 22.125, respectively.

4.2.2.4. Kulasekharam (Table 13)

The leaf P status of W_1 of the top region indicated a variation from 0.100 to 0.120 per cent (mean 0.110). The W_2 and W_3 samples recorded P content from 0.100 to 0.120 per cent (mean 0.107) and from 0.010 to 0.120 per cent (mean 0.106), respectively. The cv values for this position were 19.147, 18.880 and 17.121 respectively for the three whorls.

In the middle region the W_1, W_2 and W_3 samples yielded P content ranging from 0.110 to 0.150 per cent (mean 0.125), from 0.100 to 0.130 per cent (mean 0.115) and from 0.100 to 0.130 per cent (mean 0.114) with a cv values of 17.116, 17.63 and 22.58, respectively.

In the bottom region the P status of W_1 samples varied from 0.120 to 0.190 per cent (mean value 0.140), and from 0.110 to 0.130 per cent (mean 0.117) for both the W_2 and W_3 samples. The cv values for P content for the three whorls were 14.260, 16.520 and 22.12, respectively.

4.2.3. Potassium

4.2.3.1. Vithura (Table 14)

In the top region, the K status of W_1, W_2 and W_3 leaf samples varied from 2.176 to 2.720 per cent (mean

TABLE 13. Phosphorus concentration in leaf at Kulasekharam

(Mean values per cent)

Tree No.	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.11	0.10	0.10	0.11	0.11	0.11	0.13	0.12	0.13
2.	0.12	0.11	0.10	0.12	0.12	0.12	0.19	0.12	0.12
3.	0.11	0.10	0.10	0.13	0.12	0.11	0.13	0.11	0.12
4.	0.10	0.11	0.11	0.14	0.12	0.13	0.14	0.12	0.13
5.	0.12	0.11	0.11	0.14	0.11	0.11	0.14	0.13	0.12
6.	0.11	0.10	0.10	0.15	0.12	0.11	0.14	0.11	0.11
7.	0.10	0.11	0.11	0.12	0.11	0.11	0.14	0.12	0.13
8.	0.11	0.10	0.10	0.11	0.11	0.11	0.12	0.11	0.11
9.	0.12	0.11	0.11	0.12	0.12	0.12	0.14	0.11	0.11
10.	0.11	0.11	0.11	0.11	0.10	0.11	0.19	0.12	0.11
11.	0.11	0.10	0.10	0.14	0.12	0.12	0.14	0.11	0.11
12.	0.12	0.11	0.10	0.13	0.11	0.11	0.14	0.13	0.12
13.	0.10	0.10	0.11	0.12	0.11	0.10	0.12	0.12	0.12
14.	0.10	0.11	0.10	0.13	0.12	0.12	0.13	0.11	0.12
15.	0.10	0.11	0.10	0.11	0.11	0.11	0.14	0.11	0.11
16.	0.11	0.11	0.11	0.14	0.13	0.12	0.14	0.13	0.12
17.	0.12	0.11	0.11	0.12	0.12	0.11	0.12	0.12	0.12
18.	0.10	0.10	0.10	0.11	0.12	0.12	0.14	0.11	0.11
19.	0.11	0.11	0.10	0.12	0.11	0.10	0.13	0.12	0.12
20.	0.12	0.12	0.12	0.13	0.11	0.12	0.14	0.11	0.11
Mean	0.11	0.107	0.105	0.125	0.115	0.114	0.140	0.117	0.117
CV	19.147	18.88	17.21	17.117	17.63	22.58	14.26	16.52	22.125

Tree Regions

TABLE 14. Potassium concentration in leaf at Vithura

(Mean value - per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	2.176	2.112	1.792	2.432	2.368	1.984	2.496	2.432	2.112
2.	2.304	2.176	2.112	2.496	2.304	2.176	2.624	2.432	2.048
3.	2.612	2.240	1.984	2.240	2.240	2.112	2.496	2.496	2.176
4.	2.240	2.240	2.048	2.112	2.048	1.984	1.980	2.122	1.856
5.	2.240	2.176	1.920	1.920	1.856	1.600	2.176	2.112	1.856
6.	2.432	2.368	1.984	2.368	2.304	2.112	2.368	2.368	2.240
7.	2.344	2.176	2.112	2.176	2.176	1.824	2.400	2.304	2.048
8.	2.240	2.304	1.920	2.304	2.368	1.984	2.240	2.176	1.984
9.	2.720	1.948	1.920	2.112	2.112	1.984	2.176	2.176	1.920
10.	2.368	1.984	2.084	2.496	2.368	2.336	2.368	2.368	2.272
11.	2.432	2.368	1.984	2.176	2.112	1.792	2.400	2.112	1.984
12.	2.496	2.304	2.176	2.624	2.432	2.048	2.112	2.400	2.240
13.	2.402	2.240	2.112	2.112	1.980	1.792	2.211	1.980	1.792
14.	2.240	2.112	2.048	2.112	2.048	1.984	2.112	1.980	1.856
15.	2.400	2.176,	1.920	2.176	2.112	1.856	1.920	1.856	1.600
16.	2.304	2.112	2.304	2.432	2.368	2.112	2.368	2.112	2.112
17.	2.400	2.304	2.048	2.144	2.176	2.112	2.176	2.176	1.824
18.	2.304	2.002	1.984	2.240	2.304	1.920	2.176	1.984	1.984
19.	2.612	2.112	2.048	2.176	2.176	1.920	1.920	1.984	1.856
20.	2.568	2.368	2.272	2.368	1.984	2.084	2.496	2.368	2.336
Mean	2.262	2.192	2.038	2.260	2.198	1.985	2.256	2.246	2.004
CV	5.582	6.236	6.074	7.687	4.706	8.260	8.994	11.091	9.482

2.262) from 1.984 to 2.368 per cent (mean 2.192) and from 1.792 to 2.304 per cent (mean 2.038), with cv values of 5.582, 6.236 and 6.074, respectively.

In the middle region the K status of W_1, W_2 and W_3 ranged from 1.920 to 2.624 per cent (mean 2.26) from 0.186 to 2.432 per cent (mean 2.198) and from 1.600 to 2.336 per cent (mean 1.985) with cv values of 7.687, 6.706 and 8.260, respectively.

In the bottom region the K status of W_1, W_2 and W_3 leaf samples ranged from 1.920 to 2.624 per cent (mean 2.256) from 1.856 to 2.432 per cent (mean 2.246) and from 1.600 to 2.240 per cent (mean 2.004) with cv values of 8.994, 11.091 and 9.482, respectively.

4.2.3.2. Pattom (Table 15)

In the top region of the trees of Pattom location the K content varied from 2.176 to 2.688 per cent (mean 2.486) for W_1 samples, from 1.408 to 2.560 per cent (mean 2.169) for W_2 and from 1.408 to 2.496 per cent (mean 2.024) for W_3 leaf samples. The coefficients of variation for W_1, W_2 and W_3 leaves were 6.650, 12.374 and 12.211, respectively.

In the middle region of the tree, the K status of W_1, W_2 and W_3 leaf samples varied from 2.020 to 2.680 per cent (mean 2.393), from 1.792 to 2.680 per cent (mean 2.174) and from 1.504 to 2.464 per cent (mean 1.997)

TABLE 15 Potassium concentration in leaf at Pattom

(Mean value - per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	2.368	1.920	1.760	2.496	1.920	2.464	2.560	2.400	1.856
2.	2.560	2.176	2.240	2.680	2.680	2.336	2.400	2.212	2.020
3.	2.400	2.368	2.112	2.624	2.368	2.240	2.656	2.656	2.688
4.	2.560	2.432	1.984	2.496	2.464	2.368	2.560	2.624	2.304
5.	2.688	1.408	1.984	2.368	2.368	2.176	2.560	2.560	2.496
6.	2.496	2.240	2.144	2.400	2.144	2.144	2.240	2.144	1.856
7.	2.625	2.560	2.496	2.556	2.432	1.760	2.304	2.208	1.920
8.	2.212	2.176	1.984	2.432	2.240	2.016	2.432	2.240	2.240
9.	2.660	2.400	2.112	2.464	2.240	1.920	2.368	2.208	2.176
10.	2.176	1.984	1.696	2.368	2.240	1.632	2.432	2.368	1.696
11.	2.368	1.920	1.920	2.112	2.020	2.016	2.020	2.020	1.920
12.	2.660	2.112	2.020	2.432	1.792	1.504	2.112	1.982	1.982
13.	2.560	2.202	2.020	2.400	2.020	1.920	2.202	2.020	2.016
14.	2.368	1.920	1.920	2.202	1.920	1.760	2.112	2.020	2.020
15.	2.688	1.984	1.408	2.368	2.176	1.984	2.400	2.212	2.016
16.	2.240	2.202	1.920	2.020	2.020	1.760	2.144	2.144	1.920
17.	2.624	2.560	2.496	2.400	2.169	2.020	2.212	1.982	2.020
18.	2.400	2.212	2.176	2.240	2.016	2.016	2.400	2.020	1.976
19.	2.660	2.400	2.122	2.400	2.240	1.920	2.400	2.240	1.920
20.	2.420	2.220	2.020	2.420	2.020	2.001	2.240	2.016	2.016
Mean	2.486	2.169	2.024	2.393	2.174	1.997	2.337	2.227	2.053
CV	6.650	12.374	12.211	6.686	9.981	12.302	7.454	9.307	11.195

respectively with corresponding cv values of 6.686, 9.981 and 12.302, respectively.

The bottom region of the trees exhibited marked variation in the K status in W_1, W_2 and W_3 samples, the values being 2.020 to 2.656 per cent (mean 2.337); from 1.982 to 2.656 per cent (mean 2.227) and from 1.696 to 2.688 per cent (mean 2.053). The cv values obtained were 7.454, 9.307 and 11.195, respectively, for whole 1, 2 and 3.

4.2.3.3. Vellayani (Table 16)

At this location the leaf samples of top region recorded varied values for K in the W_1, W_2 and W_3 positions. The values ranged from 2.048 to 2.648 per cent (mean 2.227) for the first whorl, from 1.600 to 1.984 per cent (mean 1.794) for the second whorl and from 1.600 to 1.792 per cent (mean 1.693) for the third whorl. The corresponding cv values were 4.613, 7.141 and 6.433, respectively.

In the middle region the K status of W_1, W_2 and W_3 positions ranged from 1.728 to 2.304 per cent (mean 2.009), from 1.664 to 2.112 per cent (mean 1.844) and from 1.536 to 1.824 per cent (mean 1.657) with corresponding cv values of 10.074, 8.189 and 4.724, respectively

In the bottom region the K content of W_1, W_2 and W_3 leaf samples varied from 1.664 to 2.582 per cent (mean 2.094) from 1.536 to 2.432 per cent (mean 1.99) and from

TABLE 16. Potassium concentrations in leaf at Vellayani

(Mean value per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	2.048	1.696	1.600	2.176	2.112	1.536	2.240	2.400	1.600
2.	2.284	1.792	1.600	2.240	1.856	1.664	2.368	2.240	2.240
3.	2.048	1.760	1.760	2.016	1.766	1.632	2.176	1.884	1.696
4.	2.200	1.728	1.728	1.728	1.664	1.664	1.664	1.536	1.440
5.	2.272	1.984	1.792	2.304	1.824	1.824	2.582	2.432	1.738
6.	2.048	1.600	1.600	2.112	2.048	1.600	2.176	2.112	1.536
7.	2.176	1.984	1.792	2.048	1.856	1.664	1.984	1.792	1.600
8.	2.220	1.728	1.728	1.920	1.664	1.664	1.760	1.760	1.664
9.	2.648	1.920	1.664	1.728	1.728	1.600	1.984	1.984	1.600
10.	2.304	1.760	1.664	2.227	1.920	1.720	2.016	1.760	1.632
Mean	2.227	1.794	1.693	2.009	1.844	1.657	2.094	1.990	1.673
CV	4.613	67.141	6.433	10.074	8.189	4.724	13.074	15.012	12.843

1.440 to 2.240 per cent (mean 1.673) respectively. The corresponding cv values obtained were 13.074, 15.012 and 12.843 for the first, second and third whorls.

4.2.3.4. Kulasekharam (Table 17)

At this location the K status of leaves showed marked variation among the three regions of the plants. In the top region, the K status of W_1, W_2 and W_3 leaf samples varied from 2.176 to 2.688 per cent (mean 2.412) from 1.882 to 2.304 per cent (mean 2.188) and from 1.760 to 2.284 per cent (mean 1.969 per cent) with cv values of 4.846, 7.151 and 6.935, respectively.

In the middle region, the K status of W_1, W_2 and W_3 leaf samples ranged from 2.048 to 2.368 per cent (mean 2.23), from 1.856 to 2.202 per cent (mean 2.050) and 1.680 to 2.100 per cent (mean 1.916) with cv values of 5.810, 6.139 and 6.155, respectively for the three whorls.

In the bottom region, the K status ranged between 2.048 and 2.304 per cent for whorl 1, from 1.920 per cent to 2.304 per cent for whorl 2 and from 1.62 to 2.048 per cent for whorl 3 with corresponding means of 2.205, 2.011 and 1.900 per cent. The respective cv values were 8.969, 10.565 and 5.240.

TABLE 17. Potassium concentration in leaf at Kulasekharam

(Mean value - per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	2.368	1.920	1.760	2.368	2.176	1.920	2.112	1.984	1.920
2.	2.688	1.984	1.960	2.560	2.176	1.920	2.304	2.304	2.048
3.	2.560	2.176	2.176	2.240	2.176	2.048	2.176	2.176	1.920
4.	2.368	2.112	2.112	2.176	1.920	1.920	2.112	1.920	1.856
5.	2.400	2.208	2.920	2.176	2.112	1.856	2.176	1.920	1.856
6.	2.400	1.920	1.856	2.208	2.048	1.696	2.240	2.176	2.856
7.	2.304	2.304	1.920	2.176	2.048	1.856	2.112	1.920	1.856
8.	2.464	1.882	1.802	2.112	1.920	1.920	2.176	1.920	1.856
9.	2.240	2.176	1.856	2.112	1.984	1.920	2.048	1.920	1.856
10.	2.176	1.920	1.856	2.048	1.856	1.984	2.112	2.002	1.920
11.	2.400	2.028	2.002	2.176	2.112	2.002	2.112	2.112	1.920
12.	2.304	2.048	1.984	2.112	1.984	1.920	2.176	1.920	1.984
13.	2.368	2.300	2.048	2.176	1.980	1.680	2.112	1.980	1.788
14.	2.560	2.176	2.008	2.300	2.048	2.068	2.176	1.980	1.620
15.	2.688	2.084	1.864	2.200	2.008	2.002	2.112	1.920	1.856
16.	2.460	2.008	1.882	2.240	2.002	1.882	2.176	2.112	2.002
17.	2.240	2.176	1.856	2.140	2.070	1.746	2.200	2.100	1.800
18.	2.223	2.176	2.006	2.167	2.008	2.001	2.176	2.176	2.048
19.	2.443	2.284	2.284	2.224	2.184	1.800	2.114	2.004	1.900
20.	2.604	2.404	2.200	2.404	2.202	2.100	2.304	2.304	2.048
Mean	2.412	2.118	1.969	2.230	2.050	1.916	2.205	2.011	1.900
CV	4.486	7.151	6.935	5.801	6.139	6.155	8.969	10.565	5.240

4.2.4. Calcium

4.2.4.1. Vithura (Table 18)

The calcium concentration in the leaves of the top region of the trees at Vithura location varied from whorl to whorl. The W_1, W_2 and W_3 samples registered calcium content ranging from 0.233 to 0.363 per cent (mean value being 0.288 per cent), from 0.189 to 0.362 per cent (mean value of 0.286 per cent) and from 0.182 to 0.386 per cent (mean value 0.300 per cent) with cv values of 16.812, 15.893 and 21.268, respectively.

In the middle region the Ca status of W_1 leaf indicated a lowest value of 0.101 per cent and a highest value of 0.370 per cent, with the mean ~~being~~ of 0.271 per cent. A range value from 0.174 to 0.362 per cent (mean 0.280 per cent) and from 0.159 to 0.386 per cent (mean 0.299 per cent) were observed in the W_2 and W_3 leaf samples. The coefficients of variation were 20.469, 19.739 and 21.185 for W_1, W_2 and W_3 leaves, respectively.

The calcium status of W_1, W_2 and W_3 leaf samples of bottom region of the tree varied from 0.235 to 0.385 per cent (mean 0.303 per cent), from 0.168 to 0.366 per cent (mean value 0.287 per cent) and from 0.211 to 0.386 per cent (mean value 0.307 per cent) with corresponding cv values of 14.242, 15.916 and 12.573, respectively.

TABLE 18. Calcium concentration in leaf at Vithura

(Mean values - per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.233	0.205	0.226	0.101	0.174	0.217	0.235	0.241	0.283
2.	0.244	0.285	0.194	0.222	0.233	0.272	0.310	0.273	0.285
3.	0.312	0.324	0.297	0.296	0.319	0.291	0.313	0.281	0.345
4.	0.292	0.263	0.311	0.370	0.273	0.265	0.385	0.267	0.326
5.	0.336	0.253	0.272	0.320	0.260	0.230	0.325	0.226	0.238
6.	0.363	0.326	0.297	0.298	0.215	0.223	0.280	0.279	0.251
7.	0.252	0.189	0.182	0.245	0.175	0.159	0.371	0.276	0.227
8.	0.358	0.304	0.235	0.228	0.283	0.275	0.368	0.345	0.278
9.	0.259	0.270	0.273	0.242	0.262	0.268	0.352	0.280	0.246
10.	0.295	0.260	0.213	0.272	0.210	0.273	0.251	0.168	0.211
11.	0.234	0.210	0.262	0.210	0.286	0.310	0.230	0.240	0.281
12.	0.268	0.301	0.386	0.302	0.342	0.368	0.298	0.280	0.301
13.	0.290	0.311	0.362	0.266	0.304	0.344	0.290	0.326	0.386
14.	0.298	0.318	0.336	0.282	0.300	0.309	0.268	0.301	0.322
15.	0.268	0.308	0.362	0.302	0.362	0.384	0.301	0.344	0.368
16.	0.300	0.362	0.384	0.306	0.340	0.366	0.322	0.366	0.386
17.	0.260	0.298	0.309	0.296	0.316	0.266	0.296	0.342	0.342
18.	0.286	0.290	0.309	0.322	0.346	0.386	0.311	0.323	0.368
19.	0.302	0.322	0.382	0.276	0.306	0.368	0.296	0.286	0.306
20.	0.302	0.304	0.380	0.268	0.312	0.346	0.288	0.292	0.342
Mean	0.288	0.286	0.300	0.271	0.280	0.299	0.303	0.286	0.307
CV	16.812	15.893	21.268	20.459	19.739	21.185	14.242	15.916	12.573

4.2.4.2. Pattom (Table 19)

The calcium status of W_1, W_2 and W_3 leaf samples of the top region of the clove plants at Pattom varied from 0.173 to 0.435 per cent (mean 0.277 per cent), from 0.131 to 0.326 per cent (mean 0.221 per cent) and 0.173 to 0.424 per cent (mean 0.297 per cent) respectively. The cv values for W_1, W_2 and W_3 were 23.787, 24.377 and 26.488, respectively.

In the middle region the calcium content in leaves varied from 0.198 to 0.440 per cent (mean value 0.284 per cent), from 0.194 to 0.299 per cent (mean 0.274 per cent) and from 0.194 to 0.44 per cent (mean value 0.294 per cent) for W_1, W_2 and W_3 leaf samples, respectively. The cv values were 19.163, 22.057, 21.003.

In the bottom region of the tree, the leaf samples collected from W_1, W_2 and W_3 positions registered calcium content ranging from 0.177 to 0.383 per cent (mean value of 0.273 per cent), from 1.900 to 0.472 per cent (mean value of 0.259 per cent) and from 0.177 to 0.425 per cent (mean value 0.309 per cent), respectively. At this region the cv ~~for Ca content~~ were 21.308, 29.093 and 17.439 for W_1, W_2 and W_3, respectively.

