COMPARATIVE STUDY OF SOILS OF CARDAMOM PLANTATIONS AND VIRGIN FORESTS

By

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DECLARATION

I hereby declare that this thesis entitled "Comparative study of soils of cardamom plantations and virgin forests" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "Comparative study of soils of cardamom plantations and virgin forests" is a record of research work done independently by Mr. GLADSON D' CRUZ (94-11-50) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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GLADSON D' CRUZ

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

INTRODUCTION

Cardamom (*Elettaria cardamomum* L. Maton), popularly known as the "Queen of Spices" is a native of the South-West mountains of peninsular India. In India its cultivation is mainly confined to the Western Ghats comprising the states of Kerala, Karnataka and Tamil Nadu. The crop is of great importance as a foreign exchange earner and India has an unique position in the trade of this crop. Being a psiophyte, cardamom is cultivated under forest conditions and the success of cardamom cultivation depends on maintaining the necessary forest conditions suitable for its growth.

Forest soils are rich in plant nutrients and fertility is self maintained due to bio-cycling. By the growth of plants the soil is never depleted, but its fertility is only improved or preserved. Cardamom is an undergrowth and hence it protects the soil and helps in improving the fertility and physical conditions of the soil.

Reckless deforestation is a serious menace now a days and the forest cover is reducing gradually. According to official estimates, the area under forests in Kerala has been reduced from 40 to 24 per cent in the last 30 years (Forest Survey of India, 1991). Large scale denudation in and around cardamom tracts is the greatest handicap in successful cultivation of cardamom. These forests exert a domineering influence on the microenvironment where they are situated, and the locality factors and biological factors make complementary influence on the plant communities and attain a balance eco-system favouring the continued maintenance of the microenvironment.

When such a balance is upset by human interference, beyond the tolerance limit, by way of cutting forests, burning and cultivation, changes or retrogression takes place in the eco-system. When these changes become established or permanent, it may be highly injurious for the sensitive plants like cardamom. The result will be the 'survival of the fittest', suited to the changed eco-system leading to the elimination of these sensitive plants. In some cases these processes of natural elimination may be quicker, while in some cases it may be gradual. For better plant performance it is essential to maintain a suitable micro-climate in cardamom plantations.

In the forests of Kerala where cardamom plants are grown for continuously long periods after the denudation of natural forests, the soil physico-chemical properties are liable to be altered inspite of the similarity in parent material and other factors of soil formation. A study on the physico-chemical properties and nutrient status of these soils will reveal how far cardamom cultivation has altered these characters. If the cultivation of cardamom is not found to disturb the natural existence of the forests and bring about any adverse effect on soil physical and chemical properties, the plantations can be extended to new areas of natural forests in suitable locations.

However, not much study has been conducted on the subject of changes in the physico-chemical properties and nutrient status of cardamom growing soils. Further the contribution of soil and plant nutrients to the yield attributes of cardamom are also lacking.

In the light of these considerations, the present investigation has been undertaken with the following main objectives.

1. To assess and compare the physico-chemical properties and nutrient status of cardamom growing soils with the soils of the adjacent forest.
2. To compare the physico-chemical properties and nutrient status of healthy cardamom location and the location which show a decline in yield as observed in some of the plantations.
3. To find out whether any plant nutrient factors are involved in the decline of yield in cardamom.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Nutrient status of cardamom growing soils

Mathew and Azizuddin Mir (1968) reported that the soils of Chickmagalur, Hassan and Kodagu districts of Karnataka, where large cardamom plantations are located, were high in organic carbon, low in available phosphorus and medium in available potash.

According to Krishna (1970), the use of fertilizer mixtures of NPK and soil amendments like lime, dolomite and rock phosphate is very essential for proper growth and development of the cardamom plants.

Kulkarni *et al.* (1970) found that the cardamom growing soils of Koppa and Mudigere of Chickmagalur district were high in organic carbon and low in available potash.

Dattu Rao (1971) classified the soils of Koppa and Sringeri taluks of Chickmagalur and soils of Hassan district as medium in organic carbon while Mudigere soils were high in organic carbon. Further, these soils were low in available phosphorus as well as potash.

Deshpande *et al.* (1971) studied the effect of lime and nitrogenous fertilizers on bacterial population and nitrification in cardamom soils and showed that liming corrected soil acidity and enhanced rate of nitrification and urea is a better source of nitrogenous fertilizer compared to ammonium sulphate.

Kulkarni and Agnihothrudu (1972) revised the critical limits for organic carbon to a fairly higher range for classifying the available nitrogen status of plantation soils. The limits were fixed at 1.16 per cent, 1.16 to 2.32 per cent and above 2.32 per cent for low, medium and high organic content respectively.

Zachariah (1972), based on his studies on the mineralisation of nitrogen in the cardamom growing soils of Kerala and Karnataka has shown that there is a high degree of mineralisation of nitrogen in these soils.

Biddappa and Venkat Rao (1973) showed that organic matter and nitrogen content of soils showed a tendency to increase with altitude and rainfall.

Srivastava and Bopaiah (1973) reported that the available phosphorus, available potash, total calcium and organic carbon content of soils were positively correlated with the yield of green capsules of cardamom per clump. The available phosphorus, potash and soil pH were found to be positively correlated with the number of tillers per clump.

Kunhikrishnan Nair and Zachariah (1975 a) studied the suitability of 'Mussoriephos' as a phosphate fertilizer for cardamom and reported that besides phosphorus, Mussoriephos contained a lot of lime (40 - 45 %) , significant quantities of copper, zinc and other plant nutrients.

Kunhikrishnan Nair and Zachariah (1975 b) analysed the soils collected from different cardamom growing locations and reported that the cardamom soils are poor in available phosphorus, though they are rich in nitrogen and potassium. In certain locations, about 80 per cent of the soils were highly deficient in phosphorus.

Zachariah (1975 a) studied the fertility status of cardamom growing soils from 5000 soils samples collected from Kerala, Karnataka and Tamil Nadu and reported that majority of the soils were high to very high in organic matter and low to medium in available phosphorus.

Zachariah (1975 b) classified the soils of Vandanmettu and Vandiperiyar of Idukki district of Kerala as low in available phosphorus, high in available potash, very high in available magnesium and high in organic carbon.

According to Zachariah (1975 c), most of the cardamom growing soils were situated in heavy rainfall areas and therefore suffer from leaching of nutrients. Moreover, cardamom soils tend to be acidic (pH 5.0 to 5.5) due to leaching of bases.

The soil test results in Karnataka have indicated that cardamom soils were rich in organic matter, 90 per cent soils were low to medium in available phosphorus, and 86 per cent soils were low to medium in available potassium (Anonymous 1976 a).

Additional fertilizer doses of 0.65 kg N, 0.65 kg P and 1.3 kg K per plant is to be applied for every increase in yield of 2.5 kg of capsules over the normal yield (Anonymous, 1976 b).

According to Zachariah (1976) the physical conditions like friability and structure of the soil were improved by enhanced biotic activity under mulch. Soil becomes more porous as the number of macropores are increased by biotic activity.

Abdul Khader and Mohammed Syed (1977) recommended a fertilizer dose of 75 kg N, 75 kg P_2O_5 and 150 kg K_2O per hectare for cardamom.

Fertilizers should be applied in a ring of 50 cm away from the plant since most of the roots are spread in that area.

Kunhikrishnan Nair *et al.* (1978) studied the distribution of major nutrients in the different layers of cardamom soils and found that the total nitrogen and organic matter decreased with increase in soil depth and the C / N ratio narrowed towards lower layers. There was not much difference in the content of total potassium between the various layers. The availability of the nutrients decreased with soil depth in all cases. The surface horizon showed a slightly higher pH than lower layers, but the variation in pH between layers was only negligible. Though available nitrogen decreased with depth, it was found that a higher proportion of nitrogen could undergo mineralization in lower layers. [illegible] in the case of available phosphorus while it was gradual in the case of available potassium towards lower layers.

Zachariah (1978) suggested a maintenance dose of 30 kg N, 60 kg P_2O_5 and 30 kg K_2O per hectare for cardamom considering the low nutrient requirement for cardamom and high status of nitrogen and potassium in cardamom soils.

Kubendran (1980) observed that soils having 8 per cent slope lost 61 tonnes of soil per acre, while 3.7 per cent slope resulted in a loss of 20 tonnes per acre per year during the same period in cardamom plantations.

Excessive tillage practices followed in cardamom plantations were the causes for the low fertility and poor physical condition of the soil. As a result of this, the ability of soil to absorb and store moisture during rainy season would be reduced considerably (Zachariah, 1980).

According to Lekshmanan (1981), by proper shade management in cardamom plantations, the physical condition of the soil was greatly improved. As a result, the soil becames more friable, structure was improved, exchange capacity was increased and there was better absorption and retention of nutrients.

Krishna (1982a) reported that the cardamom growing soils of Shimoga, Hassan and Kadur were loamy in texture containing 50 per cent finer fraction and rich in organic matter. Most of the cardamom growing soils were leached red loam soils called Oxisols.

According to Krishna (1982b), cardamom growing soils in the Vandiperiyar region have a low to medium status of phosphorus and were highly acidic (pH 4.5 - 5.5).

Dileep Kumar (1983) studied the nutritional status of soil and plant in relation to incidence of chenthal disease in cardamom and found that exchangeable magnesium content of the soils as well as potassium and magnesium content of plants recorded a decrease with the severity of the disease indicating deficiency of these elements being possibly associated with the disease. However, soil and plant content of other nutrient elements such as N, P, Ca, Fe, Mn and Zn were not found to influence the development of the disease. Correlation studies between the yield of cardamom and soil and plant nutrient status revealed that among the various nutrients, yield was well correlated with phosphorus content in the soil and plant.

According to Korikanthimath (1984), leaching of bases (calcium) would result in reduced soil reaction thus bringing down the availability of phosphorus.

Tandon (1989) described that most of the cardamom growing soils were low in phosphorus and therefore, stress should be given to that important element in fertilizer application.

In a study on the evaluation of nutrient requirement of cardamom by desorption isotherms, Srinivasan and Biddappa (1990) collected soils from Kerala, Karnataka and Tamil Nadu. The soil pH was in the range of 4.9 to 6.2, organic carbon 1.42 to 3.37 per cent, available phosphorus 2.3 to 69 kg P_2O_5 ha^{-1} and available pottassium 228 to 1176 kg K_2O ha^{-1}. They also observed that, the recovery of added phosphorus and potassium in the above soils ranged from 8.9 to 49.2 per cent with a mean of 31.9 per cent for phosphorus and 77.9 to100 per cent with a mean of 92.8 per cent for potassium.

Verma *et al.* (1990) observed that organic matter showed negative relationship with clay content in cardamom plantation soils.

Nutrient uptake by cardamom plants

The cardamom plant has been reported to contain 5.33 per cent N, 1.33 per cent P_2O_5, 6.69 per cent K_2O, 2.70 per cent CaO and 3.50 per cent MgO on dry weight basis (John, 1967).

Ratnaval (1968) expressed the views that potassium requirement of cardamom grown under shade is more as lack of enough sunlight creates more demand for potassium, so that there would be proper functioning of the photosynthetic mechanism in plants.

Deshpande and Kulkarni (1971) noted the early appearance of deficiency symptoms in minus potassium treated plants followed by other treatments with minus Ca, Mg, and P in solution culture.

Based on plant analysis Kulkarni *et al.* (1971) reported that the uptake of potassium was maximum, followed by nitrogen, calcium, phosphorus and magnesism. The ratio of different ingredients held in relation to P as a unity are 6 : 1: 12 : 3 : 0.8 N : P : K : Ca : Mg.

Nutrient uptake studies were carried out by Kulkarni *et al.* (1971) at RRS Mudigere. Analysis of different plant parts revealed that while nitrogen, phosphorus and calcium content of leaves increased from young to mature stage, a general decrease in magnesium and potassium content was seen. However, at the bearing stage, nitrogen, phosphorus and potassium decreased in the leaf tissue while a definite increase was noticed for calcium and magnesium.

It was further reported that in the case of pseudostem, there was a general reduction in nitrogen, phosophorus and potassium content and an increase in the calcium and magnesium concentration with the age of plants. Regarding the total uptake of nutrients by the plant at harvest stage, it was seen that the removal of potassium was maximum (20.01 kg ha^{-1}). However phosphorus and magnesium were removed in comparatively lesser quantities (1.4 and 2.32 kg ha^{-1}).

The nutrient uptake studies revealed that nitrogen, phosphorus and potassium were removed continuously by the plant upto the bearing stage and these had to be applied in a soluble or available form till bearing stage. Calcium and magnesium were needed only at later stages of growth of the plant as they were taken up mainly by mature and bearing plants.

Deshpande *et al* (1972) described the diagnostic symptoms for the deficiency of nitrogen, potassium, calcium and magnesium in cardamom plants.

Abdul Khader and Mohammed Syed (1977) have reported that one kg of capsule harvested removes 122 g N, 14 g P and 200 g K. In fertilizer application one has to take into account not only the removal but also the leaching losses and soil fixation. Giving allowances for the above losses a fertilizer dose of 75 kg N, 75 kg P_2O_5 and 150 kg P_2O_5 ha^{-1} was recommended for cardamom.

Rao (1977) based on his studies on the chemical composition of leaves showed that healthy leaves contain more N P, K, Ca, Mg, Cu and Mn but less Zn than the diseased leaves. Fe content does not differ in healthy and diseased leaves.

Sundaram (1977) recognised that deficiency of micronutrients cause serious set back in production. Sometimes deficiency of micronutrients cause hormonal imbalance to the plant system and lead to problems like fruit shedding.

According to Pattanshetti (1980), the average uptake of N, P, K, Ca, Mg in the cardamom clump subjected to proliferation under high density population was 13.04, 2.81, 48.93, 7.73 and 3.29 kg per hectare respectively.

Venkatesh (1980) observed that the uptake of the nutrients in the N, P, K application was 93.78, 13.41, 167.49, 33.48 and 8.55 kg of N, P, K, Ca, and Mg per hectare. The broad ratio worked out to be N : P : K : Ca : Mg : 7 : 1 : 12 : 3 : 0.6.

The study on the effect of N, P, K and their mode of application on the dry matter production and uptake of nutrients by cardamom indicated that cardamom is a heavy feeder of potassium (Venkatesh and Pattanshetti, 1981).