TABLE 19. Calcium concentration in leaf at Pattom

(Mean value - per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.346	0.296	0.415	0.293	0.345	0.291	0.365	0.290	0.425
2.	0.319	0.131	0.173	0.312	0.235	0.194	0.325	0.306	0.315
3.	0.335	0.234	0.307	0.275	0.197	0.260	0.228	0.190	0.206
4.	0.206	0.183	0.224	0.262	0.202	0.206	0.247	0.196	0.232
5.	0.281	0.150	0.186	0.247	0.307	0.215	0.311	0.301	0.177
6.	0.248	0.201	0.211	0.304	0.294	0.285	0.224	0.203	0.212
7.	0.253	0.256	0.274	0.440	0.334	0.300	0.277	0.316	0.320
8.	0.435	0.273	0.424	0.309	0.299	0.326	0.383	0.472	0.336
9.	0.245	0.197	0.242	0.353	0.316	0.207	0.311	0.130	0.253
10.	0.285	0.240	0.318	0.316	0.252	0.280	0.311	0.275	0.338
11.	0.345	0.296	0.405	0.292	0.305	0.296	0.325	0.290	0.413
12.	0.173	0.172	0.319	0.235	0.291	0.346	0.325	0.291	0.414
13.	0.307	0.234	0.336	0.198	0.194	0.313	0.190	0.227	0.316
14.	0.210	0.182	0.226	0.261	0.202	0.273	0.197	0.246	0.282
15.	0.186	0.150	0.281	0.215	0.265	0.307	0.177	0.301	0.311
16.	0.218	0.219	0.248	0.285	0.294	0.304	0.212	0.203	0.304
17.	0.274	0.256	0.356	0.301	0.334	0.440	0.277	0.308	0.320
18.	0.286	0.326	0.404	0.308	0.299	0.289	0.286	0.296	0.346
19.	0.242	0.196	0.245	0.207	0.265	0.384	0.253	0.230	0.362
20.	0.268	0.248	0.363	0.268	0.258	0.366	0.253	0.130	0.311
Mean	0.277	0.221	0.297	0.284	0.274	0.294	0.273	0.259	0.309
CV	23.787	24.377	26.448	19.163	22.057	21.003	21.308	29.093	17.439

4.2.4.3. Vellayani (Table 20)

The calcium content in the three whorls of leaves at Vellayani site ranged from 0.165 to 0.240 per cent (mean 0.201 per cent), from 0.167 to 0.236 per cent) (mean 0.197 per cent) and from 0.148 to 0.265 per cent (mean 0.222 per cent) for W_1, W_2 and W_3 leaf samples with cv values of 12.892, 15.476 and 16.591, respectively.

The middle region yielded calcium values from 0.186 to 0.256 per cent (mean 0.221 per cent), from 0.142 to 0.288 per cent (mean 0.224 per cent) and from 0.156 to 0.291 (mean 0.224 per cent) for W_1, W_2 and W_3 leaf samples with cv values of 20.388, 18.905 and 18.758, respectively.

At the bottom region of the trees, calcium status in leaves of the different whorls viz., W_1, W_2 and W_3 ranged from 0.194 to 0.296 per cent (mean 0.229 per cent), from 0.133 to 0.259 per cent (mean value 0.189 per cent) and from 0.160 to 0.333 per cent (mean value 0.234 per cent) with coefficients of variation values of 14.175, 21.039 and 11.172, respectively.

4.2.4.4. Kulasekharam (Table 21)

The calcium content of W_1, W_2 and W_3 leaf samples of the top region of the trees at Kulasekharam had varied

TABLE 20. Calcium concentration in leaf at Vellayani

(Mean value per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.165	0.175	0.221	0.256	0.188	0.209	0.206	0.133	0.333
2.	0.236	0.236	0.251	0.246	0.288	0.291	0.237	0.154	0.227
3.	0.240	0.180	0.227	0.186	0.142	0.206	0.296	0.193	0.210
4.	0.172	0.161	0.148	0.210	0.214	0.192	0.247	0.254	0.241
5.	0.198	0.251	0.240	0.250	0.264	0.290	0.227	0.145	0.294
6.	0.168	0.156	0.187	0.196	0.167	0.157	0.194	0.169	0.160
7.	0.222	0.156	0.187	0.196	0.167	0.156	0.194	0.236	0.218
8.	0.201	0.206	0.265	0.220	0.226	0.246	0.201	0.194	0.222
9.	0.216	0.206	0.265	0.201	0.216	0.218	0.220	0.221	0.224
10.	0.204	0.198	0.234	0.211	0.216	0.226	0.201	0.200	0.216
Mean	0.201	0.197	0.222	0.221	0.213	0.224	0.229	0.189	0.234
CV	12.892	15.476	16.591	20.388	18.905	18.758	14.175	21.039	11.172

TABLE 21. Calcium concentration in leaf at Kulasekharam

(Mean value - per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.367	0.423	0.397	0.476	0.404	0.414	0.403	0.327	0.367
2.	0.389	0.312	0.304	0.318	0.302	0.307	0.382	0.385	0.312
3.	0.316	0.301	0.321	0.274	0.306	0.353	0.368	0.316	0.268
4.	0.396	0.366	0.354	0.309	0.317	0.302	0.276	0.247	0.412
5.	0.374	0.366	0.382	0.316	0.302	0.311	0.366	0.302	0.293
6.	0.376	0.304	0.316	0.351	0.370	0.378	0.363	0.323	0.465
7.	0.304	0.398	0.387	0.414	0.401	0.396	0.376	0.355	0.345
8.	0.387	0.365	0.366	0.345	0.360	0.310	0.386	0.298	0.299
9.	0.380	0.360	0.360	0.396	0.377	0.392	0.365	0.364	0.309
10.	0.296	0.265	0.291	0.290	0.261	0.265	0.286	0.271	0.250
11.	0.366	0.323	0.312	0.365	0.323	0.365	0.382	0.385	0.388
12.	0.367	0.327	0.403	0.293	0.302	0.366	0.312	0.382	0.385
13.	0.327	0.367	0.403	0.323	0.365	0.365	0.368	0.336	0.404
14.	0.293	0.302	0.306	0.276	0.247	0.312	0.312	0.227	0.385
15.	0.247	0.271	0.312	0.268	0.287	0.302	0.234	0.233	0.388
16.	0.368	0.380	0.404	0.357	0.387	0.398	0.368	0.336	0.412
17.	0.366	0.323	0.312	0.244	0.312	0.365	0.312	0.328	0.404
18.	0.296	0.265	0.291	0.294	0.266	0.284	0.266	0.248	0.340
19.	0.327	0.360	0.396	0.311	0.316	0.366	0.302	0.308	0.382
20.	0.388	0.404	0.312	0.366	0.316	0.404	0.363	0.382	0.403
Mean	0.346	0.339	0.344	0.334	0.329	0.345	0.339	0.322	0.360
CV	14.009	13.718	15.56	15.533	14.644	17.138	14.029	14.448	11.578

from 0.247 to 0.396 per cent (mean value 0.346 per cent), from 0.265 to 0.423 per cent (mean value of 0.339 per cent) and from 0.291 to 0.404 per cent (mean value 0.347 per cent), with coefficients of variation of 14.009, 13.718 and 15.56, respectively.

The middle region of the trees had varied values of calcium content among W_1, W_2 and W_3 samples. The values ranged from 0.268 to 0.476 per cent (mean 0.334 per cent), 0.261 to 0.404 per cent (mean value 0.239 per cent) and from 0.265 to 0.414 per cent (mean value 0.345 per cent) with coefficients of variation of 15.533, 14.644 and 17.138 for W_1, W_2 and W_3, respectively.

The bottom region of the trees also showed marked variation in their calcium content which ranged from 0.240 to 0.403 per cent (mean value of 0.339 per cent), from 0.233 to 0.385 per cent (mean 0.322 per cent) and from 0.250 to 0.465 per cent (mean 0.360 per cent) for W_1, W_2 and W_3 samples with corresponding cv values of 14.029, 14.448 and 11.578, respectively.

4.2.5. Magnesium

4.2.5.1. Vithura (Table 22)

The magnesium concentration in the leaf samples of W_1, W_2 and W_3 positions of the top region of the tree at

TABLE 22. Magnesium concentrations in leaf at Vithura

(Mean value - per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.226	0.203	0.195	0.190	0.183	0.152	0.212	0.190	0.185
2.	0.205	0.192	0.241	0.203	0.178	0.173	0.230	0.177	0.186
3.	0.167	0.181	0.217	0.215	0.209	0.188	0.216	0.189	0.207
4.	0.212	0.190	0.200	0.215	0.171	01162	0.209	0.172	0.175
5.	0.218	0.170	0.278	0.208	0.159	0.194	0.196	0.201	0.212
6.	0.234	0.287	0.285	0.252	0.190	0.227	0.246	0.251	0.211
7.	0.288	0.207	0.286	0.260	0.185	0.268	0.247	0.204	0.192
8.	0.294	0.311	0.290	0.275	0.288	0.230	0.308	0.222	0.223
9.	0.311	0.276	0.289	0.259	0.299	0.221	0.326	0.257	0.275
10.	0.308	0.286	0.240	0.251	0.229	0.239	0.312	0.180	0.203
11.	0.195	0.201	0.224	0.162	0.173	0.192	0.185	0.180	0.212
12.	0.140	0.182	0.206	0.172	0.178	0.202	0.186	0.176	0.232
13.	0.218	0.180	0.216	0.188	0.209	0.220	0.189	0.206	0.216
14.	0.190	0.192	0.214	0.162	0.172	0.226	0.172	0.175	0.210
15.	0.170	0.178	0.212	0.190	0.159	0.221	0.162	0.182	0.212
16.	0.186	0.216	0.312	0.221	0.192	0.226	0.211	0.241	0.246
17.	0.186	0.207	0.288	0.148	0.166	0.260	0.160	0.204	0.256
18.	0.210	0.311	0.294	0.230	0.275	0.288	0.221	0.202	0.312
19.	0.268	0.276	0.301	0.259	0.298	0.220	0.316	0.246	0.275
20.	0.302	0.268	0.244	0.261	0.228	0.236	0.312	0.262	0.202
Mean	0.226	0.225	0.251	0.216	0.206	0.219	0.231	0.205	0.222
CV	22.773	21.644	14.625	17.971	22.924	16.253	23.593	20.971	15.635

Vithura showed varied values from 0.140 to 0.302 per cent (mean 0.226 per cent), from 0.170 to 0.311 per cent (mean 0.225 per cent) and from 0.195 to 0.312 per cent (mean 0.251 per cent), respectively. The coefficients of variation of the above samples were 22.773, 21.644 and 14.625, respectively.

In the middle region, the W_1 leaf samples varied in Mg concentration from 0.148 to 0.275 per cent (mean value - 0.216 per cent) whereas W_2 and W_3 samples gave magnesium contênt ranging from 0.159 to 0.298 per cent (mean 0.206 per cent) and from 0.152 to 0.288 per cent (mean 0.219 per cent), respectively. The coefficients of variation were 17.971, 22.924 and 16.253 for W_1, W_2 and W_3, respectively.

The magnesium content of the leaf samples of bottom region varied from whorl to whorl and the values ranged from 0.162 to 0.326 per cent (mean 0.231 per cent) from 0.172 to 0.262 per cent (mean 0.205 per cent) and from 0.175 to 0.312 per cent (mean 0.222 per cent) for W_1, W_2 and W_3 samples, respectively. The cv values for magnesium for these leaf samples were 23.595, 20.471 and 15.635, respectively.

4.2.5.2. $P_a$ttom (Table 23)

The top region of the trees at this location showed remarkable variation in the magnesium content from whorl to whorl. The W_1, W_2 and W_3 leaf samples registered magnesium content varying from 0.154 to 0.338 per cent (mean 0.223 per cent), from 0.138 to 0.312 per cent) (mean 0.212 per cent) and from 0.233 to 0.362 per cent (mean 0.275 per cent) respectively. The coefficients of variation for magnesium in these samples were 28.100, 25.665 and 12.777, respectively.

In the middle region, the magnesium content of W_1, W_2 and W_3 samples were found to vary from 0.161 to 0.284 per cent (mean 0.215 per cent), from 0.172 to 0.276 per cent (mean 0.235 per cent) and from 0.171 to 0.362 per cent (mean 0.253 per cent), respectively. The cv values for the above samples were 21.017, 28.017 and 19.506 for W_1, W_2 and W_3 leaves, respectively.

In the bottom region the magnesium content of W_1, W_2 and W_3 leaf samples registered values from 0.156 to 0.278 per cent (mean 0.218 per cent), from 0.170 to 0.264 per cent (mean 0.216 per cent) and from 0.131 to 0.286 per cent (mean 0.237 per cent) with cv values of 15.688, 13.591 and 22.464, respectively.

TABLE 23. Magnesium concentrations in leaf at Pattom

(Mean value - per cent)

Tree No.	Tree Regions								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.312	0.312	0.226	0.279	0.250	0.289	0.226	0.246	0.247
2.	0.161	0.244	0.278	0.172	0.276	0.172	0.213	0.226	0.246
3.	0.169	0.169	0.290	0.272	0.272	0.172	0.231	0.213	0.131
4.	0.244	0.173	0.264	0.161	0.196	0.227	0.278	0.229	0.196
5.	0.338	0.132	0.233	0.249	0.241	0.179	0.260	0.257	0.150
6.	0.287	0.194	0.266	0.166	0.193	0.226	0.178	0.193	0.250
7.	0.289	0.225	0.274	0.284	0.228	0.236	0.237	0.211	0.194
8.	0.153	0.156	0.254	0.232	0.248	0.286	0.249	0.235	0.192
9.	0.237	0.270	0.271	0.209	0.229	0.236	0.278	0.170	0.186
10.	0.279	0.234	0.249	0.283	0.257	0.223	0.244	0.204	0.194
11.	0.226	0.302	0.312	0.269	0.260	0.298	0.236	0.257	0.266
12.	0.261	0.272	0.362	0.170	0.172	0.273	0.203	0.226	0.256
13.	0.168	0.168	0.296	0.172	0.271	0.362	0.241	0.242	0.362
14.	0.168	0.174	0.244	0.162	0.196	0.228	0.196	0.226	0.282
15.	0.136	0.138	0.301	0.178	0.242	0.268	0.156	0.168	0.262
16.	0.166	0.194	0.284	0.168	0.192	0.236	0.178	0.183	0.260
17.	0.176	0.224	0.284	0.228	0.236	0.323	0.194	0.211	0.263
18.	0.154	0.156	0.262	0.231	0.248	0.286	0.198	0.264	0.286
19.	0.271	0.270	0.290	0.201	0.249	0.262	0.186	0.170	0.278
20.	0.269	0.234	0.268	0.226	0.247	0.284	0.194	0.204	0.244
Mean	0.223	0.212	0.275	0.215	0.235	0.253	0.218	0.216	0.237
CV	28.10	25.665	12.777	21.017	28.017	19.506	15.688	13.591	22.464

4.2.5.3. Vellayani (Table 24)

The top region of the trees of this location also had variable magnesium content between the three whorls. The values ranged from 0.150 to 0.242 per cent (mean 0.178 per cent), from 0.135 to 0.233 per cent (mean 0.179 per cent) and from 0.200 to 0.278 per cent (mean 0.247 per cent) for W_1, W_2 and W_3 samples respectively. The coefficients of variation were found to be 20.973, 14.427, 9.577 for the three respective whorls.

The middle region showed marked variation in magnesium content ranging from 0.150 to 0.239 per cent (mean 0.102 per cent), from 0.138 to 0.239 per cent (mean 0.194 per cent) and from 0.142 to 0.232 per cent (mean 0.195 per cent) with coefficients of variation of 17.150, 18.601 and 16.746 for W_1, W_2 and W_3, respectively.

The magnesium content at the bottom region of the trees was found to vary from 0.157 to 0.302 per cent (mean 0.181 per cent), from 0.133 to 0.196 per cent (mean 0.171 per cent) and from 0.191 to 0.302 per cent (mean 0.212 per cent) for W_1, W_2 and W_3 leaf samples, respectively. The coefficients of variation for the above leaf samples were calculated to be 27.241, 10.713 and 22.451 respectively.

TABLE 24. Magnesium concentration in leaf at Vellayani

(Mean value - per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.196	0.183	0.200	0.239	0.215	0.142	0.235	0.183	0.302
2.	0.242	0.233	0.233	0.231	0.232	0.226	0.169	0.133	0.193
3.	0.150	0.168	0.273	0.152	0.138	0.194	0.166	0.161	0.191
4.	0.175	0.162	0.252	0.167	0.140	0.197	0.157	0.196	0.205
5.	0.134	0.135	0.248	0.191	0.192	0.230	0.135	0.173	0.195
6.	0.196	0.183	0.200	0.215	0.239	0.142	0.302	0.183	0.302
7.	0.233	0.233	0.242	0.226	0.231	0.232	0.166	0.162	0.193
8.	0.152	0.168	0.274	0.156	0.138	0.196	0.166	0.168	0.191
9.	0.152	0.166	0.278	0.168	0.180	0.198	0.162	0.064	0.192
10.	0.152	0.162	0.275	0.167	0.190	0.197	0.157	0.192	0.205
Mean	0.178	0.179	0.247	0.192	0.194	0.195	0.181	0.171	0.212
CV	20.973	17.477	9.577	17.15	18.601	16.746	27.241	10.713	22.451

4.2.5.4. Kulasekharam (Table 25)

The magnesium content in the W_1, W_2 and W_3 leaves ranged from 0.205 to 0.325 per cent (mean 0.261 per cent), from 0.216 to 0.322 per cent (mean 0.264 per cent) and from 0.224 to 0.365 per cent (mean 0.278 per cent), respectively. The coefficients of variation were found to be 50.448, 12.525 and 10.397 for W_1, W_2 and W_3, respectively.

In the middle region the magnesium content of W_1,W_2 and W_3 leaf samples ranged from 0.220 to 0.323 per cent (mean 0.247 per cent), from 0.207 to 0.340 per cent (mean 0.241 per cent) and from 0.211 to 0.360 per cent (mean 0.269 per cent) respectively. At this region the W_1, W_2 and W_3 leave samples gave coefficients of variation values for magnesium content as 11.088, 12.769 and 12.919, respectively.

The magnesium content of the leaf samples of W_1, W_2 and W_3 of the bottom region registered range values from 0.197 to 0.296 per cent (mean value 0.247 per cent), from 0.200 to 0.304 per cent (mean 0.247 per cent) and from 0.197 to 0.296 per cent (mean value 0.245 per cent) with the coefficients of variation of 16.542, 13.014 and 11.161, respectively.

TABLE 25. Magnesium concentrations in leaf at Kulasekharam

(Mean value - per cent)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	0.285	0.265	0.286	0.242	0.262	0.304	0.250	0.227	0.262
2.	0.265	0.288	0.288	0.266	0.262	0.288	0.247	0.268	0.328
3.	0.325	0.322	0.365	0.323	0.296	0.262	0.288	0.304	0.296
4.	0.312	0.306	0.130	0.244	0.262	0.284	0.221	0.225	0.197
5.	0.244	0.260	0.284	0.240	0.260	0.268	0.296	0.292	0.270
6.	0.244	0.236	00.264	0.249	0.254	0.211	0.223	0.224	0.205
7.	0.250	0.277	0.282	0.244	0.267	0.286	0.212	0.212	0.262
8.	0.247	0.268	0.268	0.223	0.244	0.260	0.212	0.222	0.240
9.	0.288	0.288	0.304	0.224	0.243	0.300	0.240	0.223	0.264
10.	0.297	0.299	0.312	0.225	0.221	0.322	0.197	0.221	0.225
11.	0.270	0.292	0.296	0.240	0.262	0.268	0.210	0.210	0.246
12.	0.205	0.223	0.224	0.200	0.213	0.238	0.210	0.212	0.264
13.	0.262	0.227	0.250	0.242	0.221	0.240	0.262	0.200	0.260
14.	0.238	0.247	0.268	0.218	0.207	0.262	0.210	0.206	0.282
15.	0.288	0.287	0.304	0.266	0.247	0.306	0.242	0.262	0.286
16.	0.270	0.292	0.297	0.230	0.340	0.360	0.210	0.230	0.260
17.	0.205	0.223	0.224	0.205	0.222	0.246	0.212	0.236	0.284
18.	0.250	0.226	0.280	0.240	0.260	0.280	0.210	0.200	0.240
19.	0.212	0.216	0.262	0.202	0.220	0.240	0.200	0.246	0.228
20.	0.240	0.264	0.284	0.223	0.266	0.304	0.212	0.218	0.226
Mean	0.261	0.264	0.273	0.247	0.241	0.269	0.247	0.227	0.245
CV	50.448	10.397	10.397	11.088	12.769	12.919	16.542	13.044	11.161

4.2.6. Copper manganese and zinc

4.2.6.1. Vithura (Table 26, 30 and 34)

At this location the Cu, Mn and Zn concentration in leaves varied from region to region of the tree. The mean values for Cu concentration in the leaves in whorls W_1, W_2 and W_3 of the top region were 5.06, 5.13 and 5.38 ppm, respectively. The cv values were 48.24, 47.11 and 46.21 respectively for the three whorls. In the middle region the mean values of leaf Cu content were 5.41, 5.45 and 5.69 ppm with respect to whorls W_1, W_2 and W_3. The cv values for these samples were 45.84, 45.62 and 43.25 for W_1, W_2 and W_3, respectively. In the bottom region the mean values were 5.70, 5.83 and 5.92 ppm for W_1, W_2 and W_3 leaf samples, respectively. The coefficients of variation for these three whorls were found to be 44.67, 42.69 and 42.08.

The manganese concentration of the leaf samples of W_1, W_2 and W_3 of top region of the trees gave mean values of 247, 231 and 250 ppm, respectively. The coefficients of variation for the above samples were 22.81, 23.46 and 20.9, respectively. In the middle region the mean values of Mn concentration in the leaves of W_1, W_2 and W_3 were found to be 221, 217 and 226 ppm with coefficients of variation values of 29.24, 30.14 and 29.01, respectively. In the

TABLE 26. Copper concentration in leaf at Vithura

(Mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	3.8	4.0	4.4	4.6	4.8	5.2	5.2	5.3	5.4
2.	4.0	4.4	4.6	4.6	4.9	5.0	5.2	5.4	5.3
3.	6.0	6.2	6.5	6.2	6.4	6.6	6.6	6.8	6.4
4.	4.0	4.2	4.4	4.6	4.6	4.8	5.0	5.2	5.4
5.	7.0	6.9	6.8	6.8	6.8	7.0	6.8	6.4	6.6
6.	7.0	6.6	7.1	6.8	6.8	6.9	6.6	6.4	6.8
7.	5.0	5.2	5.4	5.6	5.8	5.8	6.0	6.2	6.4
8.	3.0	3.2	3.4	3.6	3.6	4.0	4.0	4.2	4.4
9.	6.0	6.1	6.6	6.6	6.8	7.0	6.6	6.8	7.0
10.	7.0	7.0	7.1	6.8	6.8	7.0	7.0	7.2	7.4
11.	4.0	4.2	4.6	4.0	4.2	4.8	5.0	5.2	5.4
12.	6.0	6.1	6.6	6.2	6.2	6.4	6.2	6.4	6.6
13.	6.0	6.2	6.3	6.2	6.4	6.3	6.2	6.6	6.4
14.	4.0	4.2	4.6	6.2	6.3	6.4	6.8	6.8	6.8
15.	7.0	7.0	6.9	7.1	7.0	7.2	7.0	7.2	7.4
16.	2.2	2.6	3.1	3.2	3.2	3.5	4.0	4.2	4.4
17.	7.0	6.8	7.0	7.1	7.0	7.2	6.6	6.8	6.4
18.	2.8	3.1	3.2	3.2	3.3	3.4	3.6	3.8	3.4
19.	6.0	6.2	6.4	6.2	6.3	6.4	6.6	6.4	6.8
20.	2.4	2.6	21.8	2.6	2.8	3.0	3.2	3.4	3.6
Mean	5.06	5.13	5.38	5.41	5.45	5.69	5.7	5.83	5.92
CV	48.24	47.11	46.21	45.84	45.62	43.25	44.67	42.69	42.08

TABLE 30. Manganese concentration in leaf at Vithura

(Mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	271	205	234	186	151	151	222	209	215
2.	263	253	214	253	264	276	247	227	287
3.	360	300	277	303	329	326	242	245	309
4.	229	235	261	294	256	254	324	259	292
5.	358	285	285	354	280	253	347	300	313
6.	211	185	169	138	139	154	189	199	179
7.	248	286	176	200	151	139	241	206	193
8.	234	228	232	240	198	166	330	280	284
9.	219	225	236	184	205	209	301	244	254
10.	197	177	168	156	151	180	205	185	185
11.	205	236	272	152	166	186	212	246	310
12.	260	286	288	250	264	282	227	248	282
13.	300	340	386	312	342	368	240	266	312
14.	221	234	262	254	256	298	250	282	360
15.	280	286	342	280	288	334	300	316	348
16.	210	212	318	138	139	154	188	198	202
17.	232	188	186	168	200	212	221	242	266
18.	232	221	230	242	198	199	302	346	388
19.	218	240	262	182	206	208	268	282	298
20.	202	217	218	156	162	180	200	212	218
Mean	247	231	250	221	217	226	247	251	269
CV	22.81	23.46	20.90	29.24	30.14	29.09	22.81	19.03	17.59

TABLE 34. Zinc concentration in leaf at Vithura

(Mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	46.6	83.6	173.6	230.8	190.2	26.8	155.6	38.6	74.6
2.	29.4	9.8	16.4	11.4	21.4	9.8	10.2	108.4	109.4
3.	17.2	12.0	23.4	42.2	14.8	12.2	5.4	5.0	7.0
4.	12.8	17.2	7.6	89.0	25.0	8.2	10.0	8.0	5.8
5.	4.2	14.8	12.0	11.0	7.6	8.6	9.0	13.0	8.4
6.	14.0	54.8	10.0	42.0	2.6	3.4	4.0	7.2	104.4
7.	7.6	7.6	12.0	34.4	157.8	5.2	12.0	29.0	129.8
8.	8.4	62.6	7.6	46.6	17.0	4.0	9.8	8.8	3.2
9.	15.6	6.4	6.0	3.8	6.8	4.2	38.8	8.2	6.0
10.	24.0	8.0	9.8	18.6	4.2	29.6	9.6	32.2	14.2
11.	40.2	80.6	170.2	102.2	104.2	40.6	66.6	40.2	80.6
12.	9.4	9.2	18.4	12.4	26.2	18.8	12.2	110.2	118.4
13.	16.2	18.2	44.4	42.1	24.2	22.4	4.4	6.0	9.2
14.	10.8	18.2	14.4	80.0	26.0	24.2	10.0	16.2	15.8
15.	44.6	14.4	16.0	12.0	17.6	18.6	10.0	23.0	16.4
16.	12.0	64.8	20.0	12.0	2.4	6.4	4.0	6.2	104.6
17.	7.7	14.6	19.2	30.4	164.8	124.0	12.0	24.0	224.4
18.	8.4	62.6	7.6	42.6	27.0	4.0	9.8	18.8	3.2
19.	14.6	6.4	6.0	3.8	6.8	4.2	30.8	18.8	16.0
20.	12.0	8.0	16.8	12.0	4.2	26.6	8.6	30.2	24.2
Mean	148.5	28.55	30.74	34.22	42.4	19.9	21.57	27.33	53.61
CV	149.6	124.2	113.4	95.46	82.2	140.6	134.01	121.2	75.5

bottom region the mean values for W_1, W_2 and W_3 were 247, 251 and 269 ppm with cv values of 22.81, 19.03 and 17.59.

The mean values of Zn concentration in W_1, W_2 and W_3 leaf samples of top region were 14.865, 28.55 and 30.73 ppm, respectively with cv values of 149.6, 124.2 and 113.4 per cent respectively. In the middle region the W_1, W_2 and W_3 leaf samples, the mean values of Zn concentration were 34.22, 42.40 and 19.90 ppm, respectively. The cv values for these samples were arrived at 95.46, 82.20 and 140.60, respectively. In the bottom region the W_1, W_2 and W_3 samples had mean values of 21.57, 27.23 and 53.61 ppm zinc with cv values of 134.01, 121.20 and 75.50, respectively.

4.2.6.2. Pattom (Table 27, 31 and 35)

The Cu concentration of W_1, W_2 and W_3 leaf samples of ~~Pattom~~ top region had mean values of 2.92, 2.79 and 5.99 ppm with cv values of 139.06, 141.10 and 117.45, respectively. In the middle region the mean values of copper content in W_1, W_2 and W_3 leaf samples were found to be 3.21, 6.75, 8.33 ppm with cv values of 122.60, 85.01 and 66.43, respectively. In the bottom region the W_1, W_2 and W_3 sample registered mean values of 4.625, 6.445 and 9.26 ppm. The respective cv values were 119.42, 48.99 and 56.00.

TABLE 27. Copper concentration in leaf at Pattom

(Mean values - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	7.2	1.6	5.0	5.0	5.4	2.6	1.6	2.2	2.6
2.	5.0	1.0	4.4	2.2	4.4	1.0	2.4	4.4	8.2
3.	1.0	1.2	1.0	3.2	2.8	2.6	7.4	1.3	2.8
4.	1.2	1.4	2.8	4.4	5.4	7.0	2.6	1.0	3.6
5.	3.4	2.0	4.4	3.6	8.8	8.8	1.2	2.2	5.4
6.	3.6	4.4	5.0	5.0	2.4	6.2	6.2	8.4	4.8
7.	2.4	1.0	4.0	1.0	1.4	3.0	1.0	2.2	3.6
8.	1.0	1.2	3.2	1.0	2.0	2.2	3.8	3.2	1.8
9.	1.2	1.6	1.0	1.0	2.2	3.2	1.2	1.2	6.2
10.	2.0	2.4	3.2	2.6	2.8	3.2	1.8	2.2	4.6
11.	1.2	1.4	3.2	1.6	1.8	2.6	1.8	2.2	3.6
12.	1.4	2.2	1.8	2.0	8.6	8.8	2.6	2.4	2.6
13.	2.6	2.8	3.2	3.0	3.2	3.6	1.8	3.2	3.6
14.	2.2	2.6	3.3	3.2	4.2	6.2	4.2	8.4	4.2
15.	3.4	12.4	6.8	4.4	12.6	2.2	5.0	2.2	4.4
16.	2.6	2.8	10.2	4.4	10.2	10.8	6.2	8.2	4.6
17.	3.2	3.6	4.8	2.2	10.2	12.6	3.8	3.8	9.8
18.	8.2	4.2	10.0	8.6	10.2	12.2	4.6	12.2	3.2
19.	2.6	2.8	2.2	2.6	2.6	2.8	3.0	3.2	3.6
20.	3.0	3.3	3.6	3.2	3.8	4.0	3.3	4.2	4.8
Mean	2.92	2.79	5.99	3.21	6.75	8.33	4.625	6.445	9.26
CV	139.06	141.10	117.45	122.60	85.01	66.41	119.43	88.99	56.00

TABLE 31. Manganese concentration in leaf at Pattom

(Mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	130	131	164	206	162	160	137	139	288
2.	548	146	123	299	555	332	146	186	312
3.	384	398	670	472	516	615	434	499	491
4.	802	723	620	384	583	549	589	520	662
5.	338	341	287	281	265	641	242	232	263
6.	308	220	284	290	299	384	389	596	670
7.	151	186	195	143	384	192	184	211	262
8.	143	129	142	237	169	202	184	172	207
9.	232	290	247	113	131	169	299	137	332
10.	389	384	455	300	315	376	282	309	363
11.	132	136	264	216	186	158	162	188	265
12.	348	246	423	253	399	346	247	286	366
13.	322	368	570	272	416	530	232	366	389
14.	402	416	723	284	283	449	389	420	468
15.	318	380	420	481	480	398	442	436	502
16.	218	298	299	240	260	360	288	398	580
17.	252	286	298	240	380	290	286	298	272
18.	242	229	242	212	262	280	182	178	242
19.	212	280	268	112	130	162	280	288	389
20.	289	284	406	212	312	366	286	310	368
Mean	308	347	355	267	321	347	284	308	370
CV	47.38	43.61	40.75	62.21	50.11	43.61	51.12	47.38	37.76

TABLE 35. Zinc concentration in leaf at Pattom

(Mean values - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	9.8	19.2	8.8	8.6	13.6	13.6	15.6	24.6	38.6
2.	12.2	21.4	11.4	9.4	9.8	16.4	10.2	9.4	8.4
3.	8.2	14.8	42.2	17.2	12.0	23.4	5.4	7.0	15.0
4.	8.6	25.0	9.0	12.8	17.2	7.6	10.0	5.8	8.0
5.	3.4	7.6	11.0	4.2	14.8	12.0	9.0	8.4	13.0
6.	5.2	2.6	42.0	14.0	4.8	10.0	4.0	4.4	67.2
7.	4.0	7.8	34.2	7.6	7.6	17.0	12.0	29.8	29.0
8.	4.2	17.0	46.6	8.4	12.6	7.6	9.8	3.2	8.8
9.	29.6	6.8	3.8	15.6	6.4	6.0	38.8	6.0	18.2
10.	40.6	4.2	18.6	24.0	8.0	9.8	9.6	14.2	32.6
11.	18.8	4.2	2.2	10.2	10.6	10.2	6.6	10.6	40.2
12.	22.4	26.2	12.4	9.4	9.2	18.4	12.2	18.4	30.2
13.	24.2	24.2	42.1	16.2	18.2	44.4	4.4	9.2	16.0
14.	18.6	26.0	8.0	10.8	18.2	14.4	10.0	15.8	16.2
15.	6.4	17.6	12.0	4.6	14.4	16.0	10.0	16.4	23.0
16.	4.2	2.6	12.0	12.0	4.8	20.0	4.0	4.6	6.2
17.	4.0	4.8	10.4	7.7	14.6	19.2	12.0	24.4	24.0
18.	4.2	27.0	42.6	8.4	12.6	7.6	9.8	3.2	18.0
19.	26.6	6.8	3.8	14.6	6.4	6.0	30.8	16.0	18.8
20.	6.6	4.2	12.0	12.0	8.0	16.8	8.6	24.2	30.2
Mean	12.9	13.35	20.62	12.36	11.05	14.73	11.57	12.61	23.05
CV	123.7	116.42	97.46	132.3	134.02	107.3	130.2	118.84	82.42

The leaf Mn concentration of whorls W_1, W_2 and W_3 of top region of the trees at Pattom yielded mean values of 308, 347 and 355 ppm,respectively. The coefficients of variation for the 3 whorls were 47.38, 43.61 and 40.75,respectively. In the middle region, the W_1, W_2 and W_3 samples recorded mean values of 267, 321 and 347 ppm of Mn with cv values of 62.21, 50.11 and 43.61,respectively. In the bottom region in the W_1, W_2 and W_3 leaf samples, mean Mn concentrations were found to be 284, 208 and 370 ppm. The respective cv values were 51.12, 47.38 and 37.76.

The mean Zn concentration of W_1, W_2 and W_3 leaf samples of top region of the trees located at Pattom were found to be 12.90, 13.35 and 20.62 ppm with cv values of 123.70, 116.42 and 97.46,respectively. In the middle region, leaf samples exhibited mean values of 11.36, 11.05 and 14.73 ppm Zn in whorls W_1, W_2 and W_3. The corresponding cv values were 132.30, 134.02 and 107.3. In the bottom region, the W_1, W_2 and W_3 leaf samples recorded mean Zn concentrations as 11.57, 12.61 and 23.03 ppm with coefficients of variation value of 130.2, 118.84 and 82.43, respectively.

4.2.6.3. Vellayani (Table 28, 32 and 36)

The copper concentration of W_1, W_2 and W_3 leaf samples of the top region of the trees at Vellayani gave mean values of 4.72, 4.63 and 4.98 ppm with corresponding cv values of 55.42, 51.81 and 43.83. In the middle region the leaf samples of W_1, W_2 and W_3 registered mean values of Cu concentration as 5.14, 5.23 and 5.47 with cv values of 37.21, 32.55 and 29.30.

The Mn concentration of W_1, W_2 and W_3 leaf samples of top region recorded mean values of 339.0, 338.6 and 352.6 ppm with cv valuos of 22.13, 16.45 and 21.61. In the middle region mean leaf Mn content were 350.4, 345.6 and 373.4 ppm for W_1, W_2 and W_3 leaves. The corresponding coefficients of variation were 13.10, 14.58 and 10.85, respectively for W_1, W_2 and W_3. In the bottom region, W_1, W_2 and W_3 leaves registered mean values of 350.0, 376.5 and 379.6 ppm Mn with corresponding cv values of 13.90, 10.76 and 9.59, respectively.

The leaf Zn concentration of W_1, W_2 and W_3 leaves of the top region registered mean values of 12.82, 13.20 and 13.58 ppm and cv values of 107.02, 90.21 and 88.12, respectively. In the middle region the above whorls had mean values of 13.30, 13.64 and 14.32 ppm Zn concentration

TABLE 28. Copper concentration in leaf at Vellayani

(Mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	5.5	5.1	5.0	5.2	5.4	5.6	5.4	5.6	5.8
2.	6.2	6.2	6.2	6.2	6.4	6.6	6.6	6.8	7.0
3.	6.2	6.0	6.4	6.4	6.4	6.7	6.4	6.8	6.6
4.	5.4	5.2	5.6	5.4	5.6	5.8	5.6	5.2	5.4
5.	5.4	5.6	5.8	5.6	5.6	6.0	6.2	6.4	6.4
6.	3.6	3.2	3.8	3.6	3.6	4.1	4.2	4.2	4.8
7.	3.4	3.2	3.6	3.4	3.6	3.8	3.6	3.8	4.0
8.	3.2	3.2	3.2	3.3	3.6	3.9	3.6	3.3	3.9
9.	2.4	2.6	2.8	3.0	3.2	3.4	3.4	3.6	3.8
10.	6.2	6.0	6.4	6.4	6.2	6.6	6.4	6.6	6.8
Mean	4.72	4.63	4.98	4.85	4.98	5.25	5.14	5.23	5.47
CV	55.42	51.81	43.83	40.25	40.00	29.31	37.21	32.55	29.30

TABLE 32. MANGANESE CONCENTRATION IN LEAF AT VELLAYANI

(Mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	322	324	326	326	528	400	328	402	444
2.	402	408	414	416	440	420	442	442	460
3.	318	320	322	324	326	328	320	324	328
4.	308	300	324	326	328	400	328	400	400
5.	332	320	334	336	338	338	340	440	380
6.	242	252	262	266	268	300	268	269	288
7.	402	410	418	418	424	444	406	408	408
8.	342	346	374	376	372	378	360	366	368
9.	338	340	352	354	356	358	352	354	356
10.	384	366	400	383	362	368	360	362	364
Mean	339	338.6	352.6	350.4	345.6	373.4	350.0	376.5	379.6
CV	22.13	16.45	12.61	13.1	14.58	10.85	13.9	10.76	7.59

TABLE 36. Zinc concentration in leaf at Vellayani

(Mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	8.2	9.2	10.2	11.0	11.2	11.6	12.2	12.4	14.6
2.	7.2	8.2	9.4	10.2	10.2	11.0	11.2	11.6	14.8
3.	12.2	12.4	13.0	12.6	12.8	13.2	13.2	13.6	14.0
4.	13.4	13.6	13.8	13.6	14.0	16.2	16.4	16.8	16.8
5.	24.2	24.4	24.4	20.4	21.2	23.0	22.2	22.0	22.4
6.	11.2	11.2	11.6	11.8	12.0	12.4	12.4	12.2	14.8
7.	12.0	12.6	12.4	12.6	13.0	13.0	13.2	13.4	13.6
8.	13.4	13.6	13.8	14.0	14.2	14.4	14.2	14.8	14.8
9.	14.2	14.4	14.6	14.2	15.0	15.2	15.4	15.4	16.0
10.	12.2	12.4	12.6	12.6	12.8	13.2	13.2	13.6	14.0
Mean	12.82	13.20	13.58	13.3	13.64	14.32	14.36	14.58	15.58
CV	107.02	90.21	88.12	89.67	86.13	74.66	74.13	72.29	52.5

with cv values of 89.67, 86.13 and 74.66. In the bottom region mean values of 14.36, 14.58 and 15.58 ppm of Zn were recorded in leaves of W_1, W_2 and W_3. The cv values were computed to be 74.13, 72.29 and 52.5 for the three whorls.