According to Abdul Khader *et al.* (1981) cardamom plants accumulate major and secondary nutrients in the order of K > N > Ca > Mg > P > Na and micronutrients in order of Mn > Fe > Zn > Cu.

According to Lekshmanan (1981), the nutrient removal by way of harvest was very negligible in cardamom plants and has been estimated that by harvesting 100 kgs of cardamom only 1.28 kg of N, 0.28 kg of P_2O_5 and 3.84 kg of K_2O were removed.

Dileep Kumar (1983) studied the relation of nutrient status of plant and soil in relation to the incidence of chenthal disease of cardamom. He concluded that the content of nitrogen, phosphorus, calcium, iron, manganese and zinc were more or less similar in all the plant at different levels of the disease. He also found that no nutrient factors could be ascribed as a predisposing factor for the incidence of disease.

Korikanthimath (1984) analysed different parts of the cardamom plants at various stages of growth to determine the uptake of N, P, K, Ca and Mg. The highest uptake of the above mentioned nutrients per hectare was found with bearing suckers followed by mature suckers and young suckers.

Tissue analysis of cardamom

Ratnaval (1968) analysed the leaves and stem of healthy cardamom plant. He found out that the content of P_2O_5 was 0.423 per cent in second leaf while fifth leaf contained 0.134 per cent P_2O_5. The tissue composition of pseudostem was 5.38 per cent K_2O, 0.302 per cent P_2O_5, 0.93 per cent Ca and 0.109 per cent Mg.

Kulkarni *et al.* (1971) analysed the different parts of the cardamom plants at various stages of growth to find out the tissue composition of major ingredients. Young green leaves were found to contain 2.45 per cent N, 0.23 per cent P, 2.46 per cent K, 0.45 per cent Ca and 0.09 per cent Mg. In mature leaves nitrogen, phosphorus and calcium showed an increasing trend of 2.52, 0.37 and 0.5 per cent while potassium and magnesium showed slightly declining trend of 2.10 and 0.05 per cent respectively compared to that of young leaves. Young pseudostem showed the chemical composition of 0.68 per cent N, 0.46 per cent P, 3.69 per cent K, 0.18 per cent Ca and 0.06 per cent Mg. On attaining maturity the production showed lower percentages of N (0.63), P (0.23) and K (2.7) and higher per centages of Ca (0.23) and Mg (0.11) compared to young pseudostem.

Raghothama (1979) reported the chemical composition of tissue for N, P, K, Ca and Mg on dry weight basis in leaves as 2.72, 0.32, 2.6, 0.88 and 0.27 per cent, in shoots 1.62, 0.42, 5.57, 0.61 and 0.16 per cent, in rhizomes 1.19, 0.20. 3.6. 0.56 and 0.14 per cent and in roots 1.09, 0.23, 2.94, 0.48 and 0.11 per cent respectively.

Pattanshetti (1980) observed maximum percentage of nitrogen in the leaf (2.04 per cent) followed by shoot (1.03 per cent), rhizome (0.9 per cent) and root (0.71 per cent). Root tissue contained higher percentage of phosphorus (0.38 per cent) followed by that of shoot (0.35 per cent), rhizome (0.31 per cent) and leaf (0.18 per cent). Highest content of potassium was recorded by the shoot tissue (6.23 per cent) followed by rhizome (6.18 per cent), leaf (3.51 per cent) and roots (2.23 per cent).

Venkatesh (1980) analysed the chemical composition of tissues for N, P, K, Ca and Mg on dry matter weight basis and reported their content in leaves as 3.09, 0.49, 3.59, 1.03 and 0.25 per cent and in rhizomes as 1.30, 0.33, 4.33 and 0.55 and 0.11 per cent respectively.

Abdul Khader *et al.* (1981) in a study on the distribution of nutrients in three cardamom varieties showed that the leaf blade contained 2.52 per cent N, 0.61 per cent P, 2.82 per cent K, 0.59 per cent Ca, 0.26 per cent Mg, 124 ppm Na, 143 ppm Fe, 11 ppm Cu, 30 ppm Zn and 483 ppm Mn. Tissues of pseudostem contained 0.50 per cent N, 0.093 per cent P, 3.44 per cent K, 0.33 per cent Ca, 0.25 per cent Mg, 202 ppm Na, 183 ppm Fe, 7 ppm Cu. 90 ppm Zn and 440 ppm Mn respectively. The nutrient concentration of petiole was 0.76 per cent N, 0.098 per cent P, 4.07 per cent K, 0.64 per cent Ca, 0.28 per cent Mg, 276 ppm Na, 252 ppm Fe, 12 ppm Cu, 31 ppm Zn and 675 ppm Mn.

Effect of cultivation on the physico-chemical properties of forest soils

The physico-chemical properties of the agricultural soils are known to differ in several respects with similar properties of the adjacent forest soils. These differences might have arisen out of the specific impact of nutrient recycling characteristics of the forest ecosystem compared to the non-forest ecosystem which are more frequently subjected to disturbances and alterations by human intervention.

(a) Physical properties

Champion (1932) has concluded that soil samples from teak plantations and adjacent forests did not differ significantly in the distribution of different sized particles and chemical properties. However, the soils under plantations were found to be comparatively much harder due to exposure.

According to Castens (1942), the soils of teak plantation do not get altered in their composition relative to the natural soils in the adjacent forests.

Laurie and Griffith (1942) have suggested that laterization may be one of the factors responsible for soil deterioration in the plantations.

Griffth and Gupta (1947) showed that there was little change in chemical nature of the soil as a result of continuos teak cropping.

According to Livingston (1949), where the Colorado forest and grass lands occur side by side, forest lands were coarse textured while the soils of grassland in the contiguous areas were fine textured.

According to Mc Donald (1955), there was no change in the physical properties of soils as a result of clear felling. The soils from forest and the cleared area showed no difference in their moisture content.

From a comparative study of the physico-chemical properties of soils under cultivation and forest cover. Pathak *et al.* (1964) showed that porosity, water holding capacity, volume expansion and aggregation of soils under forest cover were higher than those of soils under cultivation. Bulk density and particle density were lower in forest soils than the cultivated soils.

Robinson *et al.* (1966) observed no significant difference in physical properties of soils under indigenous forest and under a sixteen year old softwood tree plantation.

Yadav (1968) pointed out that soils under different forest vegetation differed considerably in their physical and chemical characteristics

Jose and Koshy (1972) have reported that the constitution of clay is not altered to any marked extent by the removal of natural forests and maintaining a teak plantation.

Based on a study of the properties of soils under teak, Alexander *et al.* (1981) showed that the sand content decreased and silt and clay increased with depth indicating the downward movement of the latter due to leaching.

It was also observed by Alexander and Thomas (1985) that among the properties of soils under plantations, gravel content was the most and particle density was the least variable factor. Sand, silt and caly contents were highly variable whereas WHC, and bulk density were only intermediate.

Balagopalan and Jose (1986) reported that, eventhough there was no significant difference in mechanical composition of surface soils of eucalyptus and an adjacent virgin forest, deeper layers showed marked differences.

In a comparative study of the monoculture plantations and natural forest, Premakumari (1987) noticed that though there was significant difference in mechanical composition between the two, there was significant increase in bulk density and decrease in WHC.

According to Bargali *et al.* (1993), replacing natural forest with eucalyptus plantations will result in a decrease in WHC, porosity and increase in bulk density.

From a comparative study of the eucalyptus and adjacent forest areas, Srivastva (1993) showed that planting of eucalyptus will not cause any significant change in physico chemical properties.

Jaiyeoba (1995) investigated the soil physical properties under different land use systems and natural savanna. He stated that there was significant decrease in the coarse fractions and bulk density under plantations than natural vegetation.

According to Moossa (1997) soil profile samples of Acacia and Eucalyptus plantations recorded high coarse sand and low clay content compared to natural forest.

(b) Chemical properties

Doyne (1935) has shown that the surface soils were generally less acidic than the deeper layers because of the stand of species of trees whose foliage contain a high content of bases.

Puri and Gupta (1951) have observed that the humus in coniferous forest of Kulu (Himalaya) showed no significant correlation between organic matter, nitrogen and calcium content. Both sodium and calcium increased with increase in organic matter. The amount of organic matter and nitrogen decreased considerably in lower layers.

According to Duchaufour (1953), the destruction of forest cover lead to heavy leaching and loss of plant nutrients.

Kowal and Tinker (1959) opined that clearance of forest and subsequent cultivation leads to decrease in the content of organic matter. They have attributed this situation to a greater exposure of the soil organic matter to both biological and chemical process leading to its destruction.

Bates and Baker (1960) have observed a greater accumulation of P in the surface soils of forest. Below 15 cm there was a marked fall in the amount of organic matter and thereafter the total P content was fairly constant down the profile.

Yadav and Pathak (1963) have found that soils of different forests in India exhibited greater variation in the amount of available P ranging from 0.1 to 21 mg per 100 g of soil. Their studies have also revealed that a high accumulation of organic matter lead to pronounced reduction in P availability. The distribution pattern of P in the profile showed that total P was more in the surface than subsoil.

Yadav (1963) studied the soil profiles in Chakrata division in Uttar Pradesh and reported that N content varied from 0.013 to 0.427 per cent and organic carbon from 0.172 to 8.13 per cent. He also found that CEC of the soils varied from 9.4 to 44 me per 100 g soil. The surface horizon had the highest CEC resulting from the accumulation of humus. Ca was greater in the surface horizon and decreased markedly in the lower layers. Mg manifested an erratic behaviour with depth of profile and no definite pattern of distribution with depth was noticed in the case of K.

Pathak *et al.* (1964) from a comparative study of the physico-chemical properties of soils under cultivation and forest cover showed that the cation exchange capacity was higher for soils under cultivation while silica-sesquioxide ratio was lower in them.

Thomas (1964) reported a higher degree of acidity and more clay content in soils of moist deciduous forests, while soils supporting evergreen vegetation were generally higher in organic matter and N. Both carbon and N content decreased with depth down the profile. Organic matter and N were leached to a greater depth in deforested areas compared to natural forests.

Mithrachaly (1965) observed significant reduction in organic carbon and total nitrogen content in moist deciduous forests of Palode subsequent to deforestation.

According to Jose (1968), the organic matter and available nitrogen content of natural forest soil were significantly higher than that of the teak plantations. The soils under forest also contained higher amount of P, K, Ca and Mg and were slightly more acidic than teak plantations.

Venugopal (1969) has reported a higher content of exchangeable potassium and magnesium in natural forest.

Yadav *et al.* (1970) pointed on that some evergreen forests of Western ghats in the states of Mysore, Madras and Kerala are found acidic in reaction and poor in bases.

A higher status of available phosphorus in the forest soils may be due to the effect of mycorrhizal associations on the roots of forest trees (Alexander, 1977).

Chapin and Kedrowski (1983), in a study on the seasonal changes in nitrogen in evergreen and deciduous trees concluded that during growing season there are changes in allocation of nitrogen associated with changing plant requirement.

Balagopalan and Alexander (1983) have reported a relatively lower content of organic carbon in eucalyptus plantation than natural forest.

By the study of the soils of the monoculture plantations in comparison with the natural forest, Premakumari (1987) has shown that the natural forest soils contained higher amounts of organic carbon, total N, P, K and Mg, organic matter, and CEC than the monoculture plantations.

Byju (1989) studied the impact of monoculture plantation (eucalyptus and acacia) on the chemical characteristics of soils compared to forest and barren / cultivated soils. He showed that plantation activity improved the pH, organic carbon, CEC and available N, P and K.

Sivadasan (1989) observed that DTPA extractable iron and manganese contents were 218 ppm and 17 ppm respectively for forest soils.

Bargali *et al.* (1993) reported that replacement of natural forest with eucalyptus bring down the organic carbon and total N, P and K.

Balagopalan and Jose (1995) showed that soil chemical characteristics such as organic carbon, available nitrogen, total phosphorus and CEC were lower in monoculture plantations compared to the adjacent natural forest.

Moossa (1997) investivagated the leaf litter dynamics in Acacia and Eucalyptus plantations and stated that exchangeable acidity of plantation soils was higher than that of the adjacent forest soils. Significant reduction in total NPK were observed in all the soils studied.

The Cardamom - Microclimate - Forest Relationship

Cardamom is a plant which is adapted only to forest conditions. It comes successfully under regulated shade of forest trees in the tropical belt. The forests exert a domineering influence on the microclimate in which the plants are situated. Clearing the forest trees and cultural practices adopted in cardamom plantations have been considered responsible for changes in the microclimate, which is considered to be ideal for growth and production.

According to Bleak (1970), the gradual rise in organic carbon in plantations with altitude is due to the lower rates of litter decomposition because of low temperature.

Zachariah (1972) opined that by adopting mulching in cardamom plantations, the physical condition of the soil can be improved and helps to keep uniform soil temperature and prevents diurnal variation in temperature of the surface soil.

Zachariah (1975 c) studied the fertility status of cardamom growing soil and showed that fertility of the cardamom growing soils in general is high. He considered that the only one factor which is responsible for the high fertility status is the presence of shade trees and a favourable microclimate. He explained that a process of self liming take place by which the shade trees bring to the surface of the soil the nutrients they take up from the lower horizons by leaf shed and thus help to maintain a high fertility status under a favourable soil pH.

According to Zachariah (1976), in cardamom plantations shade acts as a moisture and temperature regulator, thus creating a microclimate which promotes vegetative growth. This microclimate creates a favourable environment for root development also.

Thomas Varghese (1976), has suggested cardamom as the only one crop among the agricultural crops which gives least disturbance to the forest ecosystem.

Cherian (1977) found that adequate number of trees that can provide shade at three storey-levels such as upper, middle and lower, improve the growth and productivity of cardamom.

Abdul Khader and Mohammed Syed (1977) reported that an unfavourable microclimate changes the temperature which in turn influence the release of N, P and S from organic matter. It also affects nitrification and absorption of P and K by the plants.

Although cardamom is a shade loving plant, excess shade is detrimental to the growth and yield of the plant (Kologi 1977).

According to Korikanthimath (1978) cardamom growing tracts generally experience heavy rainfall, so that the top soil is subjected to erosion resulting in the loss of soil nutrients.

Singh (1978) observed that the cardamom plants grow best on rich forest soils having plenty of humus and leaf mould, besides giving higher yield, maintain a suitable microclimate for a considerably longer period.