4.2.6.4. Kulasekharam (Table 29,33 and 37)

The Cu concentration of W_1, W_2 and W_3 leaf samples of the top region of the trees located at Kulasekharam registered mean values of 4.12, 4.93 and 7.86 ppm with cv values of 80.91, 57.52 and 52.62. In the middle region, the leaf samples from W_1, W_2 and W_3 yielded mean values of 6.16, 6.92 and 9.35 ppm. The cv values were found to be 57.22, 55.64 and 41.67 for the three whorls. In the bottom region, mean values of 9.03, 10.06, and 14.71 ppm Cu content were observed in W_1, W_2 and W_3 leaf samples with corresponding cv values of 46.40, 37.96 and 35.75.

The Mn concentration of W_1, W_2 and W_3 leaf samples of top region of the trees registered mean values of 274, 314 and 372 ppm and cv values of 15.01, 15.11 and 15.14. In the middle region, mean values of 304, 375 and 485 ppm Mn content were registered by W_1, W_2 and W_3 leaf samples with corresponding cv values of 15.73, 15.87, 13.12.

TABLE 29. Copper concentration in leaf at Kulasekharam

(Mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	1.2	1.6	2.0	1.6	1.8	2.2	2.1	2.6	3.2
2.	1.4	4.1	6.2	2.6	3.3	4.4	4.2	8.2	6.2
3.	2.6	2.8	3.2	3.2	3.8	12.0	11.4	11.0	12.0
4.	8.2	8.6	10.2	11.2	10.2	8.6	12.2	12.4	13.0
5.	4.4	4.6	6.6	6.8	7.2	8.2	11.6	11.8	12.2
6.	8.2	12.0	11.0	8.8	12.2	14.2	12.6	12.2	14.2
7.	1.4	1.6	2.4	2.4	3.8	12.2	11.6	11.6	14.4
8.	2.8	8.2	8.8	6.2	6.8	10.2	10.4	10.6	12.8
9.	6.2	10.2	6.6	11.6	11.8	13.0	12.2	12.4	12.4
10.	2.2	2.6	2.8	3.8	3.6	6.2	11.6	12.2	12.4
11.	2.2	2.8	4.0	2.2	3.6	4.4	2.2	2.4	3.6
12.	2.2	8.2	10.2	8.2	8.6	12.2	12.2	12.4	14.4
13.	6.2	6.8	7.2	8.2	8.6	8.2	11.4	12.4	12.8
14.	3.6	3.8	3.6	4.4	4.8	12.2	4.8	4.0	11.2
15.	6.2	8.2	8.8	8.4	8.8	12.2	11.2	11.6	11.8
16.	4.2	4.4	6.2	4.8	4.8	6.8	6.2	12.2	6.2
17.	8.2	11.2	11.4	11.1	11.4	12.6	10.2	12.4	12.4
18.	4.6	4.8	6.2	6.6	6.8	10.2	11.1	12.2	11.2
19.	2.2	2.2	2.6	2.4	2.8	4.4	2.8	4.4	4.8
20.	4.2	10.2	11.2	8.2	8.8	12.2	8.6	12.2	6.4
Mean	4.12	5.93	7.86	6.16	6.92	9.35	9.03	10.06	14.71
CV	80.91	57.52	52.62	57.22	55.64	41.67	46.40	37.96	35.75

TABLE 33. Manganese concentration in leaf at Kulasekharam

(Mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	310	360	380	320	460	516	376	565	437
2.	366	398	412	410	380	466	407	363	524
3.	282	330	382	275	306	401	308	308	369
4.	210	332	420	238	420	612	441	479	612
5.	300	310	340	312	340	386	321	357	459
6.	310	346	366	353	440	794	360	449	484
7.	280	320	436	342	420	760	350	440	482
8.	266	282	320	310	412	560	368	466	520
9.	320	380	420	340	412	488	360	412	510
10.	312	280	318	320	360	382	344	368	478
11.	288	289	340	298	292	320	412	480	612
12.	266	198	320	238	312	380	388	460	484
13.	312	368	416	344	412	620	460	480	500
14.	360	288	340	300	366	380	420	512	602
15.	244	346	506	288	484	720	320	360	480
16.	217	336	420	270	320	440	430	480	606
17.	226	260	320	288	306	388	360	394	476
18.	210	262	320	240	288	340	320	354	436
19.	260	310	380	280	340	380	366	394	476
20.	260	288	360	266	320	366	342	368	456
Mean	274	314	372	304	375	485	372	424	503
CV	15.01	15.11	15.14	15.73	15.87	13.12	13.99	13.82	11.68

TABLE 37. Zinc concentration in leaf at Kulasekharam

(mean value - ppm)

Tree No.	Tree Region								
	Top			Middle			Bottom		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	2.4	6.2	8.4	3.2	6.2	7.4	4.2	8.0	5.8
2.	16.2	12.2	120.2	4.2	10.0	6.2	4.6	5.0	3.2
3.	3.4	2.8	60.2	6.8	1.6	23.2	5.0	34.6	114.6
4.	2.2	8.2	36.2	2.0	10.2	26.2	1.0	5.2	18.6
5.	4.2	12.2	62.1	6.2	8.4	12.2	4.8	1.0	115.2
6.	12.1	24.2	26.2	70.2	13.2	8.4	50.2	4.2	5.8
7.	3.6	8.2	12.4	4.2	7.3	14.0	5.3	16.0	12.2
8.	12.2	24.0	28.2	6.2	12.0	110.0	5.7	10.0	106.4
9.	4.4	6.2	12.2	7.2	4.7	36.2	10.0	12.2	8.8
10.	4.4	12.2	30.2	4.4	12.1	66.2	2.0	6.2	28.6
11.	5.2	13.4	84.2	7.2	9.4	16.0	6.8	2.0	110.2
12.	13.2	24.2	26.0	72.2	23.2	7.4	60.2	14.2	15.8
13.	3.6	4.2	6.2	5.2	8.3	12.0	6.2	12.0	14.2
14.	14.2	16.2	36.2	12.0	11.0	120.0	6.2	5.0	116.4
15.	4.6	3.2	6.2	3.2	14.7	46.2	11.0	22.0	18.8
16.	2.6	4.2	24.2	24.4	22.1	60.2	3.0	12.2	38.2
17.	6.2	12.4	83.2	8.2	10.4	76.2	8.8	4.0	12.2
18.	4.2	12.4	74.4	6.2	8.4	115.0	5.8	1.0	119.2
19.	12.2	22.2	25.0	62.0	13.2	62.2	50.2	12.2	10.5
20.	3.6	2.2	3.2	4.2	5.2	7.2	3.2	6.2	12.2
Mean	6.73	11.55	38.26	15.97	10.58	41.63	12.71	9.65	44.34
CV	144.22	84.15	68.43	82.87	140.51	63.98	83.97	142.2	49.31

In the bottom region the W_1, W_2 and W_3 leaf samples gave mean values of 372, 424 and 503 ppm of Mn with cv values of 13.99, 13.48 and 11.68, respectively.

The mean Zn concentration of W_1, W_2 and W_3 leaf samples of the top region were found to be 6.13, 11.55 and 38.26 ppm. The corresponding cv values were 144.22, 84.15 and 68.43. In the middle region, the W_1, W_2 and W_3 samples registered mean values of 15.97, 10.58 and 41.63 ppm of Zn content with cv values of 82.87, 140.51 and 69.98. In the bottom region the mean values were 12.71, 9.65 and 44.34 ppm of Zn for whorls W_1, W_2 and W_3. The cv values for the 3 whorls were found to be 83.97, 142.2 and 49.31, respectively

4.3. CORRELATION STUDIES

Correlation studies were undertaken to find out the correlations between the soil nutrients and leaf nutrient concentrations. Simple correlation coefficients between the available soil nutrient status with reference to N, P, K, Ca, Mg, Cu, Mn and Zn and the content of these nutrients in the leaves of whorl I (W_1), whorl II (W_2) and whorl III (W_3) of top region, middle region and bottom region of the trees (totally 20 trees) were also worked out for each location except Vellayani (where only 10 trees were selected). The results are presented in Tables 38 to 45.

4.3.1. Correlation between soil available N and leaf N (Table 38)

4.3.1.1. Vithura

In the top region (W_1), significant positive correlation was observed between soil N and W_1 leaf samples ($r = 0.453^*$). The W_2 samples had positive relationship with soil N but was not found to be statistically significant. The leaf N content in W_3 samples showed negative relationship with the soil available nitrogen. In the middle region invariably all the whorls showed positive relationship with the soil nitrogen, though not significant. In the bottom region the same trend of positive relationships as in the midele region were observed.

The pooled analysis for all the regions of the canopy also indicated a positive relationship between leaf N content and the respective soil available N. But the relationship was not found to be statistically significant.

4.3.1.2. Pattom

At this location the top region yielded significant positive correlation between the soil available N and the leaf N ($r = 0.492^*$). With reference to the W_2 and the W_3 leaf samples a negative relationship was observed between leaf and soil available N. Similarly in

TABLE 38. Correlation coefficients (r) between soil available N and leaf N

Locations	Top			Middle			Bottom			Regions pooled		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
Vithura	0.453*	0.066	-0.150	0.057	0.206	0.173	0.177	0.305	0.335	0.055	0.206	0.126
Pattom	0.492*	-0.004	-0.440	0.110	-0.401	-0.369	0.004	0.069	-0.183	0.502*	-0.173	-0.440
Vellayani	0.064	-0.349	-0.521	0.108	-0.054	-0.088	0.135	0.005	0.044	0.642**	0.311	0.286
Kulasekharam	0.410	0.307	0.343	0.167	0.190	0.051	0.382	0.036	0.345	0.448*	0.225	0.319
Locations pooled	0.511**	0.016	-0.110	-0.004	-0.026	-0.057	0.179	0.119	0.139			

* Significant at 0.05 level

** Significant at 0.01 level

the midele region also the W_2 and W_3 leaf samples had negative relationship with the soil available N. But the W_1 leaf samples yielded a positive though not significant relationship between soil available N and leaf N. In the bottom region both W_1 and W_2 leaf nitrogen had positive relationships with the soil N, while the W_3 samples showed negative relationship with the soil available N.

The pooled analysis of the three regions indicated that a significant relationship ($r = 0.502^*$) exists between the W_1 leaf samples and the soil N. But in the case of W_2 and W_3 samples pooled analysis gave a negative relationship with the soil available N.

4.3.1.3. Vellayani

At this location, the relationship between the leaf N content and soil available N content with respect to all the whorls as well as in all the regions, were found to be positive though statistically not significant.

But the pooled analysis for all the 3 regions of the plant showed a significantly positive correlation between leaf N and soil available N in the case of W_1 leaves only.

4.3.1.4. Kulasekharam

In the top region the correlation coefficient values for leaf N content in all the whorls, had positive relationships with their respective soil N contents. The same trend was also exhibited by both middle and bottom regions.

The pooled analysis for all the three regions showed significant positive correlation between W_1 leaf N and the respective soil content ($r = 0.448^{**}$). The other two whorls had also positive relationships though not significant.

4.3.2. Correlation coefficient between soil available P and leaf P (Table 39)

4.3.2.1. Vithura

In the top region, W_1 and W_3 leaf P had positive correlation with the soil P content. The W_2 leaf samples showed negative relationship with the soil P content. In the midele region, in contrast to top region the W_1 leaf samples showed negative relationship and the W_2 and W_3 leaves had positive relationship with the soil P content. In the bottom region, significantly positive relationship ($r = 0.477^{**}$) was observed between W_1 leaf P content with soil available P. The other two whorls were also having positive relationship but not statistically significant.

TABLE 39. Correlation coefficients (r) between soil available P and leaf P

Locations	Top			Middle			Bottom			Regions pooled		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
Vithura	0.247	-0.307	0.107	-0.289	0.412	0.188	0.477*	0.294	0.205	0.241	0.418**	0.302*
Pattom	0.317	0.214	0.066	0.266	0.127	0.223	0.307	0.336	0.088	0.446*	0.177	0.065
Vellayani	0.426	-0.105	0.354	0.039	0.106	0.223	0.750**	0.109	0.358	0.158	-0.064	0.279
Kulasekharam	-0.314	-0.263	0.374	0.111	0.428	0.365	0.513*	0.327	0.023	0.576**	0.174	0.102
Locations pooled	0.060	0.0579	0.209	0.153	0.291*	0.280*	0.474**	0.327*	0.168			

* Significant at 0.05 level

** Significant at 0.01 level

Pooled analysis for all the whorls in the three regions showed positive relatiohship with their respective soil P content. But the correlation values were statistically significant only in the case of W_2 followed by W_3 (r = 0.418** and 0.302*).

4.3.2.2. Pattom

At this location invariably all the leaf whorls of all the regions had positive relationships with their respective soil P content though not significant.

The pooled analysis indicated that the soil P correlated well with the leaf P content of whorl 1 leaf samples (r = 0.446**). The others also indicated positive relationship though not statistically significant.

4.3.2.3. Vellayani

At this location, in the top region except W_2 leaves, leaves of the other two regions showed positive relationship, though not significant. In the middle region the soil P had positive relationship with the leaf P. Similarly in the bottom region also the soil available P had shown positive relationship with the leaf P content. But highly significant positive correlation was observed only between W_1 leaf samples (r = 0.750**) and the soil P content.

A pooled analysis of all the 3 whorls of the different regions, yielded positive correlations in whorls one and three only whereas the correlation value was negative with reference to W_2 leaves.

4.3.2.4. Kulasekharam

In the top region, the soil available P had negative relationship with leaves of W_1 and W_2 whorls but expressed positive relationship with W_3 leaf samples. But positive relationship was obtained among available soil P content and leaf P content of W_2 and W_3 whorls of the middle and bottom regions. Positive and significant correlation was obtained only in the case of leaves of whorl I in the bottom region and the soil available P ($r = 0.513^*$).

The pooled analysis of the three regions indicated that the soil available P had significant positive correlation with the W_1 leaf P content ($r = 0.576^{**}$). The P content of W_2 and W_3 leaves and soil available P in all the three regions were also found to be positively correlated with the soil available P, but the correlation values were not found to be statistically significant.

4.3.3. Correlation coefficients between soil available K and leaf K (Table 40)

4.3.3.1. Vithura

In the case of top region, soil K content was found to be positively correlated only with leaves of W_1 and W_3 whorls whereas the relationship was negative with reference to W_2.

The relationship between the leaf K content and the soil available K was positive in relation to all the three whorls of both middle and bottom regions.

The pooled analysis for this relationship was found to positive but not significant in the case of all the three whorls.

4.3.3.2. Pattom

The correlation between soil available K and leaf K in whorl I of the top region was significantly positive whereas the correlation was negative in the case of leaves of W_2 and W_3 samples. In the case of the middle region W_1 and W_3 leaf K content was found to be negatively correlated with soil available K, though the 2nd whorl had a positive but statistically insignificant correlation. In the bottom region of the

TABLE 40. Correlation coefficients (r) between soil available K and leaf K

Locations	Top			Middle			Bottom			Regions pooled		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
Vithura	0.151	-0.007	0.186	0.322	0.150	0.003	0.149	0.113	0.090	0.123	0.148	0.104
Pattom	0.485*	-0.345	-0.066	-0.310	0.277	-0.370	-0.430	-0.180	0.170	0.455*	-0.398	-0.141
Vellayani	0.311	-0.342	-0.315	0.009	0.106	-0.323	-0.283	-0.315	0.002	0.149	-0.288	-0.198
Kulasekharam	0.510*	-0.266	-0.128	0.317	0.419	0.226	-0.103	0.060	0.093	0.474*	0.043	0.179
Locations pooled	0.280*	0.226	0.041	0.097	0.103	-0.087	-0.236	-0.042	0.102			

* Significant at 0.05 levels

canopy the correlation between the K content of W_1 and W_2 leaves were negatively correlated with the soil available K. The corresponding correlation was positive but not statistically significant in the case of W_3.

The pooled analysis for the three regions revealed that leaves of the W_1 whorl gave significantly positive correlation between leaf K and soil available K, whereas the relationship was negative, in the case of W_2 and W_3 whorls.

4.3.3.3. Vellayani

The soil available K was positively correlated with the K content of leaves of W_1 leaves in the top region whereas the relationship was negative with reference to leaves of whorl_2. and W_3. I_n the case of the middle region, the correlation was positive but not significant in relation to whorl 1 and whorl 3. The correlation between soil available K and leaf K in whorls 1 and whorl 2 was negative whereas the value was positive with feference to W_3 in the bottom region.

The pooled analysis showed a positive though not significant relationship in whorl 1 while the corresponding correlation values were negative in the case of W_2 and W_3.

4.3.3.4. Kulasekharam

The correlation between the soil available K and the W_1 leaf K was found to be positive and statistically significant in the top region of the plants, whereas the relationship was negative in the case of W_2 and W_3 whorl leave. In the middle region W_1, W_2 and W_3 leaves yielded a positive but not significant relationship between the soil available K and leaf K. In contrast to the above results, a negative correlation was found to exist between the soil available K and leaf K in whorl 1 of bottom region whereas W_2 and W_3 gave a positive but not significant relationship.

Pooling all the three regions and the three whorls, the correlation coefficient value for the whorl I was found to be statistically superior to W_2 and W_3, whereas also the values were positive but not significant.

Pooling the results of the four locations of top region showed that leaf K content of the W_1 leaves was positively and significantly correlated with soil available K.

4.3.4. Correlation coefficient between soil available Ca and leaf Ca (Table 41)

4.3.4.1. Vithura

The available Ca content of the soil was found to be positively correlated with the W_1, W_2 and W_3 leaves of the top region of the clove plants at this site. But the relationship was not found to be statistically significant. In the middle region a negative correlation was found to exist in the case of W_1 leaves where as W_2 and W_3 leaves showed a positive but statistically non-significant relationship. The same trend was noticed in the case of bottom region of the clove plants at this location.

The pooled analysis also gave positive correlation between soil and leaf Ca in all the three whorls, with highly statistically significant values in the case of W_2 and W_3.

4.3.4.2. Pattom

As against the Vithura location, a negative correlation was observed in the case of W_1 whorl while the correlation values were positive but not significant for W_2 and W_3. In contrast to the top region the correlation values for the middle region were all positive for the leaves of all the whorls. The bottom region

TABLE 41. Correlation coefficients (r) between soil available Ca and leaf Ca

Locations	Top			Middle			Bottom			Regions pooled		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
Vithura	0.112	0.317	0.293	-0.241	0.353	0.347	-0.122	0.356	0.324	0.141	0.366**	0.352**
Pattom	-0.128	0.120	0.025	0.001	0.234	0.296	-0.309	0.034	0.559*	0.184	0.116	0.538**
Vellayani	0.197	0.025	0.109	-0.121	0.015	0.019	-0.289	0.112	0.126	0.222	0.085	0.012
Kulasekharam	-0.253	-0.054	0.283	0.109	0.085	0.166	-0.024	0.151	0.477*	0.060	0.074	0.206
Locations pooled	-0.073	0.119	0.187	-0.057	0.197	0.245	0.168	0.226	0.329**			

* Significant at 0.05 level

** Significant at 0.01 level

presented a different picture with a negative correlation value for whorl 1 and positive values for whorls 2 and 3, the last being statistically significant.

On a pooled analysis of this parameter for all the regions the correlation coefficient values of all the three whorls were found to be positive, the value for whorl 3 being highly statistically significant.

4.3.4.3. Vellayani

As in the case of Vithura location, the correlation values between leaf and soil Ca of the top region were found to be positive but not stastically significant. In the case of middle region, negative correlation was observed for W_1 and positive values for W_2 and W_3. None of the values were statistically significant. The trend in the bottom region was the same as in the case of middle region. Leaves of W_2 and W_3 whorls gave a positive though not significant values.

The pooled analysis showed a positive correlation~~ship~~ between the Ca content of the soil and that of the leaf of all the three whorls. But the values were not statistically significant.

4.3.4.4. Kulasekharam

The correlation between leaf Ca and soil Ca in W_1 and W_2 of the top region was found to be negative while the value was positive in the case of W_3 leaves. The correlation coefficient values for W_1, W_2 and W_3 leaves Vs. soil Ca of the middle region were all positive but not statistically significant. In the bottom region the correlation coefficient value was negative with reference to Ca content in W_1 leaves as in the case of the previous three locations. The corresponding values were positive with reference to W_2 and W_3 leaves, the latter being statistically significant as in the case of the plants of Pattom location. The results of the pooled analysis for all the regions of the plant showed that the correlation coefficients were positive, but not significant among W_1, W_2 and W_3 leaves.