Zachariah (1978) and Leskshmanan (1981) quantified that on an average 5-8 tonnes of dried leaves fall from shade trees annually in a hectare of cardamom estate adding 100-160 kg N, 25-40 kg P_2O_5 100-160 kg K_2O and 25-40 kg Mg per hectare.

According to Jose (1982), humus rich loamy soils under the canopy of lofty evergreen forest provide the best habitat for cardamom, at an altitude range of 800-1500 meters.

Kurup (1984) viewed that the immediate requirement for the rejuvenation of cardamom plantation is to establish a secondary canopy of shade trees to create ideal condition similar to that existing in an evergreen forest. Such a condition would help to improve the microclimate within the estates and enrich the soil to a considerable extent.

Abey Singhe (1986) reported that cardamom in Srilanka is traditionally planted under natural forest cover.

According to Pruthi (1993) cardamom thrives at an elevation from 600-1500 m but the most productive range of elevation is from 1000-1800 m. Humus rich soils holding a good growth of evergreen forest are ideal for this crop.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation on the comparative study of the soils of cardamom plantation and virgin forest soils was undertaken with a view to assess and compare the physico-chemical properties and nutrient status of cardamom cultivated soils and the soils of the adjacent virgin forests in the Idukki district of Kerala state. In addition to this, a comparison was also made between plantations where a high yield of cardamom is obtained with those where a decline in yield is noticed. For this, surface soil samples and typical profile samples were collected from the selected locations and analysed for their physico-chemical properties, nutrient status and downward distribution of nutrients in them. Plant samples were also collected from the plantations and subjected to detailed chemical analysis to assess whether any nutritional factors are involved in the decline in yield in cardamom.

Location of site

Two different cardamom plantations located in the Idukki district of Kerala and two virgin forest area lying adjacent to these plantations were selected as the sites of the study. In both plantations, six locations each giving a high and low yield of cardamom and two adjacent forest areas were identified for the collection of soil samples. The leaf samples were collected from the specified locations in these two cardamom plantations.

The details of the location are given below :

Name of the plantation	Location	Treatments	Elevation (metre above MSL)	Slope (%)
Devikanam Estate, Vandiperiyar (P_1)	1) Healthy location	$P_1 L_1$	1065	15-25
	2) Location which show a decline in yield	$P_1 L_2$	1065	15-25
	3) Adjacent forest	$P_1 L_3$	1085	15-25
Valiakutti-kattil Estate, Pampanar (P_2)	1) Healthy location	$P_2 L_1$	950	33-50
	2) Location which show a decline in yield	$P_2 L_2$	950	33-50
	3) Adjacent forest	$P_2 L_3$	950-1000	33-50

Collection of soil samples

a) Collection of surface soil samples

Twenty surface soil samples (0-15 cm) at a distance of 50 cm away from the base of the plants, each were collected from the six locations in the above plantations and adjacent forests during the last week of September, 1995.

Thus, a total number of 120 surface samples were collected from six locations. The samples were collected in plastic bags, serially numbered and brought to the laboratory for further analysis.

b) Collection of soil profile samples

Five profile pits of size 3 x 3' to a depth of 1.25 m each were dig in each of the two plantations and in the adjacent forests. The soil samples were collected at depths of 0-20 (D_1), 20-40 (D_2), 40-60 (D_3), 60-90 (D_4) and 90-125 cm (D_5). Altogether 30 pits were opened. Depthwise soil samples were collected in plasitc bags, serially numbered and brought to the laboratory for further analysis.

c) Preparation of soil samples for analysis

The surface soil and soil samples from the different horizons of the profile were brought to the laboratory, air dried, powdered with a wooden mallet and passed through a 2 mm sieve and stored in plastic capped bottles for further analysis.

Collection of plant samples

Twenty plant samples, each from the healthy cardamom location as well as the location which show a decline in yield were collected at the time of collection of soil samples during the last week of September, 1995.

From each plant, the second, fifth and eighth leaves from the top were collected in brown paper envelops and serially numbered as in the case of soil samples.

a) Biometric observations

The following biometric observations were made from the plants at the time of collection of samples for chemical analysis.

(a) Crop stand

(b) Age

(c) Number of tillers per clump

(d) Number of suckers

(e) Height of the plant

(f) Yield per plant

b) Preparation of plant samples for analysis

The leaf samples were air dried for two days and then dried to constant weight in a hot air oven at 60 to 65^{0}C. The dried leaf samples were mixed and powdered in a grinder and stored in serially numbered polythene leaves in a desiccator.

Analysis of soil samples

The physico-chemical characters of the soil samples were determined by adopting standard analytical procedures as detailed below.

A. Physical properties

Soil parameters	Method of determination	Reference
Mechanical composition	International pipette method	Piper (1967)
Single value constants	Troell's method by using Keen Raczkowski box	Wright (1939).

B. Chemical properties

pH	Measured in a Perkin - Elmer pH meter	Jackson (1973)
Electrical conductivity	Measured in a solubridge	Jackson (1973).
Organic carbon	Walkley and Black's rapid titration method	Jackson (1973)
CEC	Leaching with neutral N ammonium acetate distillation method	Jackson (1973)
ECEC	Addition of total bases and exchangeable acidity	van Reeuwijk (1993)
Exchangeable H & Al	Titration of IN KCl extract	Black (1965)
Exchangeable Ca	N ammonium acetate extract read in AAS	Jackson (1973)
Exchangeable Mg	N ammonium acetate extract read in AAS	Jackson (1973)
Exchangeable Na	N ammonium acetate extract read in flame photometer	Jackson (1973)
Exchangeable K	N ammomium acetate extract read in flame photometer	Jackson (1973)
Total N	Modified microkjeldahl digestion - distillation method	Jackson (1973)

Total P	Vanadomolybdate yellow colour method of sulphuric acid extract	Jackson (1973)
Total K	Flame photometer method of sulphuric acid extract	Jackson (1973)
Available N	Alkaline permanganate distillation and titration method	Subbiah and Asija (1956)
Available P	Molybdenum blue colour method read in Klett Summerson photoelectric colorimeter	Jackson (1973)
Available Fe	DTPA extract read in AAS	Lindsay and Norwel (1978)
Available Mn	DTPA extract read in AAS	Lindsay and Norwel (1978)
Available Zn	DTPA extract read in AAS	Lindsay and Norwel (1978)
Available Cu	DTPA extract read in AAS	Lindsay and Norwel (1978)

Analysis of plant samples

Powdered leaf samples were used for the determination of nitrogen, phosphorus, calcium, magnesium and micronutrients by adopting standard analytical procedures as detailed below.

Preparation of plant extract

Triple acid extract was used for the determination of nutrient elements in the leaf tissue (Johnson and Ulrich,1959). For this, one gram of the powdered leaf sample was digested with triple acid mixture until clear. The digest was made upto 100 ml with distilled water, filtered and used for further analysis.

Plant parameters	Method of determination	Reference
Nitrogen	Microkjeldhal digestion distillation method	Jackson (1973)
Phosphorus	Vanadomolybdophosphoric yellow colour method in nitric acid system -- by using a Klett Summerson photoelectric colorimeter	Jackson (1973)
Potassium	Measured in a flame photometer	Jackson (1973)
Ca and Mg	Measured in a AAS	Lindsay and Norwel (1978)
Micronutrients (Fe, Mn, Zn, Cu)	Measured in a AAS	Lindsay and Norwel (1978)

Statistical analysis

The data pertaining to the various soil characteristics were subjected to statistical analysis by applying the technique of analysis of variance (Panse and Sukhatkme, 1967). The CD values are at 5 per cent level of significance wherever F value is found to be significant.

The data obtained for plant samples were analysed by applying the students 't' test.

RESULTS

RESULTS

This chapter contains the results of analysis of soil samples collected for the study in comparison with the soils of cardamom growing plantation and virgin forest. The comparison was also made between healthy plantation and plantation which show a decline in yield based on the soil and plant sample analysis.

SURFACE SOIL ANALYSIS

Physical properties

Mechanical analysis

The mean values for the various soil fractions obtained on mechanical analysis of the surface soils are given in Table 1.

The coarse sand content of various locations revealed that the soils of the healthy plantation contained the highest amount of coarse sand (38.43 per cent) which was on par with cardamom plantation and the lowest in the soils of the adjacent forest (33.24 per cent) which was on par with soils with plantation which show a decline in yield.

Adjacent forest soil recorded the highest fine sand content of 10.46 per cent and the lowest in the soils of the healthy plantation (9.18 per cent). However the fine sand content of the adjacent forest varied insignificantly with that of the cardamom plantations.

There was no significant difference in the silt content between the locations. Silt content was high (11.32 per cent) in the healthy plantation and

Surface soil samples

Table 1 Mechanical composition (%)

Locations	Coarse sand	Fine sand	Silt	Clay
Healthy plantation	38.43	9.18	11.32	38.29
Plantation which show a decline in yield	33.74	10.05	11.09	41.91
Cardamom plantation	36.09	9.62	11.21	40.35
Adjacent forest	33.24	10.46	11.12	42.06
CD	2.75	-	-	2.38

Table 2 Single value constants

Locations	Bulk density Mg m^{-3}	Particle density Mg m^{-3}	WHC (%)
Healthy Plantation	1.20	2.17	41.06
Plantation which show a decline in yield	1.16	2.05	41.74
Cardamom Plantation	1.18	2.39	41.40
Adjacent forest	1.20	2.17	40.18
CD	-	-	-

low (11.09 per cent) in the soils of the plantation which show a decline in yield, which was on par.

With respect to clay content, there was significant difference in clay content between healthy plantation and plantation which show a decline in yield. Not much significant variation was noticed between soils of adjacent forest and cardamom plantation. The highest clay content was observed in the soils of the adjacent forest (42.06 per cent) and the lowest in the soils of healthy plantation (38.29 per cent).

Single value constants

Mean values of single value constants like bulk density, particle density and WHC of surface soil samples of various locations are presented in Table 2.

The mean values of bulk density did not vary significantly among the locations. The highest value for bulk density was observed in the adjacent forest and healthy plantation (1.20 Mg m^{-3}) and lowest value of 1.16 Mg m^{-3} in the soils of plantation which show a decline in yield, which were on par.

Particle density of the surface samples of various locations revealed that there was no significant variation in particle density among locations. The soils of the plantation which show a decline in yield had the highest value of the particle density (2.39 Mg m^{-3}), which was on par with others.

Data on WHC of surface soil samples showed that the variation between the locations was insignificant. The mean WHC was the highest for the plantation which show a decline in yield (41.74 per cent) which was on par with the lowest (40. 18 per cent) for the adjacent forest.

Chemical properties

pH and EC

Table 3 shows the mean values for pH and EC of the surface soil samples of various locations.

With respect to pH content, all the soils were acidic in reaction and the adjacent forest soil recorded the highest value of pH (5.23) followed by the healthy plantation (5.18). The lowest value was observed in the plantation which show a decline in yield (5.09) which was on par with the healthy plantation. However, no significant variation in pH was noticed between the locations.

Electrical conductivity was negligible in the soils of all the locations.

Organic carbon

Table 3 shows the mean values of soil organic carbon of various locations. It showed that there was no significant difference between the locations. The soils of the adjacent forest contained the highest level of organic carbon (3.08 g kg^{-1}) against the lowest value of 2.50 g kg^{-1} in the soils of the plantation which show a decline in yield, which were not significantly different.

CEC

The mean values of the CEC of surface soil samples of different locations are given in Table 4. It showed no significant variation between the locations. The highest mean CEC value was observed in adjacent forest (10.77

Table 3 Organic carbon, pH and EC

	pH	EC (d Sm^{-1})	Organic carbon (%)
Healthy Plantation	5.18	0.158	2.59
Plantation which show a decline in yield	5.09	0.147	2.50
Cardamom plantation	5.14	0.153	2.55
Adjacent forest	5.23	0.161	3.08
CD	0.09	-	-

Table 4 CEC, ECEC and exchangeable acidity [cmol (p^+) kg^{-1}]

	CEC	ECEC	Exchangeable acidity
Healthy Plantation	10.60	5.805	1.864
Plantation which show a decline in yield	9.46	5.037	1.841
Cardamom plantation	10. 03	5.421	1.853
Adjacent forest	10.77	5.537	1.161
CD	0.94	0.361	0.371

cmol (p^+) kg^{-1}) and lowest value in the plantation which show a decline in yield (9.46 cmol (p^+) kg^{-1}).

ECEC

Table 4 shows the effective CEC values of surface samples of various location. The highest ECEC value of 5.805 cmol (p^+) kg^{-1} was noticed in the healthy plantation and the lowest value of 5.037 cmol (p^+) kg^{-1} in the soils of the plantation which show a decline in yield. Not much variation was noticed between adjacent forest and cardamom plantation, but ECEC value of healthy plantation and plantation which show a decline in yield varied significantly.

Exchangeable acidity

Mean values of exchangeable acidity are given in Table 4. There was no significant difference between the healthy plantation and plantation which show a decline in yield although the exchangeable acidity of the cardamom plantation was significantly different than the adjacent forest. Exchangeable acidity was high (1.864 cmol (p^+) kg^{-1}) in the healthy plantation and low (1.161 cmol (p^+) kg^{-1}) in the adjacent forest.

Exchangeable bases

Data on exchangeable K, Na, Ca, Mg of surface soil samples are given in Table 5.

Exchangeable K content expressed a non-significant difference between the locations. The highest value of exchangeable K was recorded in the soils of adjacent forest (0.418 cmol (p^+) kg^{-1}) and the lowest value of 0.336 cmol (p^+) kg^{-1} in the plantation which show a decline in yield.

Mean values for exchangeable Na content of surface samples did not vary significantly. The soils of the adjacent forest recorded the highest exchangeable Na value of 0.383 cmol (p^+) kg^{-1} and soils of the cardamom which show a decline in yield (0.274 cmol (p^+) kg^{-1}) recorded the lowest value.

The highest value for exchangeable Ca was observed in the soils of adjacent forest (2.062 cmol (p^+) kg^{-1}) and the lowest value (1.667 cmol (p^+) kg^{-1}) in the soils of the plantation which show a decline in yield. Ca content of the soil was not significantly different in all the locations.

Soils of the adjacent forest recorded the highest value (1.711 cmol (p^+) kg^{-1}) for exchangeable Mg and the soils of the plantation which show a decline in yield (0.928 cmol (p^+) kg^{-1}) recorded the lowest value. No significant variation was observed between the healthy cardamom plantation and plantation which show a decline in yield.

Total N, P and K

Table 6 shows the mean values of total N, P and K of soils of various locations.

The adjacent forest soil recorded the highest nitrogen content of 0.211 per cent and the soils under the plantation which show a decline in yield recorded the lowest value of 0.173 per cent. The healthy plantation and plantation which show a decline in yield did not vary significantly; but the variation between cardamom plantation and adjacent forest was significant. N

Table 5 Exchangeable bases [cmol (p^+) kg^{-1}]

Locations	Ca	Mg	Na	K
Healthy Plantation	1.987	1.225	0.350	0.373
Plantation which show a decline in yield	1.667	0.928	0.274	0.336
Cardamom plantation	1.827	1.077	0.312	0.355
Adjacent forest	2.062	1.711	0.383	0.418
CD	-	0.650	-	-

Table 6 Total N, P and K and available N and P

	Total N, P and K (%)			Available N and P kg ha^{-1}	
	N	P	K	N	P
Healthy Plantation	0.194	0.098	0.188	341.81	60.39
Plantation which show a decline in yield	0.173	0.084	0.180	278.25	55.51
Cardamom plantation	0.184	0.091	0.184	310.03	57.95
Adjacent forest	0.211	0.121	0.217	341.04	62.28
CD	0.026	0.022	0.002	25.71	-

Table 7 Available micronutrients (mg kg^{-1})

Locations	Fe	Mn	Zn	Cu
Healthy Plantation	44.126	5.726	0.881	0.898
Plantation which show a decline in yield	34.333	4.025	0.824	0.863
Cardamom plantation	39.210	4.876	0.848	0.881
Adjacent forest	48.887	6.457	0.914	0.937
CD	10.471	1.975	0.063	-

content of adjacent forest soil was high in comparison with soils of the healthy cardamom plantation and plantation which show a decline in yield.

Total phosphorus also followed the same trend as that of total N and highest value was observed in the adjacent forest (0.121 per cent) and the lowest value (0.084 per cent) in the plantation which show a decline in yield. There was significant variation between cardamom plantation and adjacent forest. P content was high in the soils of the adjacent forest while no significant difference was seen in other locations.

Significant variation was noticed for total K between the locations. Adjacent forest soils recorded the highest total K content of 0.217 per cent and the lowest in the soils of the plantation which show decline in yield (0.180 per cent).

Available N and P

Mean values of available N and P content of surface soil samples of various locations are given in Table 6.

The data on available N showed that the soils in the healthy plantations showed a higher status of available N (341.81 kg ha^{-1}) followed by adjacent forest (341.04 kg ha^{-1}) and the lowest in the plantation which show a decline in yield (278.25 kg ha^{-1}). Significant variation was noticed between the healthy plantation and plantation which show a decline in yield. The available N content of cardamom plantation significantly differed from the adjacent forest which was on par with healthy plantation.

The available phosphorus of the soils of various locations varied from 55.51 kg ha^{-1} to 62.28 kg ha^{-1}. The highest value of 62.28 was reported in the adjacent forest and the lowest value in the plantation which show a decline in yield. There was insignificant difference between the locations.

Available micronutrients

The available micronutrients like Fe, Mn, Zn, Cu of the surface soil samples of various location are presented in Table 7.

Adjacent forest soil recorded the highest Fe content of 48.887 mg kg^{-1} followed by healthy plantation (44.120 mg kg^{-1}) and the lowest in the plantation which show a decline in yield (34.333 mg kg^{-1}). The locations differed nonsignificantly in the content of available Fe.

High Mn content of 6.457 mg kg^{-1} was reported in adjacent forest followed by healthy plantation (5.726 mg kg^{-1}) and the lowest in the plantation which show a decline in yield (4.025 mg kg^{-1}). There was no significant difference between the healthy plantation and plantation which show a decline in yield. No significant difference was also noticed between adjacent forest and cardamom plantation which was on par with the plantation which show a decline in yield.

The available Zn content in the soils of the locations varied from 0.824 to 0.914 mg kg^{-1}. It was the lowest in the plantation which show a decline in yield and the highest in the adjacent forest. Considerable variation in the available Zn status was noticed between the cardamom plantation and adjacent forest while healthy plantation and the plantation which show a decline in yiled did not vary significantly. The highest value was observed in the adjacent forest (0.914 mg kg^{-1}) and the lowest (0.824 mg kg^{-1}) in the plantation which show a decline in yield.

There was no significant difference in the Cu content between the locations. Adjacent forest soil recorded the highest Cu content (0.937 mg kg^{-1}) followed by healthy plantation (0.898 mg kg^{-1}) and the lowest in the plantation which show a decline in yield (0.863 mg kg^{-1}).

ANALYSIS OF PROFILE SAMPLES

Physical properties

Mechanical analysis

Tables 8 to 12 shows the mean values for the various soil fractions obtained on mechanical analysis of the profile samples.

Coarse sand

Table 8 shows the coarse sand content in the soils of different locations. In all the locations, it showed a tendency to increase with depth upto the 3rd horizon, and then it steadily decreased. Coarse sand content was significantly different in the different horizons of the adjacent forest. In the plantations, coarse sand content varied significantly in the first three horizons but variation was not noticed in the 3rd and 4th horizons. The highest coarse sand content of 35.85 per cent was observed in the healthy plantation which was significantly higher than that of the location which show a decline in yield. The lowest value of 32.26 per cent was recorded in the adjacent forest and significantly varied with that of the cardamom plantation.

Profile soil samples

Mechanical analysis

Table 8 Depthwise variation in coarse sand content of profile soil samples (%)

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	38.34	36.53	33.84	35.56	36.05	
$P_2 L_1$ (Pampanar)	38.60	36.95	35.23	34.32	33.11	
Mean	38.47	36.74	34.54	34.94	34.98	35.85
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	32.68	30.08	30.44	31.38	32.77	
$P_2 L_2$ (Pampanar)	34.47	35.48	34.94	35.80	85.19	
Mean	33.58	32.78	32.69	33.59	33.98	33.28
Mean cardamom plantations	36.03	34.78	33.62	34.27	34.48	34.57
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	33.09	32.18	30.41	32.29	33.72	
$P_2 L_3$ (Pampanar)	34.30	33.50	30.90	30.40	31.84	
Mean	33.70	32.84	30.66	31.35	32.78	32.26

CD Locations - 1.6 Depths - 0.49

Table 9 Depthwise variation in Fine sand content of profile soil samples (%)

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	9.15	8.42	7.75	6.50	6.47	
$P_2 L_1$ (Pampanar)	9.21	8.42	6.81	6.61	6.07	
Mean	9.18	8.42	7.26	6.56	6.27	7.57
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	10.52	9.72	8.91	8.24	7.74	
$P_2 L_2$ (Pampanar)	10.45	8.49	7.49	6.68	6.56	
Mean	10.49	9.11	8.20	7.46	7.15	8.53
Mean cardamom plantations	9.84	8.80	7.74	7.11	6.79	8.08
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	10.17	8.70	7.89	7.24	6.78	
$P_2 L_3$ (Pampanar)	11.01	9.60	8.50	6.44	6.50	
Mean	10.59	9.15	8.20	7.09	6.64	8.33

CD Locations - - Depths - 0.26

Fine sand

The mean values of fine sand are given in Table 9. It showed a tendency to increase with depth and varied significantly between depths. The fine sand content was high in the soils of the plantation which show a decline in yield (8.53 per cent) and low (7.57 per cent) in the healthy plantation. Significant variation was observed between the healthy plantation and plantation which show a decline in yield; but did not vary between adjacent forest and cardamom plantation.

Silt

The distribution of silt showed no regularity in the different horizons of the profiles of the various locations (Table 10). No significant difference was noticed between the locations. However, the soils under the adjacent forest recorded the highest silt content of 8.90 per cent and the lowest in the soils of plantation which show a decline in yield (8.71 per cent). In the adjacent forest and cardamom plantation which show a decline in yield, a decrease in silt content with increase in depth was noticed, which trend was not seen in healthy plantation.

Clay

From the Table 11, it may be seen that the clay content was high in the lowest horizon of the plantations as well as in the adjacent forest. Clay content increased with increase in depth irrespective of the locations and the variation was significantly higher. The soils of the adjacent forest contained

Table 10 Depthwise variation in silt content of profile soil samples (%)

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	10.88	9.98	8.56	6.66	7.05	
$P_2 L_1$ (Pampanar)	10.18	9.07	8.20	7.46	8.18	8.82
Mean	10.53	9.53	8.38	7.06	7.62	
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	11.36	9.86	10.36	8.27	7.11	
$P_2 L_2$ (Pampanar)	11.13	8.46	6.52	6.89	7.18	
Mean	11.25	9.16	8.44	7.58	7.15	8.71
Mean cardamom plantations	11.39	9.60	8.41	7.32	7.39	8.77
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	10.49	9.46	9.74	8.56	7.32	
$P_2 L_3$ (Pampanar)	11.64	7.90	9.13	8.50	6.51	
Mean	11.07	8.68	9.44	8.53	6.93	8.90

CD Locations - - Depths - 0.26

Table 11 Depthwise variation in clay content of profile soil samples (%)

Locations	**D_1**	**D_2**	**D_3**	**D_4**	**D_5**	**Mean values**
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	38.92	41.97	47.48	48.20	49.01	
$P_2 L_1$ (Pampanar)	37.63	43.03	47.64	49.15	49.94	45.29
Mean	38.28	42.50	47.56	48.68	49.48	
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	42.06	46.16	47.53	48.83	49.91	
$P_2 L_2$ (Pampanar)	41.93	45.68	49.41	48.67	48.07	
Mean	42.00	45.92	48.47	48.75	48.99	46.82
Mean cardamom plantations	40.14	44.21	48.02	48.72	49.24	46.06
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	43.94	46.52	48.55	49.20	50.46	
$P_2 L_3$ (Pampanar)	41.19	46.76	49.46	57.95	53.30	
Mean	42.57	46.64	49.01	50.58	57.88	48.13

CD Locations - - Depths - 0.46

the highest amount of clay (48.13 per cent) and the lowest in the healthy plantation (45.29 per cent). The variation in clay content was non significant in all the locations. Clay content in the horizons of adjacent forest showed a greater variation than that of the cardamom plantation.

Bulk density

In all the profiles studied, the bulk density steadily increased with depth (Table 12) and the highest value of (1.26 Mg m^{-3}) was recorded for the soils of the healthy plantation. The plantation which show a decline in yield had the lowest bulk density of 1.23 Mg m^{-3}. Significant variation in bulk density was noticed in the different depths of the location. However, there was no significant difference in the mean bulk density between the locations.

Particle density

As in the case of bulk density, the particle density of the soils increased with depth in all the profiles of the locations (Table 13). Particle density of various locations revealed that there was significant difference between the various horizons. Healthy plantation soils recorded the highest particle density of 2.25 Mg m^{-3} and the plantation which show a decline in yield recorded the lowest value of 2.20 Mg m^{-3}. Particle density did not show any significant variation between the locations.

WHC

Data on mean values of WHC of various locations given in Table 14 revealed that WHC was high in the surface horizon in all the locations and it

Single value constants

Table 12 Depthwise variation in Bulk density of profile soil samples (Mg m^{-3})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	1.14	1.19	1.22	1.27	1.29	
$P_2 L_1$ (Pampanar)	1.25	1.27	1.29	1.31	1.33	
Mean	1.20	1.23	1.26	1.29	1.31	1.26
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	1.07	1.15	1.20	1.25	1.28	
$P_2 L_2$ (Pampanar)	1.23	1.25	1.27	1.29	1.31	
Mean	1.15	1.20	1.24	1.27	1.30	1.23
Mean cardamom plantations	1.18	1.22	1.25	1.28	1.31	1.25
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	1.11	1.14	1.19	1.26	1.29	
$P_2 L_3$ (Pampanar)	1.24	1.30	1.32	1.34	1.35	
Mean	1.18	1.22	1.26	1.30	1.32	1.25

CD Locations - - Depths - 0.01

Table 13 Depthwise variation in Particle density of profile soil samples (Mg m^{-3})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	2.17	2.23	2.26	2.30	2.25	
$P_2 L_1$ (Pampanar)	2.16	2.19	2.25	2.28	2.34	
Mean	2.17	2.21	2.26	2.29	2.35	2.25
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	2.12	2.18	2.23	2.27	2.33	
$P_2 L_2$ (Pampanar)	2.09	2.12	2.16	2.22	2.27	
Mean	2.11	2.15	2.19	2.25	2.30	2.20
Mean cardamom plantations	2.14	2.18	2.23	2.27	2.33	2.23
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	2.15	2.19	2.25	2.28	2.31	
$P_2 L_3$ (Pampanar)	2.14	2.19	2.23	2.29	2.32	
Mean	2.15	2.19	2.24	2.29	2.32	2.24

CD Locations - - Depths - 0.02

Table 14 Depthwise variation in WHC of profile soil samples (%)

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	41.98	38.42	34.12	31.30	29.64	
$P_2 L_1$ (Pampanar)	40.77	36.87	32.52	30.50	27.92	
Mean	41.38	37.65	33.32	30.90	28.78	34.40
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	42.96	38.30	35.57	31.36	28.92	
$P_2 L_2$ (Pampanar)	41.89	37.82	34.37	30.80	28.41	
Mean	42.43	38.06	34.97	31.08	28.67	35.04
Mean cardamom plantations	41.91	37.86	34.15	30.99	28.73	34.72
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	41.24	38.73	36.28	33.65	30.83	
$P_2 L_3$ (Pampanar)	39.95	38.98	32.74	30.50	27.97	
Mean	40.60	38.86	34.51	32.08	29.40	35.09

CD Locations - - Depths 0.89

showed a tendency to decrease with depth. WHC of the soils in the various depths showed significant ·n. Adjacent forest soils recorded higher value for WHC (35.09 pe: ınd the lowest value of 34.40 per cent in the healthy plantation. Not much variation was noticed between the soils of various locations.

Chemical properties

pH and EC

pH values of the profiles of various locations are shown in Table 15. All the soils were acidic in reaction and ranged from 5.12 to 5.26. In all the locations, pH value decreased with depth and the difference was significant only when compared to surface layers. Also, the pH value did not show any significant difference in the 2nd, 3rd and 4th horizons, but was significantly different in the lowest horizon of all the profiles. The pH value was high in the adjacent forest (5.26) and low in the plantation which show a decline in yield (5.12). Marked variation in pH among locations was not observed.