However, a highly significant correlation (0.329**) was obtained in the case of W_3 leaves taking into consideration the leaves of all the whorls in all the regions of the plant at all the localities.

4.3.5. Correlation coefficient between soil available Mg and leaf Mg (Table 42)

4.3.5.1. Vithura

At Vithura location the correlation coefficient between soil extractable Mg and leaf Mg were positive in W_2 and W_3 while it was negative in W_2 of the top region. The corresponding value for W_3 was found to be statistically significant ($r = 0.580^{**}$). In the middle region the correlation coefficient values were negative in W_1, positive in W_2 and W_3 but not statistically significant. In the bottom region the correlation coefficients between soil Mg and leaf Mg were all positive, but not significant.

When all the three regions were pooled, the value for W_1 was found to be statistically significant ($r = 0.271^{*}$). The correlation between soil available Mg and the leaf Mg was found to be positive and significant in the case of W_3 leaves also. ($r = 0.439^{**}$).

4.3.5.2. Pattom

The corresponding values were positive but not significant for W_1 leaves, negative for W_2 and positive and statistically significant for W_3 with regard to the top region. In the middle region the 'r' value was negative in relation to W_1 and positive in the case of

TABLE 42. Correlation coefficient (r) between soil available Mg and leaf Mg

Locations	Top			Middle			Bottom			Regions pooled		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
Vithura	0.183	-0.298	0.580**	-0.234	0.278	0.403	0.345	0.147	0.077	0.271*	-0.285	0.439**
Pattom	0.208	-0.205	0.480*	-0.325	0.329	0.076	0.169	0.084	0.255	-0.311	-0.263	0.387**
Vellayani	0.011	0.104	0.183	0.011	0.037	0.140	0.017	0.137	0.029	0.017	0.037	0.018
Kulasekharam	0.331	-0.358	0.471*	0.150	0.416	0.155	0.424	0.385	0.393	0.172	-0.259	0.499**
Locations pooled	-0.138	0.273	0.409**	-0.114	0.216	0.039	0.013	-0.143	-0.0714			

* Significant at 0.05 level

** Significant at 0.01 level

W_2 and W_3, both of which were not statistically significant. All the correlation coefficient values for W_1, W_2 and W_3 leaves for the bottom region were positive but not statistically significant. When all the values were pooled and analysed, the correlation between soil and leaf Mg were found to be negative for W_1 and W_2 while the value was positive and significant for W_3 ($r = 0.387^{**}$).

4.3.5.3. Vellayani

The correlation between soil and plant Mg was invariable found to be positive among the regions and among the whorls and also when pooled. None of the value was found to be statistically significant.

4.3.5.4. Kulasekharam

The correlation coefficient was positive but not significant in W_1, negative in W_2 and positive and statistically significant in W_3 in the top region of the plant. In the middle region the 'r' values were all positive, but not significant. The same trend was noticed in the bottom region of the plants in all the three whorls. On pooling the results of all the locations, it was found that W_3 was statistically superior ($r = 0.499^{**}$) to W_1 and W_2.

Considering locations, regions of the plant and leaves of different whorls, it was found that W_3 was very much statistically correlated between the leaf and soil Mg ($r = 0.409^{**}$).

4.3.6. Correlation coefficients between soil DTPA extractable Cu and the leaf content (Table 43)

4.3.6.1. Vithura

The correlation between the DTPA extractable Cu and the leaf Cu content was found to be negative in W_3 of top region, W_2 of middle region and W_1 and W_2 leaves in the bottom region only. The correlation coefficient values were positive but not significant with reference to all other whorls of the three regions. The pooled analysis showed that a positive correlation exist between the soil Cu and leaf Cu in W_2 and W_3 leaves of all the three regions of the plant ($r = 2.77^{*}$ and $R = 2.64^{*}$).

4.3.6.2. Pattom

At this site all the correlation values were positive between the DTPA extractable Cu and leaf Cu but statistically significant only in the case of W_3 leaves of the bottom region of the plant ($r = 0.513^{*}$). The pooled analysis revealed that the relationship between

TABLE 43. Correlation coefficient (r) between soil DTPA Cu and leaf Cu

Location	Top region			Middle			Bottom			Regions pooled		
	W_1	W_1	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
Vithura	0.119	0.220	-0.043	0.242	-0.145	0.128	-0.073	-0.408	0.300	0.002	0.277*	0.264*
Pattom	0.267	0.399	0.178	0.363	0.432	0.432	0.068	0.033	0.513*	0.241	0.412**	0.543**
Vellayani	0.078	0.373	-0.031	-0.395	0.300	0.365	-0.039	-0.110	0.583**	-0.178	0.105	0.535**
Kulasekharam	0.355	0.071	-0.073	0.294	0.176	0.082	0.262	0.214	0.491*	0.335**	0.175	0.107
Location pooled	0.159	0.254*	0.112	0.216	0.149	0.076	0.072	-0.064	0.471**			

* Significant at 0.05 level

** Significant at 0.01 level

soil DTPA extractable and soil Cu was highly significant in W_2 and W_3 leaves ($r = 0.412^{**}$ and $r = 0.543^{**}$).

4.3.6.3. Vellayani

The correlation between soil and leaf Cu content was found to be positive in W_1 and W_2 of top region, W_2 and W_3 of middle region and W_3 of bottom region, the last only being statistically significant ($r = 0.583^{**}$). Pooled analysis of the data from all the three regions of the plant showed a positive and significant correlation in the case of W_3 only ($r = 0.535^{**}$).

4.3.6.4. Kulasekharam

Except W_3 of the top region the correlation coefficient values were positive in all other cases. But among these, the value was statistically significant in W_3 of the bottom region only ($r = 0.491^{*}$). The pooled analysis however yielded statistically significant coefficient of variation in the case of W_1 leaves alone ($r = 0.335^{**}$).

A pooled analysis of the data from all the regions of the plant from the four locations studied, gave significantly positive relationship in W_2 of top region ($r = 0.254^{*}$) and W_3 of bottom region ($r = 0.471^{**}$) only.

4.3.7. Correlation between DTPA extractable soil Mn and leaf Mn content (Table 44)

4.3.7.1. Vithura

All the correlation coefficient values except for W_1 of middle region were positive, but statistically not significant. The pooled analysis also did not reveal any superiority among W_1, W_2 and W_3.

4.3.7.2. Pattom

At this site the extractable Mn and the leaf Mn content were positively correlated. But the value was statistically significant only in the case of W_3 of bottom region only ($r = 0.493^*$). The pooled analysis gave positive correlationships in the case of all the three whorls ($r = 0.384^{**}$ for W_1, $r = 0.397^{**}$ for W_2 and $r = 0.463^{**}$ for W_3).

4.3.7.3. Vellayani

The same trend as in the case of Pattom location was noticed at this site also, with the correlation coefficient value of $r = 0.424^*$ for W_3 of bottom region. Pooled analysis of all the data relating to the three whorls in the three regions of the plant yielded positively significant correlation coefficients ($r = 0.422^{**}$, 0.422^{**} and 0.498^{**} for W_1, W_2 and W_3 respectively).

TABLE 44. Correlation coefficient (r) between soil DTPA Mn and leaf Mn

Location	Top region			Middle			Bottom			Regions pooled		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
Vithura	0.123	0.079	0.041	-0.069	0.003	0.073	0.202	0.146	0.092	0.088	0.088	0.055
Pattom	0.358	0.410	0.288	0.177	0.323	0.413	0.363	0.437	0.493*	0.384**	0.397**	0.463**
Vellayani	0.204	0.351	0.045	-0.234	0.129	0.030	0.431	0.384	0.424*	0.422**	0.422**	0.498**
Kulasekharam	-0.187	-0.222	-0.213	0.313	0.325	0.325	0.111	0.235	0.557*	-0.177	0.177	0.373**
Locations pooled	0.141	0.124	0.041	-0.033	0.133	0.012	0.271*	0.213	0.320*			

* Significant at 0.05 level

** Significant at 0.01 level

4.3.7.4. Kulasekharam

At this location, the correlation between soil extractable Mn and leaf Mn content was found to be negative in the case of all the three whorls ~~for the go~~ of top region. In the case of middle and bottom region of the plants, the correlation coefficient values were positive but statistically significant only in the case of W_3 of bottom region ($r = 0.557^*$). The pooled analysis revealed that a positively significant correlationship existed only between the soil extractable Mn and leaf Mn content in whorl 3.

The pooled analysis of the data from all the whorls of the three regions of the plants from the four localities, showed that W_1 and W_3 of bottom region alone had positive and significant correlation values.

4.3.8. Correlation between DTPA extractable soil Zn and leaf Zn content (Table 45)

4.3.8.1. Vithura

The correlation coefficient values between the soil extractable Zn and the leaf Zn content were positive except in W_2 of the bottom region of the plant. The correlation coefficient value was statistically superior only in the case of W_3 of the bottom region ($r = 0.586^{**}$).

TABLE 45. Correlation coefficient (r) between soil DTPA Zn and leaf Zn

Locations	Top region			Middle			Bottom			Regions pooled		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
Vithura	0.106	0.437	0.153	0.381	0.385	0.201	0.317	-0.177	0.586**	0.365**	0.249	0.791**
Pattom	-0.356	-0.001	0.116	0.415	0.051	0.329	-0.388	-0.321	0.396	0.413**	-0.285	0.227
Vellayani	-0.430	-0.434	0.075	-0.369	-0.111	0.066	0.291	0.348	0.445*	-0.348	-0.304	0.572**
Kulasekharam	-0.333	-0.419	0.194	-0.436	-0.173	0.213	-0.431	0.145	0.529*	-0.475	-0.244	0.343**
Location pooled	0.025	0.181	0.294*	0.164	0.116	-0.074	0.320*	-0.075	0.481**			

* Significant at 0.05 level

** Significant at 0.01 level

A pooled analysis showed that leaves of whorls W_1 and W_3 were superior and significant, as compared to W_2 ($r = 0.365^{**}$ for W_1 and $r = 0.791^{**}$ for W_3).

4.3.8.2. Pattom

At this location the correlation coefficients between DTPA extractable Zn and leaf Zn was found to be negative in the case of W_1 and W_2 of the top and bottom regions. The value for all other whorls of the three regions were positive, but not significant. The pooled analysis revealed that the W_1 leaves were the most indicative of the influence soil extractable Zn to leaf Zn.

4.3.8.3. Vellayani

The correlation coefficient values at this site presented a different picture. The values were negative for W_1 and W_2 of top region and the middle region only. All the other values were positive but of which the value of W_3 of the bottom region proved to be positive and statistically significant ($r = 0.445^{*}$). A pooled analysis has revealed that the extractable DTPA Zn was positively and significantly correlated with the leaf Zn content in W_3 ($r = 0.572^{**}$).

4.3.8.4. Kulasekharam

The correlation coefficients were almost similar to Vellayani in trend in the case of Kulasekharam, the exception being a negative correlation coefficient value for W_1 leaves of the bottom region. Only the W_3 leaves of the bottom region gave a positively significant value of correlation coefficient ($r = 0.529^*$). The pooled analysis also was exactly similar to that of Vellayani location. Only whorl 3 showed statistical superiority over the other two whorls ($r = 0.343^{**}$).

A pooled analysis of data from all the locations also showed that the zinc content of the W_3 whorls of the bottom region had a highly significant positive correlation with DTPA extractable soil zinc ($r = 0.481^{**}$).

4.4. YIELD DATA OF DRIED FLOWER BUDS (Table 46)

The mean value of yield of dried flower buds for 2 years in kg per tree per year are presented hereunder (Table 46). The mean yield data at Vithura ranged from 1.2 to 4.450 kg per plant with a mean of 3.153 kg per tree per year. At Pattom the mean value of yield ranged from 1.15 to 4.6 with a mean of 2.593 kg per tree per year. At Vellayani it ranged from 0.6 to 1.6 (mean value 0.82 kg per tree per year). At Kulasekharam, the yield data varied from 10.75 to 14.5 kg per tree per year with a mean value of 12.439 kg per tree per year.

TABLE 46. Yield data of dried flower buds

(Mean values kg/tree/year)

Tree No.	Locations			
	Vithura	Pattam	Vellayani	Kulasekharam
1.	3.000	1.400	0.600	11.750
2.	1.750	1.400	1.600	12.250
3.	1.200	2.300	0.800	13.625
4.	3.750	2.400	0.400	13.500
5.	3.985	2.125	0.600	13.650
6.	2.600	1.150	1.050	11.750
7.	3.375	2.400	1.150	10.125
8.	3.375	3.800	0.800	12.750
9.	1.500	2.200	0.600	11.750
10.	2.300	3.125	0.600	11.000
11.	3.400	2.150	-	12.150
12.	3.000	2.400	-	13.225
13.	3.750	1.700	-	11.750
14.	3.500	3.900	-	12.225
15.	3.375	4.600	-	14.500
16.	4.000	2.600	-	12.750
17.	4.375	2.395	-	12.250
18.	3.125	2.325	-	13.250
19.	3.250	2.625	-	12.575
20.	4.450	4.375	-	11.570
Grand total	63.060	51.870	8.206	248.775
Mean	3.153	2.593	0.820	12.439

4.4.1. Correlation studies with yield (Table 47 and Fig. 1 to 5)

In order to make an attempt to standardise the index leaves for various nutrients, the values of leaf concentrations of nutrients having significant correlation with the soil nutrients were correlated with the yield data obtained from the respective trees. The correlation coefficients and the regression equations arrived from these studies are presented in Table 47.

The leaf nitrogen concentrations of the W_1 leaves of the top region at all the four location had positive significant relationship with yield and the correlation coefficients were r = 0.873**, r = 0.627**, r = 0.455* and r = 0.533* for Vithura, Pattom, Vellayani and Kulasekharam respectively. The regression equations were also worked out for this variable as given in Table 47.

The leaf P concentration of W_1 samples of bottom region of Vithura, Pattom, Vellayani and Kulasekharam had also well correlated with the respective yields (r = 0.465*, 0.465*, 0.542* and 0.592* respectively).

The leaf K concentration of W_1 leaf samples of the top region at Kulasekharam only had significant positive relationship with the respective yield (r = 0.540*).

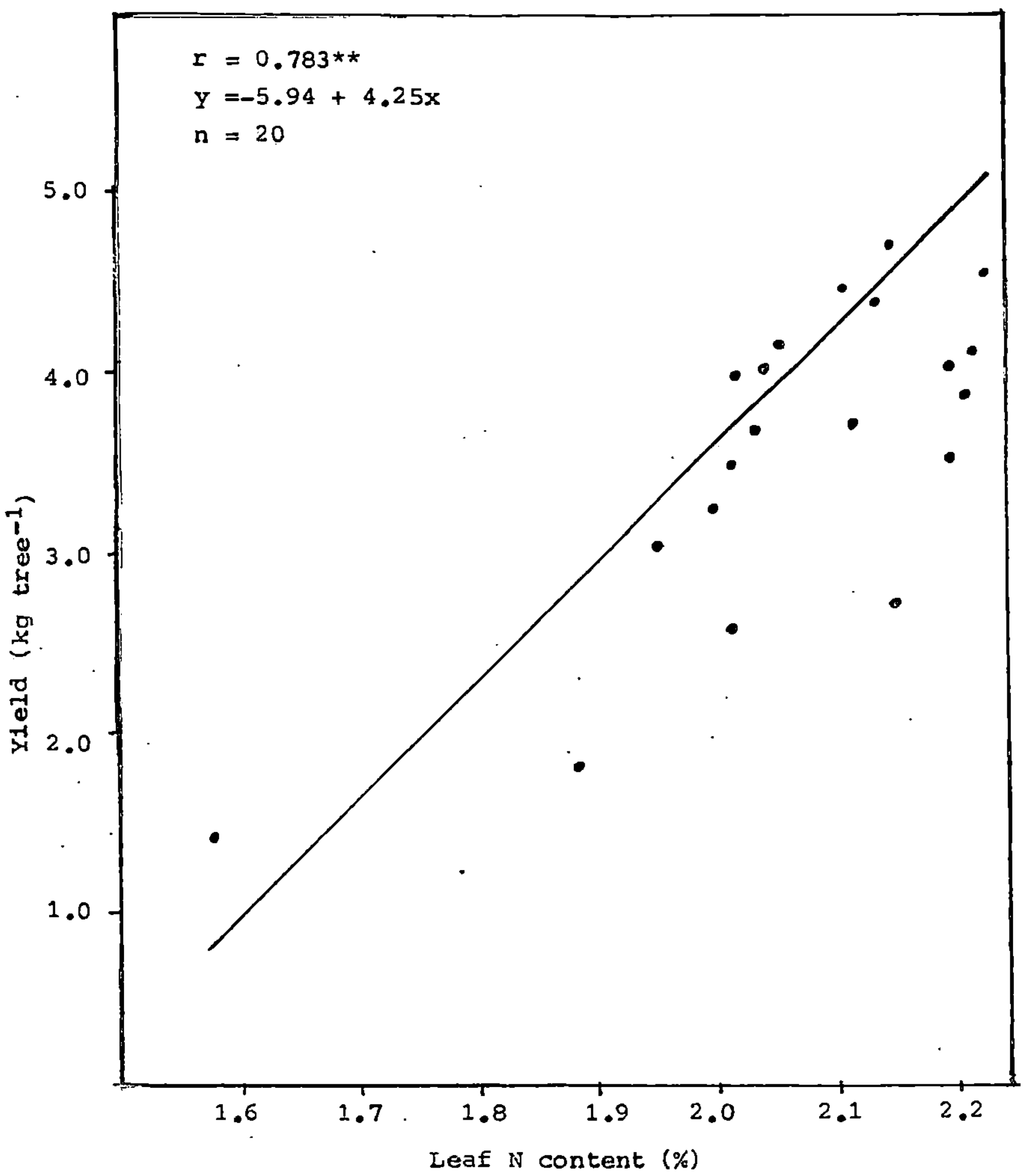
TABLE 47. Correlation coefficients between leaf nutrient concentrations and the yield

Sl No.	Relationship between X	Y	Correlation coefficient 'r'	Regression equation $Y = a \pm bx$	No. of pairs
1.	Leaf N of top (W_1) at Vithura	Yield	0.783**	Y = ~~-6.07~~ −5.94 + ~~4.32x~~ 4.25x	20
2.	Leaf N of top (W_1) at Pattom	Yield	0.627**	Y = ~~12.5471~~ −6.547 + ~~6.34x~~ 6.34x	20
3.	Leaf N of top (W_1) at Vellayani	Yield	0.455*	Y = -2.51 + 1.55x	10
4.	Leaf N of top (W_1) at Kulasekharam	Yield	0.533*	Y = 0.563 + 5.23x	20
5.	Leaf P of bottom (W_1) of Vithura	Yield	0.465*	Y = 0.75 + 10.75x	20
6.	Leaf P of bottom (W_1) of Pattom	Yield	0.490*	Y = -0.47 + 12.02x	20
7.	Leaf P of bottom (W_1) of Vellayani	Yield	0.542*	Y = 0.277 + 3.505x	10
8.	Leaf P of bottom (W_1) of Kulasekharam	Yield	0.592*	Y = 10.04 + 16.71x	20
9.	Leaf K of top (W_1) at Kulasekharam	Yield	0.540*	Y = 6.67 + 2.43x	20
10.	Leaf Ca of bottom (W_3) at Vithura	Yield	0.455*	Y = 1.44 + 5.68x	20
11.	Leaf Mg of top (W_3) at Kulasekharam	Yield	0.462*	Y = 9.21 + 11.12x	20

TABLE 47. (Contd..)