The data on mean EC values of various locations showed that EC was negligible in the soils of all the profiles (Table 16).

Organic carbon

Table 17 shows the mean values relating to the organic carbon content of different locations. With respect to depth wise variation, the highest organic carbon was present in the surface horizon which tend to decrease steadily with depth. It may be noted that the highest level of organic carbon (1.64 g kg^{-1}) was obtained from the soils of adjacent forest and the lowest from the soils of

Table 15 Depthwise variation in pH of profile soil samples

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	5.21	5.24	5.24	5.26	5.28	
P_2 L_1 (Pampanar)	5.15	5.16	5.17	5.17	5.20	
Mean	5.18	5.20	5.21	5.22	5.24	5.12
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	5.07	5.09	5.10	5.12	5.13	
P_2 L_2 (Pampanar)	5.11	5.13	5.14	5.16	5.17	
Mean	5.09	5.11	5.12	5.14	5.15	5.12
Mean cardamom plantations	5.14	5.16	5.17	5.18	5.20	5.17
Adjacent forest						
P_1 L_3 (Vandiperiyar)	5.25	5.27	5.28	5.30	5.31	
P_2 L_3 (Pampanar)	5.20	5.22	5.24	5.26	5.27	
Mean	5.23	5.25	5.26	5.28	5.30	5.26

CD Locations - - Depths 0.01

Table 16 Depthwise variation in EC of profile soil samples (d S m^{-1})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	0.166	0.170	0.166	0.166	0.154	
P_2 L_1 (Pampanar)	0.142	0.144	0.170	0.126	0.120	
Mean	0.154	0.157	0.153	0.146	0.137	0.149
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	0.174	0.170	0.172	0.162	0.158	
P_2 L_2 (Pampanar)	0.126	0.136	0.128	0.118	0.116	
Mean	0.150	0.153	0.150	0.140	0.137	0.146
Mean cardamom plantations	0.152	0.155	0.152	0.143	0.134	0.148
Adjacent forest						
P_1 L_3 (Vandiperiyar)	0.176	0.174	0.168	0.170	0.152	
P_2 L_3 (Pampanar)	0.148	0.138	0.136	0.132	0.126	
Mean	0.162	0.156	0.152	0.151	0.139	0.152

CD Locations - - Depths - (0.004)

Table 17 Depthwise variation in Organic carbon content of profile soil samples (g kg^{-1})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	2.82	1.84	0.86	0.71	0.52	
P_2 L_1 (Pampanar)	2.44	1.80	1.39	1.04	0.73	
Mean	2.63	1.82	1.13	0.88	0.63	1.42
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	2.22	1.74	0.87	0.68	0.46	
P_2 L_2 (Pampanar)	1.90	1.30	0.94	0.73	0.47	
Mean	1.61	1.52	0.91	0.71	0.47	1.13
Mean cardamom plantations	2.12	1.70	1.02	0.80	0.55	1.28
Adjacent forest						
P_1 L_3 (Vandiperiyar)	3.24	1.84	1.25	0.87	0.70	
P_2 L_3 (Pampanar)	3.33	1.88	1.42	1.07	0.82	
Mean	3.29	1.86	1.34	0.97	0.76	1.64

CD Locations - - Depths - 0.03

cardamom plantation which show a decline in yield (1. 13 g kg^{-1}). However, there was no significant variation between the locations.

CEC

Mean values for CEC of different soils are presented in Table 18. It showed a decreasing tendency with depth in all the locations. Marked difference in their distribution among the different horizons was noticed. The highest CEC value was observed in the soils of the adjacent forest (6.97 cmol (p^+) kg^{-1}) and the lowest value in the soils of the plantation which show a decline in yield (5.87 cmol (p^+) kg^{-1}). There was no significant difference in the CEC of the plantation soils when compared to adjacent forest.

ECEC

The data on ECEC values of depth wise distribution presented in Table 19, revealed that there was significant difference in mean ECEC values at various depths. In all the locations, the highest ECEC was observed in the surface layers and it decreased steadily as the depth increased. No significant variation was observed between the locations. The ECEC was high in the healthy plantation (4.12 cmol (p^+) kg^{-1}) and low (3.63 cmol (p^+) kg^{-1}) in the plantation which show a decline in yield.

Exchangeable acidity (exchangeable H & Al)

Table 20 shows the mean values for exchangeable acidity. As the soil depth increased, the exchangeable acidity values significantly decreased in the cardamom

Table 18 Depthwise variation in CEC of profile soil samples [cmol (p^+) kg^{-1}]

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	10.84	7.25	5.83	5.20	4.82	
P_2 L_1 (Pampanar)	10.37	6.75	5.31	4.53	4.21	
Mean	10.67	7.00	5.57	4.87	4.52	6.51
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	9.21	6.79	5.29	4.56	3.89	
P_2 L_2 (Pampanar)	9.73	6.17	4.92	4.84	3.83	
Mean	9.47	6.48	5.11	4.45	3.86	5.87
Mean cardamom plantations	10.04	6.74	5.34	4.60	4.19	6.19
Adjacent forest						
P_1 L_3 (Vandiperiyar)	11.26	7.59	6.43	5.39	5.18	
P_2 L_3 (Pampanar)	10.57	7.22	5.48	5.08	4.82	
Mean	10.92	7.50	5.96	5.24	5.00	6.97

CD Locations - - Depths - 0.02

Table 19 Depthwise variation in ECEC of profile soil samples [cmol (p^+) kg^{-1}]

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	6.17	5.23	4.09	3.62	2.87	
P_2 L_1 (Pampanar)	5.43	4.30	3.65	3.13	2.71	
Mean	5.80	4.77	3.87	3.38	2.79	4.12
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	4.56	4.63	3.67	3.24	2.60	
P_2 L_2 (Pampanar)	5.56	3.73	3.39	2.66	2.22	
Mean	5.06	4.18	3.53	2.95	2.41	3.63
Mean cardamom plantations	5.43	4.49	3.70	3.14	2.32	3.88
Adjacent forest						
P_1 L_3 (Vandiperiyar)	6.20	4.43	3.68	3.42	3.27	
P_2 L_3 (Pampanar)	5.28	4.17	3.52	3.20	287	
Mean	5.74	4.30	3.60	3.31	3.07	4.00

CD Locations - - Depths - 0.02

Table 20 Depthwise variation in exchangeable acidity of profile soil samples [cmol (p^+) kg^{-1}]

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	1.68	1.84	1.49	1.29	1.22	
$P_2 L_1$ (Pampanar)	2.05	1.81	1.56	1.42	1.33	
Mean	1.87	1.83	1.53	1.36	1.28	1.57
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	1.95	1.90	1.82	1.63	1.36	
$P_2 L_2$ (Pampanar)	1.78	1.61	1.46	1.30	1.08	
Mean	1.87	1.76	1.64	1.47	1.22	1.59
Mean cardamom plantations	1.87	1.80	1.59	1.42	1.25	1.58
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	1.29	1.18	1.56	1.42	1.33	
$P_2 L_3$ (Pampanar)	1.24	1.32	1.22	1.25	1.26	
Mean	1.27	1.25	1.39	1.34	1.30	1.26

CD Locations - - Depths - 0.02

plantation. The adjacent forest soils did not show any regularity in the depth wise distribution. There was no significant variation between the first two horizons of adjacent forest and the other horizons varied significantly. The highest mean exchangeable acidity values of 1.59 cmol (p^+) kg^{-1} was observed in the plantation which show a decline in yield and lowest value of 1.26 cmol (p^+) kg^{-1} in the soils of adjacent forest. There was no significant difference between the various locations.

Exchangeable bases

Exchangeable K

Exchangeable K content of the soils under study was comparatively low (Table 21) and varied from 0.331 cmol (p^+) kg^{-1} in the adjacent forest to 0.234 cmol (p^+) kg^{-1} in the plantation which show a decline in yield. With regard to the distribution of exchangeable K content in the different horizons of the soil profile, a steady decrease with depth was observed and the content in the 5th horizon was found to be lowest in all the locations. Considerable variation in exchangeable K was noticed in the surface layer compared to the lower layers. Not much significant variation was exhibited between the healthy plantation and the plantation which show a decline in yield although the exchangeable K of the soils of cardamom plantation and adjacent forest varied significantly.

Exchangeable Na

The mean values for exchangeable Na are presented in Table 22. As the depth increased, exchangeable Na significantly decreased irrespective of the

Table 21 Depthwise variation in Exchangeable K content of profile soil samples [cmol (p^+) kg^{-1}]

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	0.409	0.360	0.270	0.232	0.190	
P_2 L_1 (Pampanar)	0.332	0.267	0.219	0.188	0.164	
Mean	0.371	0.314	0.245	0.210	0.177	0.263
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	0.388	0.325	0.237	0.202	0.181	
P_2 L_2 (Pampanar)	0.287	0.211	0.189	0.169	0.153	
Mean	0.338	0.268	0.213	0.186	0.163	0.234
Mean cardamom plantations	0.355	0.291	0.229	0.198	0.172	0.249
Adjacent forest						
P_1 L_3 (Vandiperiyar)	0.445	0.380	0.298	0.265	0.243	
P_2 L_3 (Pampanar)	0.389	0.361	0.336	0.313	0.269	
Mean	0.422	0.371	0.331	0.289	0.256	0.331

CD Locations - 0.053 Depths - 0.004

Table 22 Depthwise variation in Exchangeable Na status of profile soil samples [cmol (p^{+}) kg^{-1}]

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	0.314	0.215	0.155	0.100	0.072	
P_2 L_1 (Pampanar)	0.386	0.283	0.222	0.156	0.084	
Mean	0.350	0.249	0.189	0.128	0.078	0.199
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	0.261	0.215	0.153	0.102	0.066	
P_2 L_2 (Pampanar)	0.286	0.223	0.166	0.122	0.069	
Mean	0.274	0.219	0.160	0.112	0.068	0.166
Mean cardamom plantations	0.312	0.234	0.175	0.120	0.073	0.183
Adjacent forest						
P_1 L_3 (Vandiperiyar)	0.346	0.205	0.151	0.100	0.085	
P_2 L_3 (Pampanar)	0.415	0.297	0.156	0.109	0.090	
Mean	0.381	0.251	0.154	0.105	0.088	0.145

CD Locations - - Depths - 0.004

Table 23 Depthwise variation in Exchangeable Ca status of profile soil samples [cmol (p^+) kg^{-1}]

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	2.305	1.935	1.623	1.475	0.918	
P_2 L_1 (Pampanar)	1.674	1.262	1.185	0.975	0.768	
Mean	1.989	1.599	1.404	1.225	0.483	1.340
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	1.989	1.524	0.982	0.851	0.609	
P_2 L_2 (Pampanar)	1.344	1.037	0.983	0.690	0.609	
Mean	1.667	1.281	0.983	0.786	0.609	1.065
Mean cardamom plantations	1.828	1.440	1.194	1.006	0.546	1.203
Adjacent forest						
P_1 L_3 (Vandiperiyar)	2.357	1.636	1.246	1.142	1.075	
P_2 L_3 (Pampanar)	1.782	1.337	1.279	1.075	0.836	
Mean	2.070	1.487	1.263	1.169	0.956	1.377

Cd Locations - - Depths - 0.008

location. The soils under healthy plantations recorded the highest value of 0.199 cmol (p^+) kg^{-1} and the lowest value of 0.145 cmol (p^+) kg^{-1} in the soils of the adjacent forest.

Exchangeable Ca

Table 23 shows the mean values for exchangeable Ca in the various locations. Depth wise distribution of exchangeable Ca showed that the values differed significantly. Decrease in content with increase in soil depth was also noticed in the profiles. The highest value of 1.377 cmol (p^+) kg^{-1} was observed in the soils of adjacent forest and lowest value of 1.065 cmol (p^+) kg^{-1} in the soils of the plantation which show a decline in yield. Mean values of exchangeable Ca content of various locations did not show any significant difference.

Exchangeable Mg

The exchangeable Mg in the soils of the locations varied from 0.567 to 0.872 cmol (p^+) kg^{-1} (Table 24). It was highest in the adjacent forest and lowest in the plantation which show a decline in yield. Significant variation between depth was noticed for the profiles of all locations. The exchangeable Mg content steadily decreased as the depth from the surface increased. No marked variation was observed between the locations.

Total N

The variation in nitrogen content of horizons of different locations showed significant difference as seen from the Table 25. The content of nitrogen in all the

Table 24 Depthwise variation in Exchangeable Mg status of profile soil samples [cmol (p^+) kg^{-1}]

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	1.468	0.884	0.558	0.488	0.455	
P_2 L_1 (Pampanar)	0.981	0.679	0.462	0.387	0.361	
Mean	1.225	0.782	0.500	0.438	0.408	0.697
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	0.980	0.679	0.482	0.428	0.386	
P_2 L_2 (Pampanar)	0.891	0.642	0.583	0.375	0.313	
Mean	0.936	0.661	0.533	0.402	0.350	0.576
Mean cardamom plantations	1.081	0.722	0.517	0.420	0.379	0.637
Adjacent forest						
P_1 L_3 (Vandiperiyar)	1.970	1.034	0.741	0.659	0.589	
P_2 L_3 (Pampanar)	1.451	0.868	0.539	0.453	0.411	
Mean	1.711	0.951	0.640	0.556	0.500	0.872

CD Locations - - Depths - 0.007

Table 25 Depthwise variation in Total N status of profile soil samples (%)

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	0.191	0.180	0.129	0.110	0.088	
$P_2 L_1$ (Pampanar)	0.203	0.186	0.128	0.098	0.082	
Mean	0.197	0.183	0.129	0.104	0.085	0.140
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	0.167	0.152	0.120	0.097	0.083	
$P_2 L_2$ (Pampanar)	0.185	0.167	0.112	0.093	0.081	
Mean	0.176	0.160	0.116	0.095	0.082	0.126
Mean cardamom plantations	0.187	0.172	0.153	0.099	0.084	0.133
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	0.207	0.195	0.157	0.126	0.102	
$P_2 L_3$ (Pampanar)	0.214	0.197	0.141	0.114	0.095	
Mean	0.211	0.196	0.179	0.120	0.099	0.155

CD Locations - - Depths - 0.005

locations decreased with depth. The highest value (0.155 per cent) was recorded in the soils of adjacent forest, followed by the soils of healthy plantation (0.140 per cent). The lowest value for total nitrogen (0.126 per cent) was recorded in the soils of the plantation which show a decline in yield. There was no significant difference between the different locations.

Total P

The status of total P in the soils ranged from 0.081 to 0.107 per cent (Table 26). The lowest value of 0.081 per cent being present in the plantation which show a decline in yield and the highest value of 0.107 per cent in the soils of adjacent forest area. In all the locations it showed a tendency to accumulate in the second horizon. Significant difference was noticed between the locations.

Total K

Table 27 gives the depth wise distribution of total K content of various locations. It may be seen that the total K content was the highest in the surface horizon and which decreased with depth irrespective of the locations. The total K content varied significantly between various horizons. The status of K was the highest (0.165 per cent) in the adjacent forest, which was significantly higher than that of the cardamom plantation. The lowest value of 0.122 per cent was observed in the plantation which show a decline the yield and was on par with the healthy plantation.

Table 26 Depthwise variation in Total P status of profile soil samples (%)

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	0.096	0.103	0.092	0.084	0.064	
P_2 L_1 (Pampanar)	0.103	0.110	0.091	0.080	0.071	
Mean	0.099	0.107	0.092	0.082	0.069	0.096
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	0.074	0.092	0.087	0.072	0.067	
P_2 L_2 (Pampanar)	0.091	0.098	0.088	0.075	0.067	
Mean	0.083	0.095	0.088	0.074	0.067	0.081
Mean cardamom plantations	0.091	0.101	0.090	0.078	0.068	0.086
Adjacent forest						
P_1 L_3 (Vandiperiyar)	0.126	0.134	0.117	0.090	0.072	
P_2 L_3 (Pampanar)	0.119	0.125	0.109	0.098	0.081	
Mean	0.123	0.127	0.113	0.094	0.077	0.107

CD Locations - 0.011 Depths - 0.003

Table 27 Depthwise variation in Total K status of profile soil samples (%)

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	0.197	0.182	0.135	0.118	0.109	
P_2 L_1 (Pampanar)	0.183	0.160	0.120	0.110	0.102	
Mean	0.190	0.171	0.128	0.114	0.106	0.142
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	0.177	0.165	0.132	0.111	0.096	
P_2 L_2 (Pampanar)	0.128	0.121	0.110	0.097	0.089	
Mean	0.153	0.142	0.121	0.104	0.093	0.122
Mean cardamom plantations	0.172	0.157	0.125	0.109	0.099	0.131
Adjacent forest						
P_1 L_3 (Vandiperiyar)	0.220	0.195	0.173	0.133	0.121	
P_2 L_3 (Pampanar)	0.216	0.185	0.163	0.126	0.113	
Mean	0.218	0.190	0.168	0.127	0.117	0.165

CD Locations - 0.022 Depths - 0.002

Table 28 Depthwise variation in available N status of profile soil samples (kg ha^{-1})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	342.66	321.64	304.20	267.30	246.28	
P_2 L_1 (Pampanar)	335.82	316.44	294.04	253.66	233.70	
Mean	339.24	319.04	299.12	261.98	239.99	291.87
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	275.96	264.38	239.74	230.70	219.26	
P_2 L_2 (Pampanar)	268.52	247.76	235.20	226.48	215.70	
Mean	272.24	236.16	237.47	228.59	217.48	242.39
Mean cardamom plantations	305.74	286.61	268.27	241.24	228.74	267.13
Adjacent forest						
P_1 L_3 (Vandiperiyar)	342.50	319.48	284.74	256.66	240.20	
P_2 L_3 (Pampanar)	336.52	305.66	285.64	257.66	239.34	
Mean	339.51	312.57	285.19	257.11	239.77	296.83

CD Locations - 24.12 Depths - 5.85

Available N

The available N of the different locations are presented in Table 28. It showed a tendency to decrease with depth in all the location and there was appreciable variation among different depths. The highest content of 291.83 kg ha^{-1} was recorded in the healthy plantation which varied significantly compared to plantation which show a decline the yield (242.59 kg ha^{-1}). The available N content of cardamom plantation and adjacent forest soils were also varied significantly.

Available P

Table 29 shows the mean values for available P. It may be noted that the soils which were generally low in available P. Analysis of depth wise sample revealed that surface horizon recorded the highest amount of phosphorus which decreased with depth in all the locations. Significant difference was observed between various horizons of all the locations. The highest value of 43.13 kg ha^{-1} was recorded in the soils of healthy plantation and the lowest value of 34.60 kg ha^{-1} in the plantation which show a decline in yield. There was no significant variation between the locations.

Available micronutrients

Available Fe

Depth wise distribution of available Fe are given in Table 30. As the depth increased, the available Fe content decreased irrespective of the locations. The soils under adjacent forest recorded the highest value of 26.04 mg kg^{-1} and the lowest (17.09 mg kg^{-1}) in the plantation which show a decline in yield. No significant variation was there between the locations.

Table 29 Depthwise variation in Available P status of profile soil samples (kg ha^{-1})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	66.74	48.32	39.35	29.72	24.37	
P_2 L_1 (Pampanar)	67.98	55.31	40.27	32.85	26.25	
Mean	67.36	31.82	89.86	31.29	25.81	43.13
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	57.51	44.66	33.37	29.22	26.85	
P_2 L_2 (Pampanar)	53.49	40.45	23.88	20.44	19.11	
Mean	52.50	42.50	28.63	24.83	21.48	34.60
Mean cardamom plantations	59.93	47.19	34.25	28.06	23.40	38.87
Adjacent forest						
P_1 L_3 (Vandiperiyar)	67.98	55.31	33.37	29.22	2385	
P_2 L_3 (Pampanar)	56.44	43.69	26.32	24.76	20.64	
Mean	62.61	49.50	29.85	26.99	21.48	38.16

CD Locations - - Depths 0.13

Available Micronutrients

Table 30 Depthwise variation in Available Fe status of profile soil samples (mg kg^{-1})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	42.31	25.29	17.72	8.95	8.17	
$P_2 L_1$ (Pampanar)	46.27	29.46	19.91	11.04	8.91	
Mean	44.29	27.38	18.82	10.00	8.54	21.70
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	32.65	19.76	14.03	8.29	6.39	
$P_2 L_2$ (Pampanar)	36.70	22.27	14.35	7.52	6.98	
Mean	34.68	21.02	14.19	8.75	6.69	17.09
Mean cardamom plantations	39.49	24.20	16.51	9.38	7.62	19.38
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	48.84	38.36	21.43	14.64	9.22	
$P_2 L_3$ (Pampanar)	49.38	35.35	19.50	14.28	9.76	
Mean	48.69	36.86	20.47	14.46	9.49	26.04

CD Locations - - Depths - 0.25

Table 31 Depthwise variation in Available Mn status of profile soil samples (mg kg^{-1})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	6.32	3.24	2.27	1.22	0.76	
P_2 L_1 (Pampanar)	5.10	2.63	1.08	0.81	0.53	
Mean	5.71	2.94	1.68	1.02	0.65	2.40
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	4.58	2.70	1.39	0.89	0.63	
P_2 L_2 (Pampanar)	3.49	1.75	1.00	0.80	0.49	
Mean	4.04	2.23	1.20	0.85	0.56	1.77
Mean cardamom plantations	4.89	2.59	1.44	0.94	0.60	2.08
Adjacent forest						
P_1 L_3 (Vandiperiyar)	7.08	3.78	1.69	1.09	0.82	
P_2 L_3 (Pampanar)	6.85	3.21	1.28	0.89	0.65	
Mean	6.97	3.50	1.49	0.99	0.74	2.73

CD Locations - - Depths - 0.003

Available Mn

The data on depth wise distribution of available Mn in the various locations revealed that the highest content was present in the surface horizon and it tended to decrease with depth (Table 31). There was significant variation between various depths of all the locations. However, there was not much variation between the locations in the available Mn content. The available Mn content was high in the adjacent forest soil (2.73 mg kg^{-1}) and low (1.77 mg kg^{-1}) in the location which show a decline in yield.

Available Zn

Table 32 shows the available Zn content in the soils of different locations which varied from 0.338 to 0.390 mg kg^{-1}. It was highest in the adjacent forest and lowest in the plantation which show a decline in yield. In all the locations, the surface soil contained the highest amount of available Zn, which decreased considerably as the depth increased. Not much variation was noticed between the locations in their available Zn content.

Available Cu

The data on available Cu presented in Table 33 showed that the copper content decreased as the soil depth increased. The available Cu content values varied significantly between horizons. The highest value of 0.440 ppm was recorded in the adjacent forest and the lowest in the plantation which show a decline in yield (0.415 mg kg^{-1}). There was no significant variation between adjacent forest and cardamom plantation.

Table 32 Depthwise variation in Available Zn status of profile soil samples (mg kg^{-1})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
$P_1 L_1$ (Vandiperiyar)	0.845	0.364	0.211	0.175	0.151	
$P_2 L_1$ (Pampanar)	0.918	0.378	0.267	0.208	0.181	
Mean	0.882	0.371	0.239	0.192	0.166	0.370
Plantation which show a decline in yield						
$P_1 L_2$ (Vandiperiyar)	0.783	0.329	0.191	0.162	0.131	
$P_2 L_2$ (Pampanar)	0.849	0.348	0.254	0.176	0.155	
Mean	0.816	0.339	0.223	0.169	0.143	0.338
Mean cardamom plantations	0.849	0.355	0.231	0.171	0.155	0.354
Adjacent forest						
$P_1 L_3$ (Vandiperiyar)	0.864	0.371	0.232	0.191	0.169	
$P_2 L_3$ (Pampanar)	0.941	0.425	0.291	0.224	0.190	
Mean	0.903	0.796	0.262	0.208	0.180	0.390

CD Locations - - Depths - 0.004

Table 33 Depthwise variation in Availabe Cu status of profile soil samples (mg kg^{-1})

Locations	D_1	D_2	D_3	D_4	D_5	Mean values
Healthy plantation						
P_1 L_1 (Vandiperiyar)	0.881	0.565	0.333	0.167	0.124	
P_2 L_1 (Pampanar)	0.915	0.612	0.384	0.193	0.162	
Mean	0.898	0.589	0.359	0.180	0.143	0.434
Plantation which show a decline in yield						
P_1 L_2 (Vandiperiyar)	0.844	0.538	0.318	0.151	0.112	
P_2 L_2 (Pampanar)	0.822	0.595	0.369	0.190	0.151	
Mean	0.863	0.567	0.344	0.171	0.132	0.415
Mean cardamom plantations	0.881	0.579	0.352	0.176	0.138	0.424
Adjacent forest						
P_1 L_3 (Vandiperiyar)	0.906	0.594	0.382	0.192	0.144	
P_2 L_3 (Pampanar)	0.973	0.632	0.420	0.220	0.176	
Mean	0.940	0.613	0.401	0.206	0.160	0.440

CD Locations - - Depths - 0.004

PLANT LEAF ANALYSIS

The nutrient content of leaves from the healthy area as well as from the location which show a decline in yield of cardamom are presented in Table 34. It may be seen that the nutrient content of the leaves from the healthy area was comparatively higher than the location which show a decline in yield.

Macronutrients

Nitrogen

Nitrogen content was on par in the leaves from healthy plantation (2.145 per cent) and in the plantation which show a decline in yield (2.137 per cent). There was no significant variation between leaves in N content.

P

Content of P was very low in all the leaves. There was significant variation between the content of phosphorus of healthy plantation (0.188 per cent) and plantation which show a decline in yield (0.165 per cent).

K

K content was higher in the leaves from healthy plantation (2.257 per cent). Significant variation was observed in the content of this element in healthy plantation with that of the plantation which show a decline in yield.

Ca

The value of this element was comparatively higher in healthy plantation (0.822 mg kg^{-1}) and lower in the plantation which show a decline in yield (0.748 mg kg^{-1}). It varied significantly among plantations.

Table 34 Comparison of nutrient content of leaves of healthy cardamom plantation and plantation which show a decline in yield

Locations	N (%)	P (%)	K (%)	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Healthy Cardamom plantation	2.145	0.188	2.757	0.822	0.342	221.29	377.33	75.08	18.35
Cardamom plantation which show a decline in yield	2.137	0.165	2.092	0.748	0.240	221.12	380.97	69.10	16.60
't' values	1.006	8.672	24.315	12.253	28.858	8.29	2.61	5.43	2.80

Table t values - 5 % - 2.026

1 % - 2.712

Mg

Mg content was significantly higher in the healthy plantation (0.342 mg kg^{-1}) when compared to the plantation which show a decline in yield (0.240 mg kg^{-1}).

Micronutrients

Fe

More Fe was noticed in the healthy plantation (221.29 mg kg^{-1}). There was significant variation among leaves in their Fe content.

Mn

The value of this element was comparatively higher in healthy plantation (377.33 mg kg^{-1}). Significant variation existed between the locations only at 5 per cent level.

Zn

The Zn content of different leaves varied significantly and it was more in healthy plantation (75.08 mg kg^{-1}).

Cu

Variation was significant between the locations, but the content was higher in healthy plantation (18.35 mg kg^{-1}).

Growth characters of cardamom

The data pertaining to the values on growth characters of cardamom such as crop stand, age, number of suckers, tillers, height of the plant and yield per plant are presented in the Appendix I (Table 1 and 2) and II (Table 1 and 2).

DISCUSSION

DISCUSSION

The present investigation was aimed at comparing the physico-chemical properties of the cardamom growing soils and the adjacent forest soils. It also studies the effect of soil and plant nutrient factors in the decline in yield in cardamom. The properties of cardamom growing soils are compared with similar properties of the forest adjacent to the plantation and the salient findings are discussed and presented in this chapter.

Comparison of physico-chemical properties of soils of cardamom plantation and adjacent forest

Physical properties of soils

Results obtained from the present study revealed that remarkable changes in the physical properties of forest soils did not take place as a result of cardamom plantation.