Sl No.	Relationship between X	Y	Correlation coefficient	Regression equation $Y = a \pm bx$	No. of pairs
12.	Leaf Cu of bottom (W_3) at Vellayani	Yield	0.512*	Y = 0.46 + 0.07x	10
13.	Leaf Mn of bottom (W_3) at Vellayani	Yield	0.503*	Y = -0.03 + 0.002x	10
14.	Leaf Mn of bottom (W_3) at Kulasekharam	Yield	0.465*	Y = 9.19 + 0.006x	20
15.	Leaf Zn of bottom (W_3) at Kulasekharam	Yield	0.484*	Y = 12.07 ± 0.008x	20

Fig.1. RELATIONSHIP BETWEEN LEAF N CONTENT OF TOP (W1) AND THE YIELD AT VITHURA



-150

Fig.2. RELATIONSHIP BETWEEN LEAF P CONTENT OF BOTTOM (W1) AND THE YIELD AT KULASEKHARAM

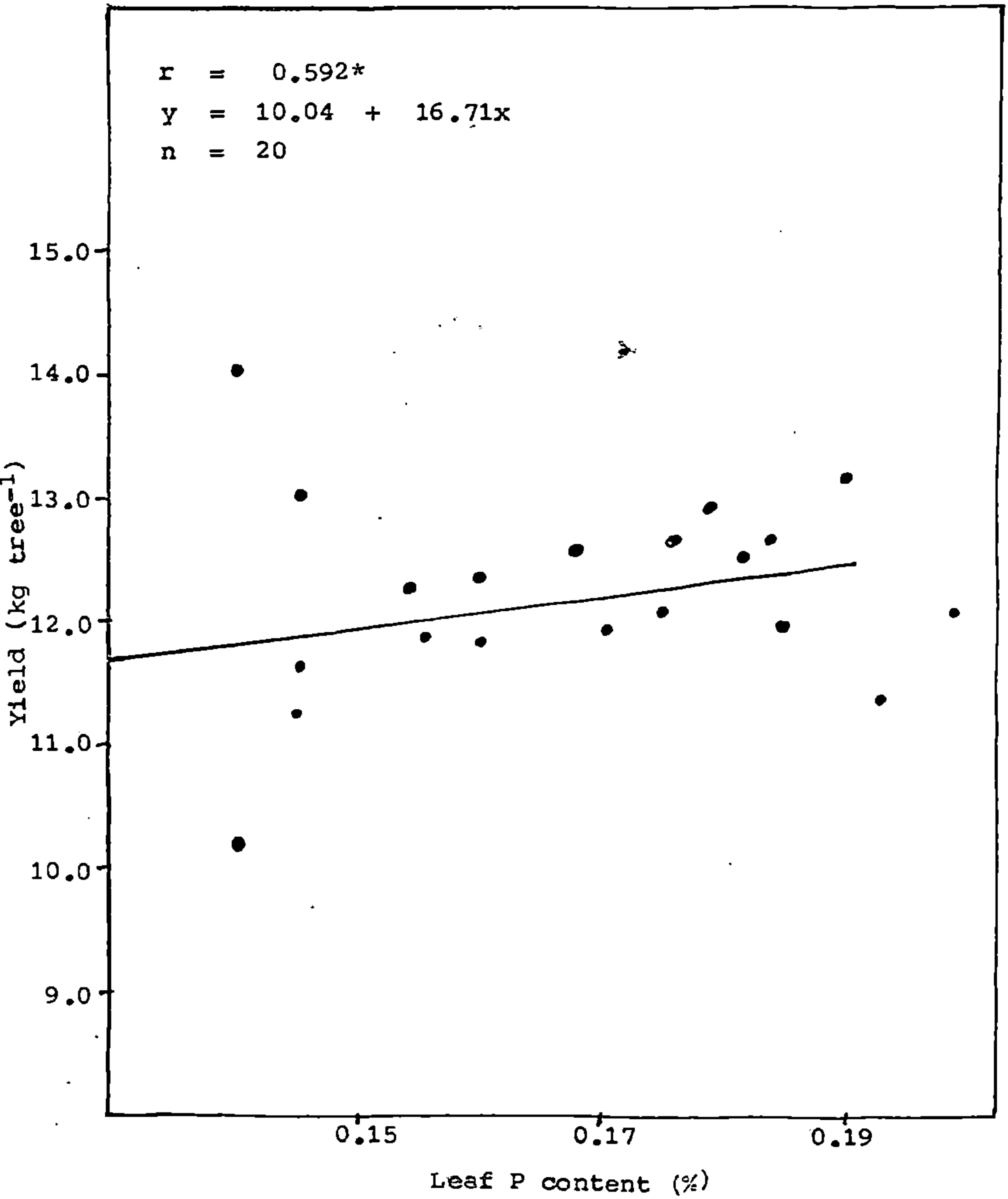


Fig.3. RELATIONSHIP BETWEEN LEAF K CONTENT OF TOP (W1) AND THE YIELD AT KULASEKHARAM

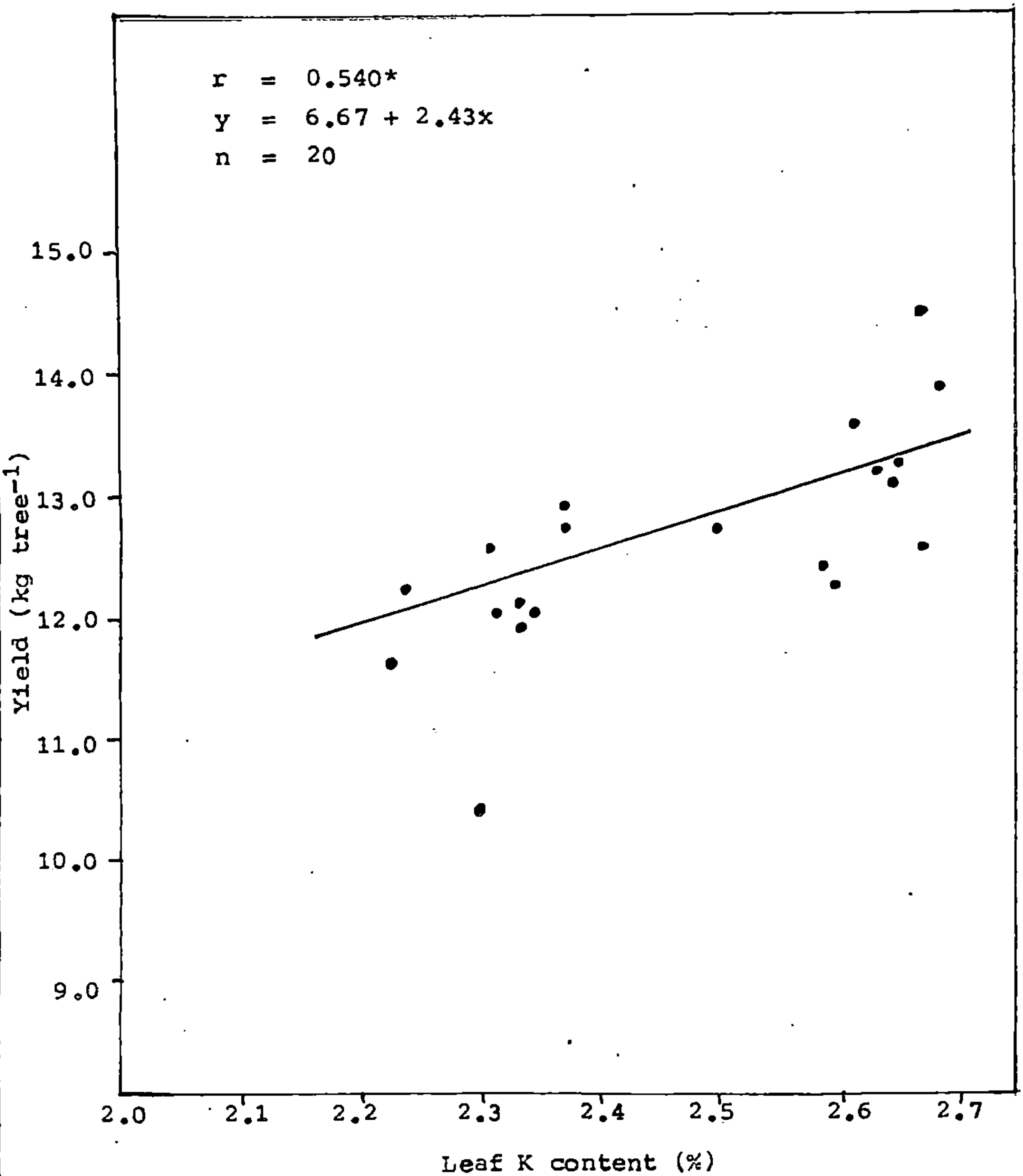


Fig.4. RELATIONSHIP BETWEEN LEAF Ca CONTENT OF BOTTOM (W3) AND THE YIELD AT VITHURA

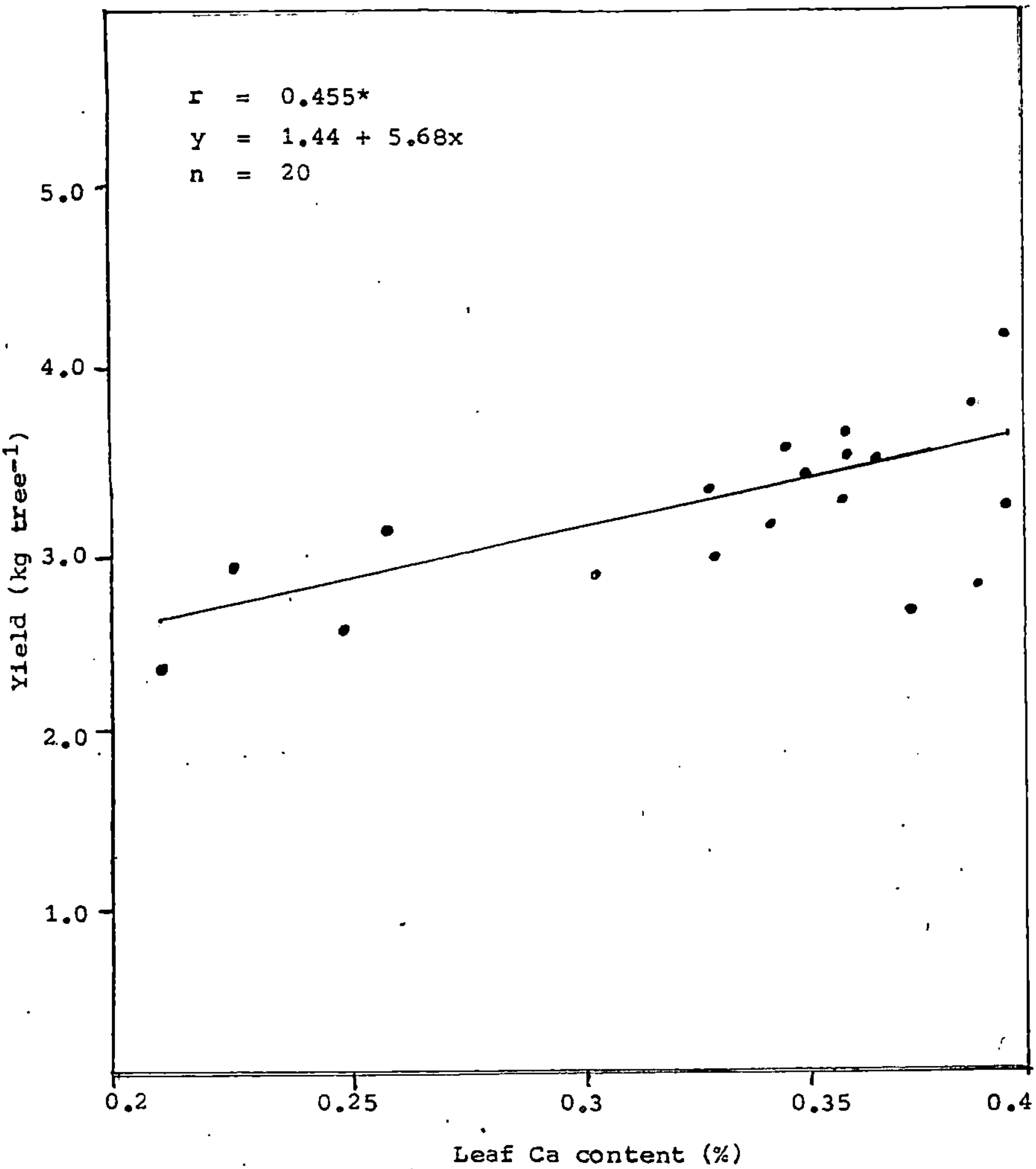
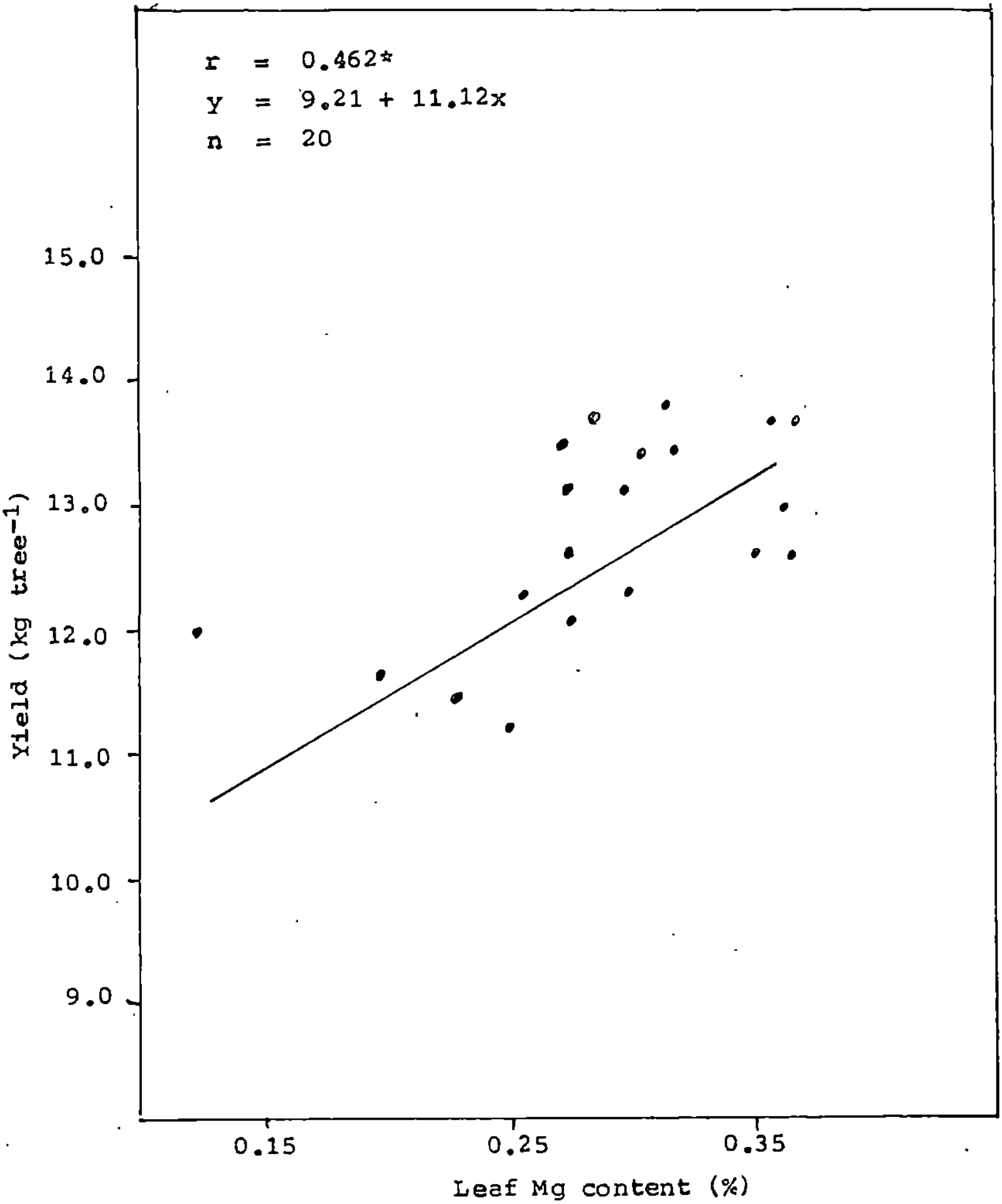


Fig. 5. RELATIONSHIP BETWEEN LEAF Mg CONTENT OF TOP (W3) AND THE YIELD AT KULASEKHARAM



The leaf Ca concentration of W_3 leaves of bottom region at Vithura correlated well with the respective yield. ($r = 0.455^*$). In the case of magnesium the W_3 leaves of top region at Kulasekharam correlated well with the respective yield ($r = 0.462^*$). The leaf copper and manganese concentration of W_3 leaves of bottom region of the trees at Vellayani had positive significant relationship with their respective yield ($r = 0.512^*$ and 0.503^* respectively). The leaf manganese concentration of W_3 of bottom region at Kulasekharam also indicated significant positive relation with the yield ($r = 0.465^*$). In the case of zinc the leaf concentration of W_3 leaf samples of bottom region at Kulasekharam had correlated significantly with the yield ($r = 0.484^*$).

Regression equations were also worked out for the above significant correlation coefficient values for the prediction of response as furnished in Table 47.

DISCUSSION

5. DISCUSSION

The result data presented in the previous chapter pertained to the physico-chemical properties of the experimental soils, the available nutrient status of the soils in which the experimental trees are located; the leaf concentrations of the nutrients under study; the correlation coefficients between soil nutrients and leaf concentrations; yield data and the correlation studies are discussed below :

5.1. PHYSICO-CHEMICAL PROPERTIES OF SOIL

The soil type of Vithura, Pattom, Vellayani and Kulasekharam was found to be forest soil (sandy clay); laterite soil (sandy clay loam); red soil (sandy clay loam) and forest soil (clay loam) respectively, all acidic in reaction and in low in electrical conductivity. The organic carbon content was found to be highest in Kulasekharam followed by Vithura, Pattom and Vellayani. The total nitrogen percentage was found to have the same trend in relation to the organic carbon content. The cation exchange capacity and the exchangeable cations were also found to be highest in Kulasekharam sample and lowest in Vellayani soils. Vithura soils registered highest value for total phosphorus (0.06 per cent) followed by Vellayani, Pattom and Kulasekharam. The total Cu, Mn and Zn status of the soil were highest in Kulasekharam followed by Pattom, Vithura and Vellayani as given in Table 1.

Clove grows satisfactorily on laterite, clay loam and rich black soils having good drainage (Clove,1979) and in India it is grown successfully in loamy soils rich in humus (Shanmugavelu and Madhawa Rao, 1977). Since the experimental sites of the present study are also located in places where forest soils, laterite soils and red soils occur, it is evident that the selection of sites for this present study are in concurrence with the above literature.

It was observed that Kulasekharam soil is best suited for clove cultivation among the four soils, as the same soil was found to have highest amount of organic carbon and other essential elements besides being good in their physical make up. Vellayani soils were considered not ideally suitable for profitable clove cultivation, as the physico-chemical properties were found to be very poor. From the yield data of this location also it is safe to presume that this soil need to be improved in its physical properties for bringing it up for profitable clove cultivation.

The Vithura and Pattom soils were also found to have the required fertility for clove cultivation (Table 1) and the yield data from this location vouches for their suitability for clove cultivation.

5.2. VARIATION IN AVAILABLE SOIL NUTRIENTS AS INFLUENCED BY THE LOCATION AND THE DISTANCES FROM THE MAIN TRUNK OF THE TREE

The mean values of soil available nutrients such as N, P, K, Ca, Mg, Cu, Mn and Zn recorded from different radial distances from the boll of the plant are presented in Table 2 and the datai are discussed below.

5.2.1. Nitrogen

The mean values of available N status of soil for different radial distances from the main trunk of the tree located in Vithura were 0.023, 0.018 and 0.01 per cent for half metre, one metre and one and half metre respectively (Table 2). At Pattom, the mean values were 0.027, 0.01 and 0.015 per cent respectively (Table 3). At Vellayani, the mean values of N status were 0.014, 0.013, 0.011 for the above distances. Mean values of 0.016, 0.014 and 0.014 were recorded in Kulasekharam soils. From these data, it is found that the soil available nitrogen status varies from place to place and for different radial distances from the main trunk of the tree. These observations are in accordance with the findings of Annie (1982) who reported that specific variations were observed in the major and sub-major nutrient contents of the soils of the tree tract in a study in Trivandrum district of Kerala on cocoa plants.