The mechanical composition of depthwise samples of various locations showed that in general the cardamom plantation soils have higher sand content and lower clay content compared to adjacent forest (Fig. 1). The coarse sand content is significantly higher in healthy cardamom plantation, the fine sand content in the plantation which show a decline in yield, the silt and clay content in the adjacent forest. Increase in sand and decrease in clay content by monoculture plantations was reported by Balagopalan and Jose (1993), Moossa (1997). Coarsening of soil texture associated with monoculture plantations as pointed out by Jaiyeoba (1995) supports the findings of present investigation. Krishna (1982 a) cardamom plantation soils have

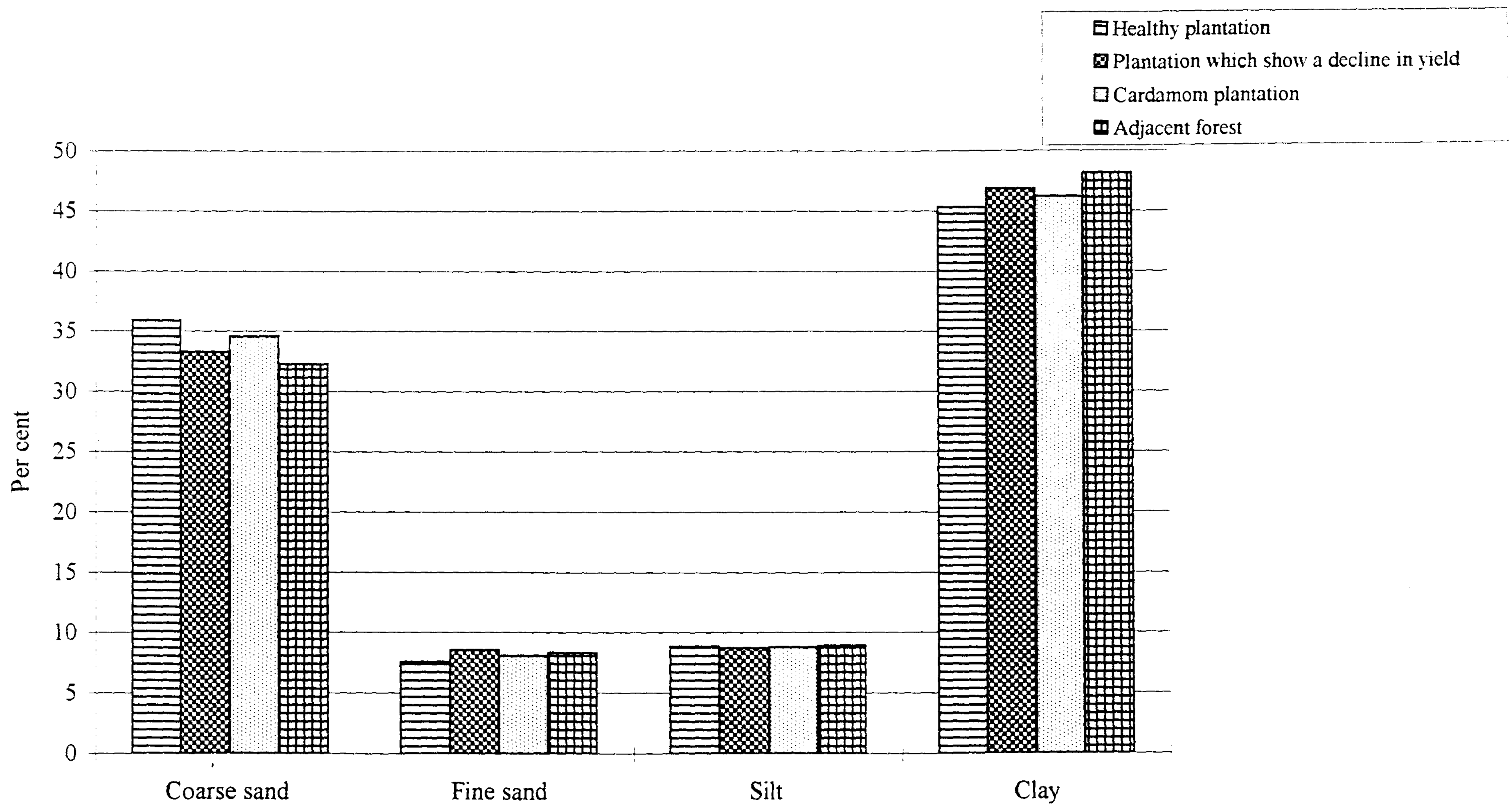

Fig. 1 Comparison of mechanical composition of soils of different locations

50 % finer fractions of which the predominance is for coarse sand.

In all the profiles the sand and silt content decreased and clay content increased with depth. This observation is in agreement with the findings of Pathak *et al.* (1964) from their studies on the physical and chemical properties of soil under cultivation and forest cover. Higher amount of sand and low clay content in surface soil may be due to the loss of clay particles from the surface soil by clay translocation or loss of clay particles by soil erosion. It is also inferred that though the surface soils of healthy cardamom plantation and plantation which show a decline in yield, contained lower amount of clay, a corresponding increase in the amount of clay in lower layers did not take place. This contradictory observation showed that low clay content and high sand content in the surface soils of cardamom plantations are not only due to clay translocation but also due to the loss of clay particles by soil erosion. A higher rate of soil erosion under monoculture plantations was reported by Zachariah (1975 a) supported the above observation. Kubendran (1980) quantified the soil loss from cardamom plantations as 61 tonnes per acre having 8 % slope and 20 tonnes per acre having 3.7 % slope.

An examination of the data on single value constants revealed that the physical conditions of soils of adjacent forest have not been significantly changed as a result of the influence of cardamom plantation (Fig. 2). The bulk density and particle density of all the soils including the adjacent forest increased with depth, the highest value for bulk density and particle density were recorded in the soils of healthy cardamom plantation. There was no significant difference between the locations in this single value constants. A higher content of organic matter is known to be responsible for decreasing

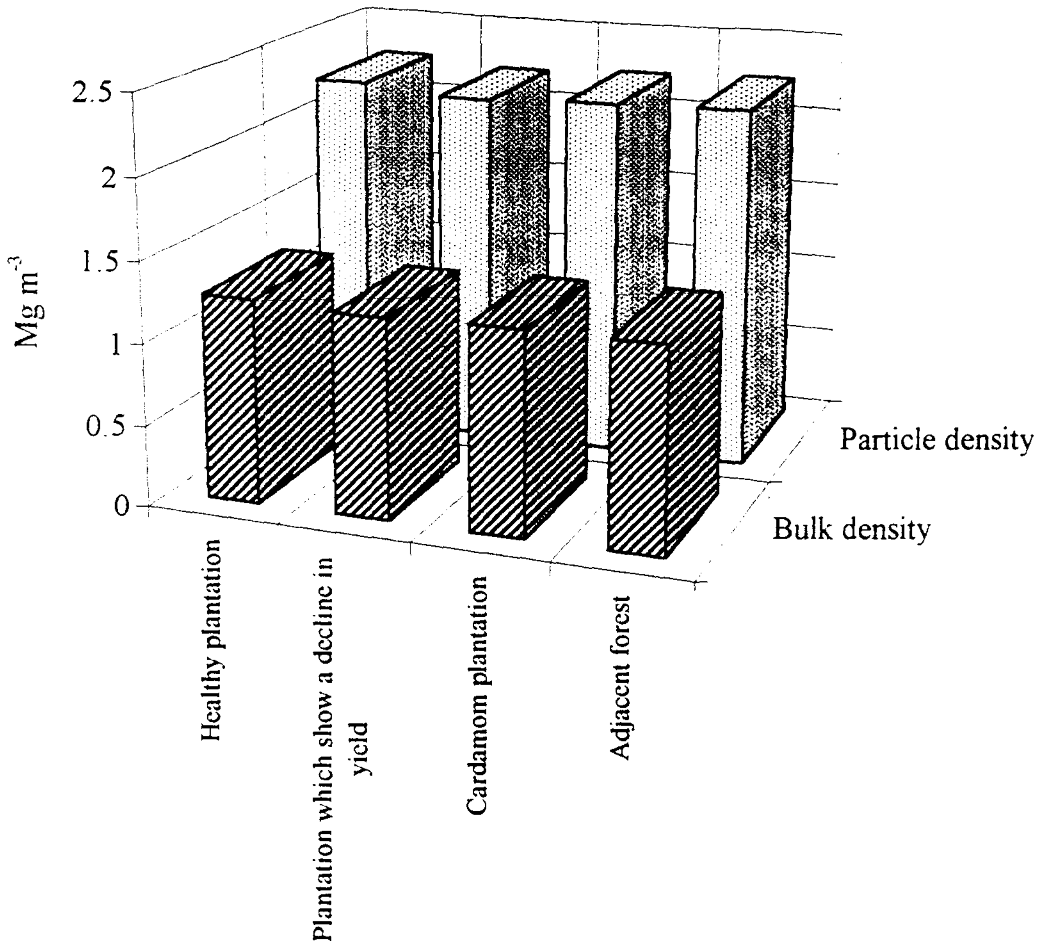

Fig. 2 Comparison of bulk density and particle density of soils of different locations

the bulk density of the soils. It may be seen from the distribution of organic matter in various soils that its content also decreased with depth in the soil profile. Therefore, the increase in bulk density with depth may be the direct consequence of a decrease in organic matter which also shows a corresponding decrease in content with depth. Higher values of particle density with increasing depth may be similarly due to a lower content of organic matter and a higher content of minerals. Page (1968) has reported a most significant change in physical parameters of the soil as a result of cropping due to the supply of organic matter.

The water holding capacity of the soils which decreased with depth in the soil profile is highest (35.09 per cent) in the adjacent forest and the lowest (34.40 per cent) in the healthy cardamom location. Thus the adjacent forest soil is having high WHC and the bulk density and particle density is highest in the cardamom plantation Pathak *et al* (1964) have reported higher values for bulk density and particle density and lower values for WHC in the surface soils of monoculture plantation compared to the adjacent forest WHC is known to be mostly influenced by the organic matter content of the soil. The adjacent forest soil which has the highest amount of organic carbon (1.64 per cent) is found to possess the maximum WHC.

Chemical properties

The pH values of the soils of the cardamom plantations and adjacent forest suggest that they are acidic in reaction. Kunhikrishnan Nair and Zachariah (1975 b) have pointed out that the cardamom growing soils of Kerala are acidic in reaction and about 42 per cent of the soils are in the acid range of below 5.5. This was well supported by the findings of Krishna (1982 b) and Srinivasan and Biddappa (1990). The acidity can be attributed to the long and continued leaching these soils have been subjected to. The present investigation has also shown that soils of cardamom plantations are more acidic than the soils of the adjacent forest. The decrease in soil pH due to monoculture plantations have been reported by Byju (1989) and Moossa (1997). Lowering of soil pH because of the loss of cations from the cardamom growing soils is in accordance with the findings of Kunhikrishnan Nair *et al.* (1978) and Korikanthimath (1984). In the case of natural forest the accumulation of organic matter in the surface soil which may give rise to organic acids during their decomposition may be the cause of higher acidity. According to Requier (1953) the removal of forest increased the pH of the soil by checking the subsequent accumulation of organic matter.

Since the electrical conductivity of the soils were nonsignificant between soils of cardamom plantations and adjacent forest, it may be concluded that the soils were more or less similar in this factor.

The results have made it clear that organic carbon was higher in the surface layers of adjacent forest compared to the cardamom plantations. There exists a non-significant relation between these locations in their organic carbon content. A slightly higher organic carbon in soils under natural forest compared to monoculture plantations obtained in the present study was also supported by the findings of Premakumari (1987) and Jaiyeoba (1995). In all the profiles the organic carbon content decreased with depth. Higher organic carbon in the surface layers was due to the high rate of litter addition and decomposition. Since the erosion hazard is minimum and the disturbance to the soil is less, incorporation of organic matter to deeper layers was more in natural forest.

The cardamom growing soil were also reported to contain a high content of organic carbon. Zachariah (1975 c) from the data collected from 5000 soil samples from cardamom plantations of Tamil Nadu, Kerala and Karnataka pointed out that majority of the soils are very high in organic matter. Kulkarni *et al.* (1970) and Dattu Rao (1971) have found that the cardamom growing soils of Chickmagalur district were high in organic carbon. Srinivasan and Biddappa (1990) have reported a relatively higher content of organic carbon in the cardamom growing soils of Kerala, Tamil Nadu and Karnataka and were in the range of 1.42 to 3.37 per cent.

Exchangeable properties

It is seen that the soils of the adjacent forest which contain the highest amount of organic matter possess the maximum cation exchange capacity also. But the variation between the two locations was insignificant in their CEC values (Fig. 3). Decrease of CEC values of soils under monoculture plantations has been reported by Pathak *et al.* (1964), Balagopalan and Jose (1993). The decrease in CEC due to deforestation followed by planting them with cardamom observed in the present study may be due to the loss of organic matter as a result of higher decomposition in cardamom plantation. Higher CEC values throughout the profiles of natural forest is due to the organic carbon content as these are highly related (Lundgran, 1978).