It was also interesting to note that the highest available nitrogen content was recorded at the half metre distance from the main trunk of the tree invariably in all the locations. This might be due to the presence of highest amount of microorganisms associated with high organic matter in this place which might have been responsible for the mineralisation of nitrogen.

5.2.2. Phosphorus

The soil available phosphorus content at Vithura recorded mean values of 0.0011, 0.0010 and 0.0010 per cent for the radial distances of half metre, one metre and one and a half metre from the main trunk of the tree respectively. At Pattom the mean values were 0.0012, 0.0012 and 0.0011 per cent and at Vellayani the mean values were 0.0012, 0.0012 and 0.0012 per cent and at Kulasekharam the mean values were 0.0007, 0.0007 and 0.0007 per cent half metre, one metre and one and a half metre of radial distances from the tree of the said locations respectively.

It was seen from the data that the available phosphorus content of soil varied from place to place as already reported by Annie (1982). But the phosphorus availability at different radial distances from the tree trunk was more or less same in all the locations.

5.2.3. Potassium

The mean available potassium content at the radial distances of half metre, one metre and 1½ metre from the tree base, at Vithura were 0.03,0.024 and 0.016 per cent, at Pattom 0.03, 0.024 and 0.03 per cent at Vellayani 0.018, 0.015 and 0.015 per cent and at Kulasekharam 0.025, 0.026 and 0.025 per cent.

It was observed that at Vithura, Pattom and Vellayani the soil available potassium content was highest at half metre distance from the main trunk and the values decreased at one metre distance from the main trunk and further decreased at one and half metre distance. The decrease in available potassium content with distance was only minimal in the case of Kulasekharam. This may be due to the good management practices followed there and the uniformity in fertility status irrespective of distance from the tree trunks.

At Vellayani the content of available potassium was comparatively lower than the other locations indicating the poor fertility status of the soil as already discussed.

5.2.4. Calcium

The exchangeable calcium at Vithura had mean values of 0.019, 0.012 and 0.009 per cent for half metre, one metre and one and a half metre respectively. At Pattom the values were 0.101, 0.090 and 0.082 per cent; at Vellayani the values were 0.019, 0.014 and 0.011 per cent and at Kulasekharam the values were 0.081, 0.070 and 0.085 per cent for half metre, one metre and one and a half metre respectively (Table 2,3,4 and 5).

It is to be noted from the data that the exchangeable calcium content of soil varied from place to place. Pattom and Kulasekharam soils contained much more exchangeable calcium when compared to other 2 sites. This fact may be linked to better management practices followed at these places and also to regional variation. The exchangeable calcium content had the similar pattern of soil nitrogen indicating the highest values recorded at half metre distance from the main trunk of the tree and the lowest values decreasing progressively from one metre distance of the tree onwards.

5.2.5. Magnesium

The exchangeable magnesium content of soil at Vithura yielded mean values of 0.017, 0.015 and 0.015 per cent for half metre, one metre and one and a half metre distance from the main trunk of the tree respectively. At Pattom also the same mean values were recorded. At Vellayani the mean values were uniformly 0.011 per cent in the soils from the three distances. At Kulasekharam, the mean values were 0.02, 0.019 and 0.018 per cent for soils from the three distances respectively (Table 2,3, 4 and 5). The place to place and the distance to distance differences in exchangeable magnesium is not much. However the amount of exchangeable calcium recorded at Vellayani were lowest as in the case of other nutrients. The highest values in all the locations were recorded at half metre distance from the main trunk of the tree, which diminished with an increase in distance.

5.2.6. Copper, manganese and zinc

The DTPA extractable copper content of soil at Vithura registered mean values of 16.736, 10.821 and 12.26 ppm for half metre, one metre and one and a half metre distance from the main trunk of the tree respectively. The mean values were 9.674, 5.723, 10.987 ppm at Pattom;

0.648, 0.685 and 0.742 ppm at Vellayani and 2.47, 2.97 and 3.52 ppm in Kulasekharam, at half, one and one and a half metre distances from the main trunk of the tree.

The mean values of DTPA extractable manganese content of soil were 6.194, 6.341 and 5.83 ppm at Vithura, 62.98, 64.29 and 73.75 ppm at Pattom, 18.3, 17.38 and 19.28 ppm at Vellayani and 35.1, 69.63 and 66.47 ppm at Kulasekharam at half, one and one and a half metre distance respectively (Table 2, 3, 4 and 5).

The DTPA extractable zinc had the mean values of 3.498, 2.656 and 2.27 ppm in Vithura soils, 2.539, 2.105 and 2.022 ppm in Pattom soils, 1.64, 1.391 and 1.71 ppm in Vellayani soils and 4.81, 4.8 and 5.31 ppm in Kulasekharam soils, at half,one and one and ahalf metre distances respectively.

The DTPA extractable Mn, Cu and Zn content in soils from the distances of half, one and one and half metre distances from the four locations did not show any consistent trend. Copper showed an increasing trend with increasing distance from the tree at Vellayani and Kulasekharam sites. But at Vithura copper content was highest at 1½ metre followed by ½ metre and then 1 metre. The same trend was observed in Pattom soils also.

In the case of manganese, the Vithura and Pattom soils showed an increasing content with increasing distance from the plants. Entirely different trend was observed in the other two locations. The manganese content was maximum at a distance of 1½ metre, followed by ½ metre and one metre at Vellayani. In Kulasekharam soils the decreasing trend was in the order of 1 metre, 1½ metre and ½ metre with reference to this element.

The DTPA extractable zinc showed a decreasing trend with distance from the tree in soils from Vithura and Pattom. In Vellayani and Kulasekharam soils the maximum zinc content was noticed at 1½ metre, followed by ½ metre and one metre.

While analysing the soil available nutrients as influenced by locations and by the distances from the main trunk of the tree it is inferred that the quantity of all the available nutrients contents varied from locations to locations. This is in conformity with the findings of Annie (1982) who observed similar trend in cocoa plants. It was also noted that within each location, the soil available N, P, K, Ca and Mg contents were found to be the highest at half metre distance of the main trunk of the tree and afterwards the mean values were found to decrease and the lowest values were recorded at one and half metre distance in most of the cases.

In the absence of available literature it is difficult to explain the covalic occurrence and quantity of micronutrients, Zn, Cu and Mn with reference to distances from the tree base. The availability of these elements is dependent on the organic matter content, natural abundance, presence of microflora and moisture regimes.

5.3. VARIATIONS IN THE LEAF NUTRIENT CONCENTRATIONS AS INFLUENCED BY THE LOCATIONS AND THE SAMPLING POSITIONS

The leaf nutrient concentrations were found to be influenced more by the sampling positions, than by the locations.

5.3.1. Nitrogen (Tables 6, 7, 8 and 9)

The mean value of nitrogen concentration in leaf at Vithura ranged from 1.744 to 2.133 per cent. The highest concentrations was recorded by W_1 of the top region of the tree. Similar trend was also observed in other regions. The lowest value was recorded invariably in W_3 leaves of all the three regions. The coefficient of variation was also lowest (7.757) in the W_1 of the top region as given in Table 6.

At Pattom, the mean nitrogen concentration varied from 1.946 to 2.385 per cent, the highest being the W_1 leaves of top region, which gave the lowest coefficient of variations as in the previous case (Table 7). At Vellayani, the mean values ranged from 1.883 to 2.145 per cent. The highest values registered in W_1 leaves of top region, with a coefficient of variations of 2.457 (Table 8).

At Kulasekharam, the mean values varied from 1.819 to 2.755 per cent. Here also the W_1 leaves of the top region of the tree registered the highest value and also yielded the lowest co-efficient of variation among all the leaf positions (Table 9).

It was observed from the above data that the leaf nitrogen concentrations were in the normal range as reported by Loue (1962). The nitrogen concentration varied from region to region of the tree and also from wholr to whorl within each region. This finding is in conformity with the findings of Burridge et al. (1964); Murray and Maliphant (1965) and Annie (1982). It was clearly indicated that the W_1 of the top region of the tree had the highest nitrogen concentration coupled with the lowest coefficient of variations irrespective of the location and region of the tree. This might be due to the mobilization of nitrogen to the active growing region.

5.3.2. Phosphorus (Table 10, 11, 12 and 13)

At Vithura the phosphorus concentration in the leaf had mean values from 0.160 to 0.382 per cent. The highest concentration was registered in the W_1 leaves of the bottom region of the tree, which had also indicated the lowest coefficient of variation of 15.389 (Table 10). At Pattom, the mean values ranged from 0.170 to 0.258 per cent. The highest value was registered in W_1 leaves of bottom region of the tree as in the previous case. The co-efficient of variations was also the lowest (6.859) in this position (Table 11). At Vellayani the mean phosphorus concentration ranged from 0.084 to 0.165 per cent. The highest value was registered in the W_1 leaves of bottom region with lowest coefficient of variation of 12.267 (Table 12). At Kulasekaram, the mean values ranged from 0.105 to 0.140 per cent. The highest value was observed in W_1 leaves of bottom region with the lowest coefficient of variations of 14.26 per cent (Table 13).

The leaf phosphorus concentrations in all the locations were within the normal range. Within the location, the sampling regions differed in phosphorus concentrations as already observed by Murray and Maliphant (1965) and Annie (1982) as in the case of nitrogen. Within the region the W_1 leaves had highest phosphorus content followed by W_2 leaves and the least in W_3 leaves. Among all the region, irrespective of the location the W_1 leaves of the bottom region of the tree had the highest concentration of phosphorus with the lowest coefficient of variation, indicating significant presence of phosphorus at this part.

5.3.3. Potassium (Tables 14, 15, 16 and 17)

The mean potassium concentration in leaf at Vithura, ranged from 1.985 to 2.262 per cent. The highest amount of potassium was registered in the W_1 leaves of the top region of the tree. There was a tendency for the element to decline towards W_3 leaves in all the regions. Among all W_1 leaves of top region had the highest concentrations with the lowest cv. of 5.582 (Table 14). At Pattom, the mean values ranged from 1.997 to 2.486 per cent. Here also the same trend was noticed. The highest value was recorded in W_1 leaves of the top region with the lowest cv of 6.650 (Table 15). At Vellayani, the mean values ranged from 1.673 to 2.227 per cent. The highest amount was registered in W_1 leaves of top region with the lowest cv of 4.613 (Table 16). At Kulasekharam also, the same trend as in the previous cases was exhibited. The mean values ranged from 1.90 to 2.412 per cent. The highest amount was recorded in W_1 leaves of top region with a cv of 4.846 (Table 17).

It was observed from the above data that the potassium concentration in leaf had a variation from 1.673 to 2.486 per cent as influenced by the location and the sampling position. This is in accordance with the finding of Annie (1982). It was interesting to note that eventhough the potassium concentration was influenced by the above factors, the W_1 leaves of the top region of the tree invariably in all the locations had the highest potassium concentration with the lowest percentage of coefficient of variation. Hence, W_1 leaves of top region may be considered as an index of the potassium status of the plant.

5.3.4. Calcium (Tables 18, 19, 20 and 21)

The mean values of calcium concentration in leaf at Vithura, varied from 0.271 to 0.307 per cent. There was an increasing trend from W_1 to W_3 of each region of the canopy. Among all the 3 regions W_3 leaves of bottom region recorded the highest amount of calcium (cv = 12.573). At Pattom, the mean values ranged from 0.221 to 0.309 per cent. The highest amount was registered by W_3 of bottom region as in the previous case. The lowest cv (cv.=17.439) was also noticed in this group (Table 19). At Vellayani, the mean values ranged from 0.189 to 0.234 per cent. Here also, the W_3 leaves of the bottom region registered the highest calcium concentration (cv = 11.172). At Kulasekharam, the mean values varied from 0.322 to 0.360 per cent. In this case also W_3 leaves of the bottom region registered the highest concentration of Ca (cv = 11.578).

It was observed that W_3 leaves of the bottom region registered the highest amount of Ca concentration uniformly in all the locations. Annie (1982) also found similar trend in cocoa. Calcium being an immobile element usually accumulates in the older region and older leaves of any plants. This is probably the reason for the highest concentration of calcium in the 3rd whorl of the bottom region of the above plant.

5.3.5. Magnesium (Table 22, 23, 24 and 25)

The magnesium concentration in leaf at Vithura, ranged from region to region and had a mean value between 0.205 and 0.251 per cent. I_n the W_3 leaves of top region had the highest concentration of Mg with a lowest cv of 14.625 (Table 22). At $P_a$ttom, the mean values ranged from 0.212 to 0.275 per cent. Here also the W_3 leaves of the top region recorded the highest value with the lowest percentage of cv viz., 12.177 (Table 23). At Vellayani, the mean values ranged from 0.171 to 0.247 per cent. As in the previous cases, W_3 leaves of the top region registered the highest concentration of Mg with the lowest percentage of cv (9.577) as given in Table 24. At Kulasekharam, the mean values varied from 0.227 to 0.278 per cent. The W_3 leaves of the top region recorded the highest concentration of leaf Mg. The lowest coefficient of variation of 10.397, was registered in this case.

It was observed that the Mg concentration in the leaf was influenced by the sampling positions and the mean Mg concentrations ranged from 0.171 to 0.275 per cent. This was in conformity with the findings of Annie (1982). The W_3 leaves of bottom region in all the locations had invariably shown the highest concentration of Mg with lowest percentages of coefficient of variation. This might be due to higher photosynthetic activity due to the abundance of profuse sunlight at the top region of the plant canopy.

5.3.6. Copper, Manganese and Zinc

The copper concentration in leaf varied from region to region and the mean values ranged from 5.06 to 5.92 ppm at Vithura, from 2.79 to 9.26 ppm at Pattom, from from 4.63 to 5.47 ppm at Vellayani and from 4.12 to 14.71 ppm at Kulasekharam. The highest concentration of copper was recorded in W_3 of the bottom region invariably in all the locations. The percentages of coefficient of variations were also the lowest in the above sampling position (Table 25, 27, 28 and 29).

The manganese concentration in leaf also showed marked variation between the locations and within the locations between regions. The mean values of manganese concentration ranged from 217 to 269 ppm at Vithura, 267 to 370 ppm at Pattom, 345.6 to 379.6 ppm at Vellayani and 274 to 503 ppm at Kulasekharam. In all these locations, the manganese concentration was the highest in W_2 leaves of bottom region as in the case of copper. There was an increasing trend from W_1 to W_3 more or less in all the regions. The W_3 of the bottom region had also invariably the lowest coefficient of variations (Table 30,31,32 and 33).

The mean values of zinc concentrations in leaf ranged from 14.86 to 53.61 ppm at Vithura, 11.05 to 23.05 ppm at Pattom, 12.82 to 15.58 ppm at Vellayani and 6.73 to 44.34 ppm at Kulasekharam. The highest concentration of manganese was noticed in the W_3 leaves of the bottom region of the tree in all the four locations, with lowest value of coefficient of variations as given in Table 34,35,36 and 37.

From the above data it was observed that eventhough high variations were exhibited in the concentrations of copper, manganese and zinc as influenced by the location and the sampling position, the highest concentration of the above said trace elements were found to be at the W_3 leaves of the bottom region irrespective of other factors. The above position could also be confirmed with the lowest values of coefficient of variation.

5.4. RELATIONSHIPS BETWEEN SOIL AND PLANT NUTRIENTS

5.4.1. Nitrogen (Table 38)

Positive correlation between soil available nitrogen and W_1 leaves of top region leaf nitrogen was established at Vithura (r = 0.453*). The same trend was also observed at $P_a$ttom and Vellayani. At Kulasekharam the relationship was positive but not significant.

Pooled analysis for all the locations and different regions of the plant in individual locations gave positive correlations between W_1 leaves and available soil nitrogen (r = 0.511** for locations and r = 0.448* for regions).

Wessel (1970) reported that the nitrogen content of soil was an indication to the nitrogen availability to cocoa plant. The positive relationship between soil test values nitrogen and leaf nutrient concentrations were also reported by Annie (1982). Hence the above finding of the present study are in conformity with studies of the above workers.

5.4.2. Phosphorus (Table 39)

Positive correlations were observed between soil available phosphorus and leaf phosphorus more or less in all the correlation studies as given in Table 39. Significant positive relationship was observed between soil available nitrogen and W_1 leaf nitrogen of bottom region at Vithura ($r = 0.477*$) and at Kulasekharam ($r = 0.513*$). Similar highly significant positive correlation ($r = 0.750**$) was also observed at Vellayani. At $P_a$ttam location alone eventhough the correlation was positive it was not significant with reference to any leaf position. When the regions were pooled positive significant relationship was observed both at $P_a$ttom and Kulasekharam between W_1 leaves of bottom region and soil available phosphorus. The pooled analysis of data from the different locations also had highly significant positive correlation ($r = 0.474**$) between W_1 leaf samples of bottom region and soil available phosphorus.

The positive relationship brought out between soil and leaf phosphorus in the present study is in conformity with the findings of Verliere (1965), Wessel (1970) and Annie (1982). Significant positive relationships were existed in the W_1 of the bottom region in all the locations except Pattom where also positive relation existed though not significant.

5.4.3. Potassium (Table 40)

The correlation coefficients between soil available K and leaf K yielded significant positive relationship between W_1 leaves of the top region and soil available potassium both at Pattom ($r = 0.485^*$) and Kulasekharam ($r = 0.510^*$). At the other two locations the same group of leaves gave positive relationship though not significant. Analysis of pooled data from all the 3 regions of the plant also indicated positive significant relationship as given in Table 40. When data from the locations were pooled and analysed, it also yielded a significant positive relationship with reference to the W_1 leaves of the top region.

Positive relationships between soil available K and leaf K of the W_1 leaves of the top region of the plant were observed more or less in all the correlation studies which corroborates the finding of Acquaye et al. (1965) and Annie (1982).

5.4.4. Calcium (Table 41)

The correlation coefficient studies between soil available calcium and leaf calcium indicated that there was positive relationship between these variables uniformly in all the locations. Significant positive relationships between these variables were observed in the W_3 leaves of bottom region both at Pattom ($r = 0.559^*$) and at Kulasekharam ($r = 0.477$). The other locations also showed positive relationship in the same leaf group of bottom region. When region were pooled highly significant positive relationship was obtained in the same sampling position at Pattom and Vithura also. This was confirmed with the location pooled analysis which also indicated highly significant positive correlation ($r = 0.329^{**}$) in the same sampling region (Table 41). Significant positive relationship between the soil calcium and leaf calcium were already observed by Acquaye et al. (1965) and Annie (1982)

5.4.5. Magnesium (Table 42)

The correlation studies between soil magnesium and leaf magnesium showed that positive relationship existed invariably in all the locations and sampling positions. Significant positive relations were observed in the W_3 leaves of top region at Pattom ($r = 0.480^{*}$), Vithura ($r = 0.580^{**}$) and Kulasekharam ($r = 0.471^{*}$). Pooled analysis for the region gave the same trend. The correlation coefficient values for pooled analysis of data from all the locations also showed that highly significant relationship existed between the W_3 leaves of top region, and the soil available Mg (Table 42).

The findings are corroborated by the results obtained by Annie (1982) who observed positive correlations between soil test values and leaf nutrient concentration in the order of magnesium followed by calcium. Among all the sampling position W_3 leaves of top region recorded significant positive correlation irrespective of the locations which might be due to the high magnesium concentration in the same sampling position as already discussed.

5.4.6. Copper, Manganese and Zinc (Table 43,44 and 45)

The correlation studies between soil DTPA extractable copper, manganese and zinc with that of leaf copper, manganese and zinc showed that in most cases a positive relationship was present between the above variables invariably in all the locations. Significant positive relationships for these nutrients were observed in the W_3 leaves of the bottom region of the plant in Tables 43, 44 and 45. It was observed that the same sampling position was found to have significant positive relationship when data both from the regions and locations were pooled for the above nutrients separately.

It was interesting to note from the above data that all the three micronutrients under study had shown the same trend i.e., these correlation between W_3 leaves and soil available Cu, Mn and Zinc were significantly positive invariably in all the locations.

5.5. YIELD (Table 46)

The yield data of dried flower buds of clove was found to be highly influenced by the locations under study. The mean yield ranged from 0.820 to 12.439 kg $tree^{-1}$ $year^{-1}$. The highest yield was recorded at Kulasekharam followed by Vithura (3.153 kg), Pattom (2.593 kg) and the lowest by Vellayani.

The high variation in the mean yield between locations might be due to the variations in the inherent soil fertility status and other environmental factors such as climate etc. The Kulasekharam soil was found to be the best for the clove cultivation than the other locations studied. Vellayani was found to be the least suited location for profitable clove cultivation in the existing conditions.

5.6. RELATIONSHIP BETWEEN LEAF NUTRIENT CONCENTRATION AND YIELD (Table 47)

Correlation co-efficient studies between leaf nutrient concentration and yield showed that significant positive relationships existed between leaf nitrogen of W_1 leaves of top region and the yield invariably in all the locations as given in Table 47. Similarly significant positive relationships with the yield by the leaf phosphorus concentration of W_1 leaves of bottom region of all the locations were also observed. In the case of leaf potassium W_1 of top region at Kulasekharam had shown significant positive relationship with the yield. In the case of calcium, W_3 of bottom region at Vithura, had shown a significant relationship with the yield. In the case of magnesium W_3 of top region at Kulasekharam expressed significant relationship with the yield. In the case of leaf copper, manganese and zinc W_3 of bottom region at Vellayani and Kulasekharam showed significant positive relationship with yield.

The leaf nutrient concentrations in the above discussed sampling positions were having highest concentration of the respective nutrients. When the soil nutrient status was correlated with the respective leaf nutrient concentration the above said sampling positions were observed to have significant positive relationship with the respective element. To confirm the above said findings leaf nutrient concentrations were again correlated with the yield obtained from each location. It is interesting to note from these correlation studies that the same sampling positions registered significant positive relationships with the yield (Table 47).

A close relationship between leaf composition and yield was already noticed by Hardy et al. (1935), ~~Devtiene (1965)~~ and Wessel (1965).

Hence it can be safely inferred that the nutrients concentration in the index leaves now located for different nutrients could be used as a guide for a rationalised fertilizer recommendation. But before doing so an elaborate study involving more locations and more number of plants visa vis leaf samples should be undertaken to give credibility to the results of the present investigation.

SUMMARY

6. SUMMARY

The present study was an attempt in standardising the index leaf/leaves for assessing the nutritional status of clove in relation to soil fertility. Four clove growing locations, representing different soil types were selected (Vithura, Pattom, Vellayani and Kulasekharam). Clove plantations of 10 years of old at the above locations were selected for the studies. Soil samples from three different radii from the main trunk of each experimental tree and the leaf samples from three regions (viz.,top, middle and bottom) and three positions (whorl I, II and III) from each region were collected, during the flushing period invariably from all the locations. The soil samples were analysed for their important physicochemical properties and available nutrient status of N,P,K,Ca, Mg,Cu, Mn and Zn. Leaf samples were also analysed for the above said nutrient concentrations. The nutrient content of soil were correlated with the respective leaf nutrient concentrations to find out their degree of dependence. Those leaf nutrient concentrations which had positive relationship were again correlated with the respective yield obtained at different locations. The salient findings observed in the present study are summarised hereunder.

1. Among the different type of soils studied, forest soils with high organic matter and cation exchange capacity with clay loam texture was found comparatively better suited for clove cultivation than laterite and/or red soil.

2. The physico-chemical properties of the soils studied were found to be varied from locations to location and the available nutrients in the soil were highly influenced by the locations.

3. The radial distance from the main trunk of the experimental tree had significant influence on the soil available nutrients invariably in all the locations. It was found that (i) the soil available N,P,K,Ca and Mg were highest at half meter distance and lowest at one and half meter from the main trunk of the tree. (ii) The DTPA, Cu, Mn and Zn content of soils at different distances from the tree base did not show any consistency. But identical trends were not seen at different locations.

4. The leaf nitrogen concentration was highest in leaves of whorl-I (W_1) of top region coupled with lowest coefficient of variations irrespective of the location.

5. The leaf phosphorus concentration was highest in whorl-I (W_1) of bottom region of the tree invariably in

all the locations. The coefficients of variations were found to be lowest at this sampling position.

6. The leaf potassium concentration was found to be highest in the whorl-I (W_1) of top region with the lowest co-efficient of variations for all the four locations.

7. The calcium concentration of leaves was observed to be highest in the whorl-III (W_3) of bottom region of the tree with the lowest coefficients of variation irrespective of the location.

8. The magnesium concentration of leaf registered highest value in the whorl-III (W_3) of top region of the tree for all the locations, which had the lowest co-efficients of variation.

9. The copper, manganese and zinc concentration of leaf recorded the highest value in whorl-III (W_3) of bottom region of the tree irrespective of the locations.

10. The correlation studies between soil nitrogen and leaf nitrogen had shown significant positive relations in the whorl-I (W_1) of top region of the tree.

11. The soil available phosphorus and leaf phosphorus concentration expressed significant positive relationship in the W_1 leaves of bottom region of the tree.

12. Significant positive relationships were exhibited between the soil available potassium and leaf potassium in the whorl-I (W_1) of top region.

13. The soil exchangeable calcium and leaf calcium concentration had significant positive relationship in the W_3 leaf of bottom region of the tree irrespective of the locations.

14. There existed significant positive relationship between Mg content in the whorl-III (W_3) leaves of top region of the tree and the soil exchangeable magnesium.

15. The whorl-III (W_3) of bottom region of the tree gave significant positive relationships for all the locations when the soil DTPA copper, manganese and zinc were correlated with their respective leaf concentrations.

16. The highest yield of dried flower buds of clove was registered at Kulasekaram and the lowest yield was recorded at Vellayani, presumably due to the high variations in soil fertility status and agroclimatic conditions existing in these locations.

17. The correlation studies between the leaf nutrient concentration and the yield recorded significant positive relationships in the following cases.

Leaf samples

i)	Leaf nitrogen	-	whorl I (W_1) of top region of all localities
ii)	Leaf phosphorus	-	whorl I (W_1) of bottom region of all localities
iii)	Leaf potassium	-	whorl I (W_1) of top region only at Kulasekharam
iv)	Leaf calcium	-	whorl III (W_3) of bottom region of Vithura only
v)	Leaf magnesium	-	whorl III (W_3) of top region of Kulasekharam only
vi)	Leaf copper, manganese and zinc	-	whorl III (W_3) of bottom region of Vellayani and Kulasekharam only

From the observations recorded in the present study it can be concluded that the following leaf samples of clove can be taken as the index leaf/leaves for assessing the nutritional status of clove irrespective of the locations.

Index leaf		Nutrients
1. Top region-Whorl I	-	Nitrogen and potassium
2. Top region-Whorl III	-	Magnesium
3. Bottom region-Whorl I	-	Phosphorus
4. Bottom region-Whorl III	-	Calcium, copper, manganese and zinc

Though the present study gives encouraging results, for effective implementation of rationalised fertilizer recommendation, further indepth studies on the upper and lower critical limits of each nutrient for clove are needed. An extensive investigation involving large number of trees from several location or from a single location is necessary to confirm the results obtained in this preliminary study.

REFERENCES

REFERENCES

Acquaye,D.K. (1964). Foliar analysis as a diagnostic technique in cocoa nutrition. I. Sampling procedure and analytical methods. J. Sci. Fd. Agric. 15 : 855-863.

Acquaye,D.K., Smith,R.W. and Lockard, R.G. (1965). Potassium deficiency in unshaded Amazon cocoa (Theobroma cocoa L.) in Ghana. J. Hort. Sci. 40(2) : 100-108.

Agricultural Statistics of Kanyakumari District, 1979. Published by the Joint Director of Agriculture, Nagercoil, Kanyakumari District.

Annie Koruth (1982). The relationship between soil nutrient status and foliar analysis of cocoa of different age groups in the various soil types of Kerala. M.Sc.(Ag.) Thesis, College of Agri. Vellayani. Trivandrum.

Anonymous. 1979. 'Clove', published by the Directorate of Cocoa. Calicut, 1979.

* Bould,C. (1961). Plant analysis and fertilizer problems. (Washington, D.C. : Amer. Inst. of Biol. Sci.) Quoted by Acquaye,D.K. (1964). Foliar analysis as a diagnostic technique in cocoa nutrition I. Sampling procedure and analytical methods. J. Sci. Fd. Agric. 15 : 855-862.

* Boynton,D. and Compton,O.C. (1945). Soil Sci. 59 : 339. Quoted by Acquaye,D.K. (1964). Foliar analysis as a diagnostic technique in coco nutrition. I- Sampling procedure and analytical methods. J. Sci. Fd. Agric. 15 : 855-863.

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

Burridge, J.C., Lockard, R.G. and Acquaye, D.K. (1964). The levels of Nitrogen, Phosphorus, Potassium, Calcium and Magnesium in the leaves of Cacao (Theobroma cacao L.) as affected by shade, Fertilizer, Irrigation and season. Ann. Bot. (N.S) 28 (111) : 401-417.

Chapman, H.D. (1950). Foliar analysis as a diagnostic technique in Cocoa nutrition. I-Sampling procedure and analytical methods. J. Sci. Fd. Agric. 15 : 855-863.

Dufournet and Rodriguez (1972). In : Spices and Plantation Crops. Popular Book Depot, Madras.

Droupathi Devi, G. (1963). Interrelationships between physical and chemical properties of Kerala State Soils in relation to pedogenic factors. In : Relationships among constituents and properties of South Indian Soils. Agricultural College and Research Institute, Coimbatore-3

* Francois (1936). In : Spices and Condiments. Sri Isaac Pitman and Sons Ltd., Madras.

* Goodall, D.W. and Gregory, F.G. (1947). Chemical composition of plants as an Index of this Nutritional Status. Tech. Commun. Aberystwyth Imp. Bur. hort. Plantation Crops 17 Quoted by Acquqye, D.K. (1964). Foliar Analysis as a diagnostic technique in cocoa nutrition.

Hand book of Natural Rubber Production in India, 1980. Rubber Research Institute of India, Kottayam.

Hardy, F.Mc. Donald, J.A. and Rodriguez, G. (1935). Leaf analysis as a means of diagnosing nutrient requirements of tropical orchard crops. J. Agric. Sci. 25 (4) : 610-627.

Holmes, R.S. (1945). Estimation of total Cu, Zn, Co and Pb in soils and soil solution. Soil Sci. 59 : 77-84.

Humphries,E.C. (1956). Mineral components and ash analysis. Modern methods of plant analysis. Springer-Verlag. Berlin 1 : 468-508.

Jackson,M.L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi 2nd Edition pp.1-498.

Joseph,S. (1981). Effect of graded dose of N, P and K on the growth and leaf nutrient status in cocoa (*Theobroma cacao* L.) M.Sc.(Ag.) Thesis, Kerala Agricultural University.

* Kowal,J.M.L. (1959). The effect of spacing on cocoa in Nigeria. Part II. Empire J.Exp. Agric. 27. Quoted by Smyth, A.J. (1966). How useful is soil chemical analysis. Cocoa Growers Bull. 6 : 7-11.

* Lagatu,H. and Maume,L. (1926). Diagnostic de alineatation dun vege tal par le valuation eh i n gue at une fewille convenablement choisic. C.R. Acad. Sci. Paris. 182 : 653-655.

Leela,K. (1967). Forms, distribution and availability of sulphur in representative profiles of Kerala State. In : Relationships among constituents and properties of South Indian soils. Agricultural College and Research Institute, Coimbatore.

* Lindsay, W.L. and W.A.Norvell (1969). Development of a DTPA micronutrient soil test. Agron. Absts. p.84

Lone, A. (1961-62). Nutrient Deprivation and Deficiencies in the Cocoa Tree. II. Nutrient Deficiencies in the Cocoa Trees in the Plantations of the Ivory Coast. Fertilite 14 : 42-52.

Maistre. (1964). In : SPICES. Edited by Purseglove et al. 1982. Vol. I Longman, London & New York.

McDonald,J.A. (1934). A study of the relationship between Nutrient Supply and the Chemical Composition of the Cocoa Tree. Paft III. Tird. Annu. Rep. On Cocoa Research for 1933, Imp. Coll. Trop. Agric., Trinidad 55-62.

Murray,D.B. (1952). Rep. Cocoa Res. Imp. Coll. Trop. Agric., Trinidad : II Quoted by Acquaya, D.K. (1964). Foliar analysis as a diagnostic technique in cocoa nutrition. I. Sampling procedure and analytical methods. J. Sci. Fd. Agric. 15 : 855-863.

Murray,D.B. and Maliphant, G.K. (1965). Problems in the use of leaf and tissue analysis in cocoa. Conf. Int. Research Agron. Cacao yeris, Abidijan. 1965 : 36-38. (Abstr. Cocoa Growers' Bull. 11 : 30).

Panse,V.G. and P.V.Sukhatme. (1967). Statistical methods for agricultural workers, ICAR Publication, New Delhi.

Pemberton,H. 1945. Estimation of total phosphorus. J. Amer. Chem. Soc. 15 : 382-395.

Piper,C.S. (1966). Soil and Plant Analysis. Hans Publishers. Bombay.

* Pursiglov,J.W., E.G.Brown, C.L.Green and S.R.J.Robbins. Abstracted in SPICES. Vol.1 pp.238-241.

Pushpadas,M.V. and M.Ahammed (1980). Nutritional requirements and manurial recommendations. In : Hand Book of natural rubber production in India. RRID. Kottayam.

Ramig,R.E. and Vandecaveye, S.C. (1950). A study of certain nutrient levels for raspberries grown in water cultures. Plant Physiol. 25 : 617-629.

Redgrow,H.S. Spices and Condiments. Sir Isaac Pitman and Sons Ltd. London. (1933).

Ridley, H.N. (1912). Spices. Macmillan and Co., London.

* Saleh, M. (1973). The relationship between age and the mineral content of cocoa leaves. Menara Perkebunan 41(5) : 219-222. (Hort. Abstr. 44(8) : 545).

Santana,M.B.M. and Igue,K. (1979). The mineral composition of cocoa leaves as a variation of season and leaf age (in Portugese). Revista Theobroma 9(2) : 43-45.

Schroo,H. (1960). A presentation of leaf analytical data on cocoa, obtained from a fertilizer trial in Netherlands. New Guinea. Neth. J. Agric. Sci. 8 : 93-97.

Shanmugavelu, K.G. and V.N.Madhava Rao. (1977). Spices and plantation crops. Popular Book Depot, Madras.

Smith,P.F. (1962). Mineral Analysis of Plant Tissue. Ann. Rev. Plant Physiol. 13 : 81-108.

Smyth, A.J. (1966). How useful is soil chemical analysis. Cocoa Grower's Bull.6 : 7-11.

Snedecor,G.W. and W.C.Cochran (1967). Statistical methods (6th Edn.). Oxford and IBH Publishing House,Calcutta. 539.

Soils of Kerala, Soil Survey Branch, Department of Agriculture, Kerala, 1978).

Stanford,S. and L.English (1949). Use of Flame photometer in rapid soil test of K and Ca. Agron. J. 41 : 446-447.

Subbiah,B.V. and Asija,G.L. (1956). A rapid procedure for the estimation of available nitrogen in soils. Curr. Sci. 29 : 259-260.

Sushama,P.K.,A.J.Jose and V.Sukumarapillai. (1984). Standardisation of period of sampling for foliar diagnosis in pepper in relation to N, P and K. Agri. Res. Journal of Kerala, 22 : 16-21.

* Thomas,W. (1945). Soil Sci. 59 : 353. Quoted by Acquaye, D.K. (1964). Foliar analysis as a diagnostic technique in cocoa nutrition. I. Sampling procedure and analytical methods. J. Sci. Fd. Agric. 15 : 855-863.

Tidburg. 1963. In: Spices and condiments. Sir Isaac Pitman and Sons Ltd. London. (1949).

Unnikrishnan Nair,C.K. (1963). Studies on anion exchange and available phosphorus in laterite soils of Kerala. In : Relationships among constituents and properties of South Indian soils. Agri. College & Res. Institute, CBE-3.

* Verliere,G. (1965). Fertilizer trial on cocoa in the Ivory Coast. Yield increases due to fertilizers and to economic aspect. Proc. Conf. Int. Rech. agron. cocoa, 1965 : 74-81.

Vijayachandran, P.K. (1966). Studies on soil phosphorus. In : Relationships among constituents and properties of South Indian soils. Agril. Coll. and Res. Institute, Coimbatore

Walkley,A.J. and I.A.Black. (1934). An examination of Degtgaraff methods for determining soil organic matter and a proposed modification of chromic acid titraction method. Soil Sci. 37 : 29-38.

* Wessel, M. (1965). Effect of fertilizer, spacing and yield on mineral composition of cocoa leaves. Proc. Conf. Int. Rech. agron. Cocoa, 1965 : 64-66.

* Wessel, M. (1970). Intake and export of nutrients in cocoa leaves. Trop. Agr., Trinidad 47(2) : 167-170. (Abstr. Cocoa Growers' Bull. 16 : 35).

* Wessel, M. (1971). Fertilizer requirements of cocoa in South Western Nigeria. Dept. of Agric. Res. Royal Trop. Inst., Amsterdam. Communication 61 : 104p. In : Cocoa growers Bull 32 : 11-24.

* Original not seen

STANDARDISATION OF INDEX LEAF/LEAVES FOR ASSESSING THE NUTRITIONAL STATUS OF CLOVE IN RELATION TO SOIL FERTILITY

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THESIS

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ABSTRACT

Clove being an elite spice of immense economic and gastronomic importance, it was felt necessary to undertake an investigation into the fertility status of the major clove growing soils of Southern Peninsula with special reference to Trivandrum district of Kerala and Kanyakumari district of Tamil Nadu and also the mineral nutrition of the crop in relation to the fertility of the soils in which they flourish. The investigation was also aimed at establishing the index leaf/leaves for the formulation of a more pragmatic and scientific fertilizer recommendation.

With a view to achieve this aim, four major clove growing regions viz., Vithura, Pattom, Vellayani of Trivandrum district and Kulasekharam of Kanyakumari district of Tamil Nadu were chosen for the study. The soil types encountered at Kulasekharam and Vithura were forest soils, whereas laterite soil was encountered at Pattom and red soil at Vellayani. Soils from three different radii (0.5, 1.0 and 1.5 m) from the base of the plant were collected, composited, sampled and analysed.

Leaves from clove plants were collected immediately after the completion of flushing. The tree canopy was divided equally into three regions viz., top, middle and

formulation of a more pragmatic and sensible fertilizer recommendation for the crop. Moreover, an extensive investigation on the lines of present investigation involving large number of clove plants from several location or from a single location is necessary to confirm the present finding obtained from this basic study.

bottom. Three samples each from these regions were drawn by collecting the first, second and third whorls from the apex of the branchlets oriented towards the east, west, south and north. Leaves from the first whorl, second whorl and third whorl from each direction were pooled, sampled and analysed.

The soil available and plant N, P, K, Ca, Mg, Cu, Mn and Zn were correlated to find out their relationships. Yield data for two year from all the four locations were also correlated with the significant correlation values obtained from the correlation studies between soil available nutrients and their respective leaf nutrient concentration.

As a result of the study, it was brought out that forest soils of Kulasekharam with high organic matter and CEC and having a clay loam texture were found to be better suited for clove cultivation as compared to the other soils studied. The highest yield was also obtained from Kulasekharam, while lowest yield was noticed at Vellayani.

The leaf nitrogen concentration was found to be the highest in whorl I of the top region of the plant canopy. In the case of phosphorus, the whorl I leaves of bottom region were proved to be the richest. The leaf potassium was found to be the highest in whorl I of the top region of the plant.

Calcium concentration in the leaves was found to be the highest in whorl III of bottom region, while magnesium concentration was the highest in whorl III of the top region.

Copper, manganese and zinc in the leaf were found to be the highest in the whorl III of the bottom region.

Based on the correlation between soil available nutrients and the respective leaf nutrient concentration and also the correlation between leaf nutrient and yield, the following index leaves were identified in relation to different nutrients.

1. Nitrogen	-	leaves of whorl I of top region
2. Phosphorus	-	leaves of whorl I of bottom region
3. Potassium	-	leaves of whorl I of top region
4. Calcium	-	leaves of whorl III of bottom region
5. Magnesium	-	leaves of whorl III of top region
6. Copper, manganese and zinc	-	leaves of whorl III of bottom region

Though the present study has yielded several valuable findings, further indepth studies are necessary to fix the critical limits of each nutrient through field trials involving graded dose of fertilizers for the