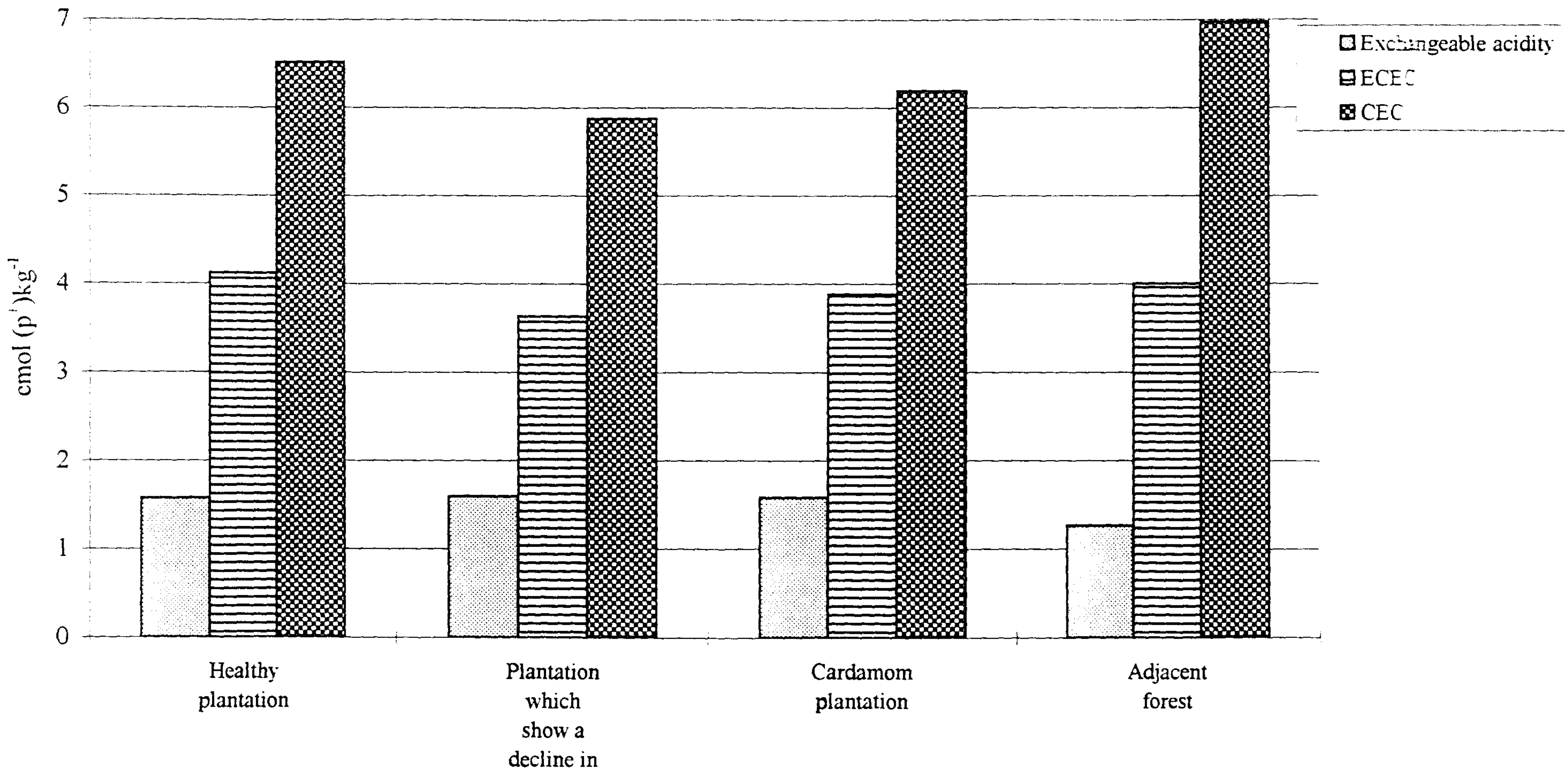

Fig. 3 Comparison of CEC, ECEC and Exchangeable acidity of soils of different locations

No variation in the ECEC values was noticed between the cardamom plantations and adjacent forest (Fig. 3). The ECEC value of the soils of healthy plantation and adjacent forest were almost similar. The high ECEC exhibited by all the profiles of the locations may be due to the high organic matter content. Higher organic matter addition and incorporation of these organic matter into deeper layers contributed the high ECEC values in almost all profiles of the locations.

The soils of the cardamom plantation showed a slightly high exchangeable acidity compared to the adjacent forests well supports the low pH values of cardamom growing soils. High exchangeable Al and titratable acidity in the monoculture plantation soils were also reported by Moossa (1997). Since the cardamom growing soils are subjected to more exposure when compared to adjacent forest soils, removal of basic cations from the exchange site were more or crop removal by bases may be the reason for high exchangeable acidity in cardamom plantation soils. The reason for lower exchangeable acidity in the adjacent forests may be due to the minimum erosion hazards and higher content of exchangeable bases as observed in the present study.

Exchangeable bases

Although the exchangeable Na, Mg, Ca contents of the soils of cardamom plantation and adjacent forest did not vary much,the exchangeable K content of the two locations significantly varied (Fig. 4). A decrease in the K content of the soils of cardamom plantations may be attributed to the higher

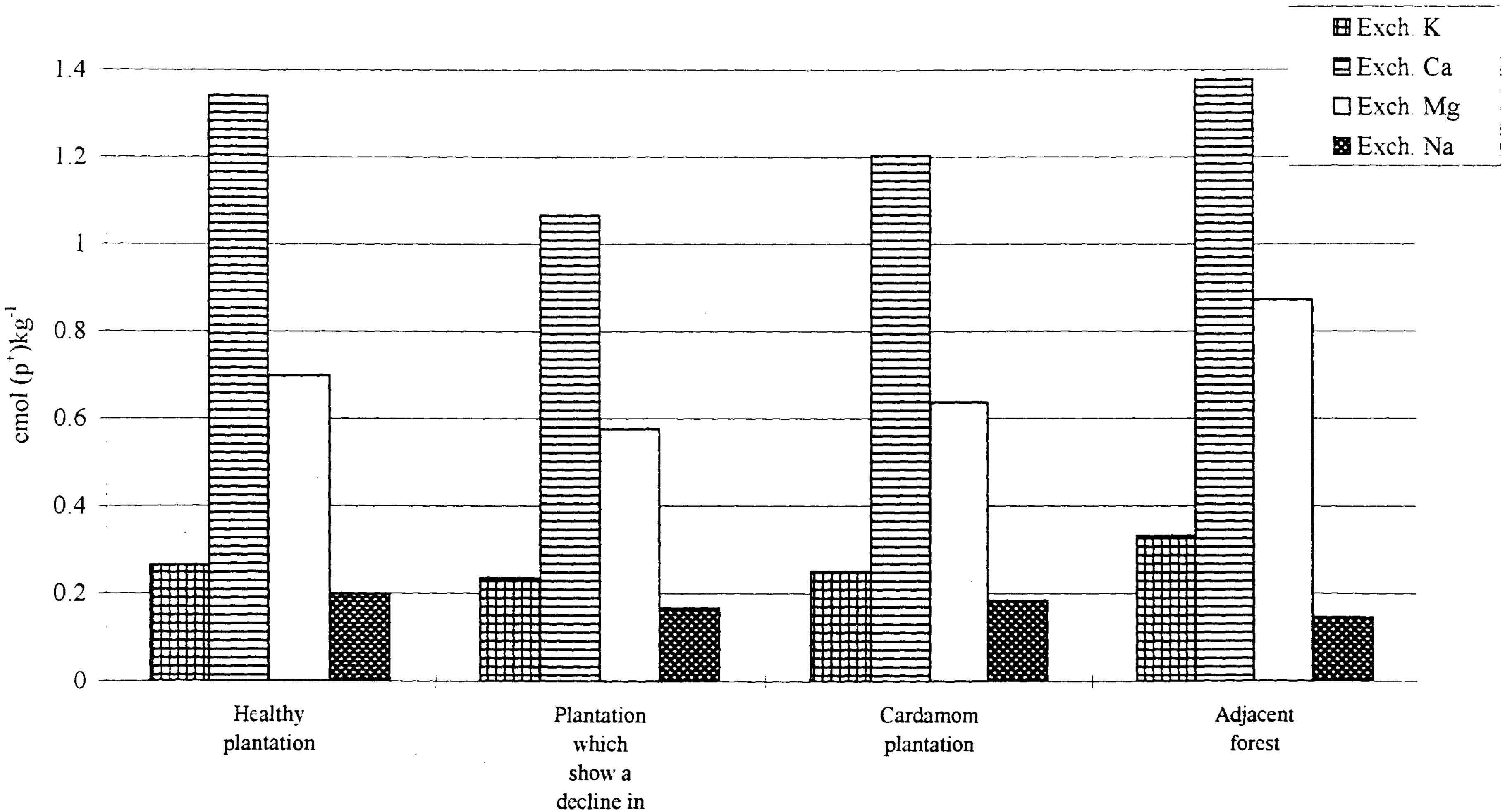

Fig. 4 Comparison of exchangeable base status of soils of different locations

uptake of potassium for the production of new tillers as well as development of capsules on the panicles. Nutrient uptake studies conducted by Kulkarni *et al.* (1971) showed that the crop required higher quantities of potassium at the time of panicle and capsule formation. Further, one hectare of cardamom removed 52.11 kg potassium from the soil while the corresponding figures for nitrogen and phosphorus were 25.97 and 4.35 kg respectively.

A comparatively higher requirement of K by the cardamom plant is indicative of the decisive role of K in the nutrition of the plants. Venugopal (1968) has reported a higher content of K in the natural forest. Low content of exchangeable bases in the surface soils under monoculture plantation was also reported by Premakumari (1987) and Byju (1989). The general nature of the deciduous trees to add more bases to the surface soil supports the relatively high content of exchangeable bases in adjacent forest compared to the cardamom plantations. The presence of high CEC and high removal of basic cations from the soil by leaching and plant uptake may be the reason for low basic cations in the soils under cardamom plantation. This observation also supports the findings of Krishna (1982 a) and Korikanthimath (1984). A comparatively lower content of K in the cardamom plantation is because cardamom is a heavy feeder of K.

Total and available mineral nutrients

The results have made it clear that the total N content of the soils of the cardamom plantation and adjacent forest shows insignificant variation but the content of total P and K showed significant difference (Fig. 5). In all locations the contents of

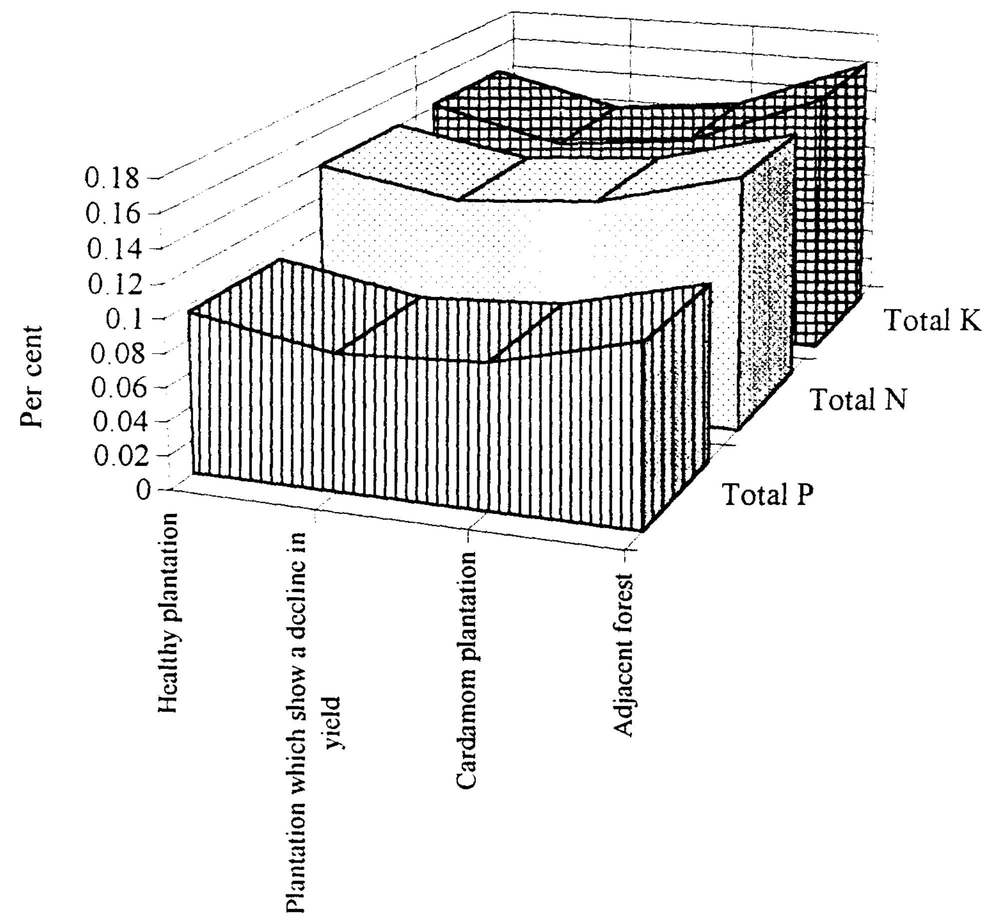

Fig. 5 Comparison of NPK status of soils of different locations

N, P, K decreased with increase in depth. It may be noted that the nitrogen content of the soil samples of the present study were in the 'high' rating range for nitrogen that there was no difference to the soils of the adjacent forest. Kulkarni *et al.* (1970), Dattu Rao (1971) and Zachariah (1975 c) also reported very high values for the organic matter content of the cardamom soils which indirectly indicates the high nitrogen status of these soils. The higher content of nitrogen may also due to a slower rate of organic matter decompositon as well as the result of high organic matter addition. Puri and Gupta (1951) have observed that humus content of coniferous forests of Kulu (Himalaya) showed nonsignificant correlation between organic matter and nitrogen content. Since the different locations coming under the experiment got the same parent material, enjoys the same climatic conditions and the equal exposure of the organic matter to biochemical reaction, the variation was not found between the soils of the cardamom plantation and the adjacent forest.

Inspite of the comparatively same content of total N, the available N content of the adjacent forest soils was significantly higher (Fig. 6). This condition points to a rapid rate of mineralisation of organic matter in the adjacent forest. The leaves from the forest trees are more succumb to microbial digestion than the leaves of cardamom. The maintenance of a larger pool of available nitrogen in the adjacent forest also reflects a state of low absorption by the forest trees. Available nitrogen shows a tendency to decrease with depth in the soil profile in all the locations. It is considerably lowest in the deeper depths compared to the surface horizons of the same profile.

Phosphorus and Potassium

It could be noted that, the total P and K content was significantly lower in the soils of cardamom plantation that the adjacent forest (Fig. 5). The distribution of total P and K in the different horizons of the plantations show a decreasing trend with depth. Inefficient biocycling associated with the cardamom plantation compared to the adjacent forest and losses of bases from the system by leaching and erosion may be the reason for low P and K content in the cardamom plantation soils. Mathew and Azisuddin Mir (1968), Kulkarni *et al.* (1970), Dattu Rao (1971) and Anonymous (1976 a) have reported that the soils of cardamom plantations in general are low to medium in Phosphorus and medium in Potassium. Kunhikrishnan Nair and Zachariah (1975 b) showed that about 80 per cent of the cardamom growing soils are highly deficient in phosphorus. The reason for the low content of Phosphorus may be due to the leaching of bases resulted in the reduced soil reaction, thus bring down the phosphorus as observed by Korikanthimath ((1984). According to the Venkatesh and Pattanshetti (1981) cardamom is a heavy feeder of potassium and that may be the reason for its lower content in the soil.

The status of available phosphorus was nonsignificant in the cardamom plantation compared to the adjacent forest, inspite of the fact that the cardamom plantation contain only a lesser amount of total P (Fig. 6). Such an increase in the content of available P in the cardamom plantations compared to the adjacent forest tells upon a situation where more of available P is coming to the available pool under the influence of the plantation. Kulkarni *et al.* (1971) reported that the phosphorus requirement of cardamom was very little compared to the other nutrients like N and K.

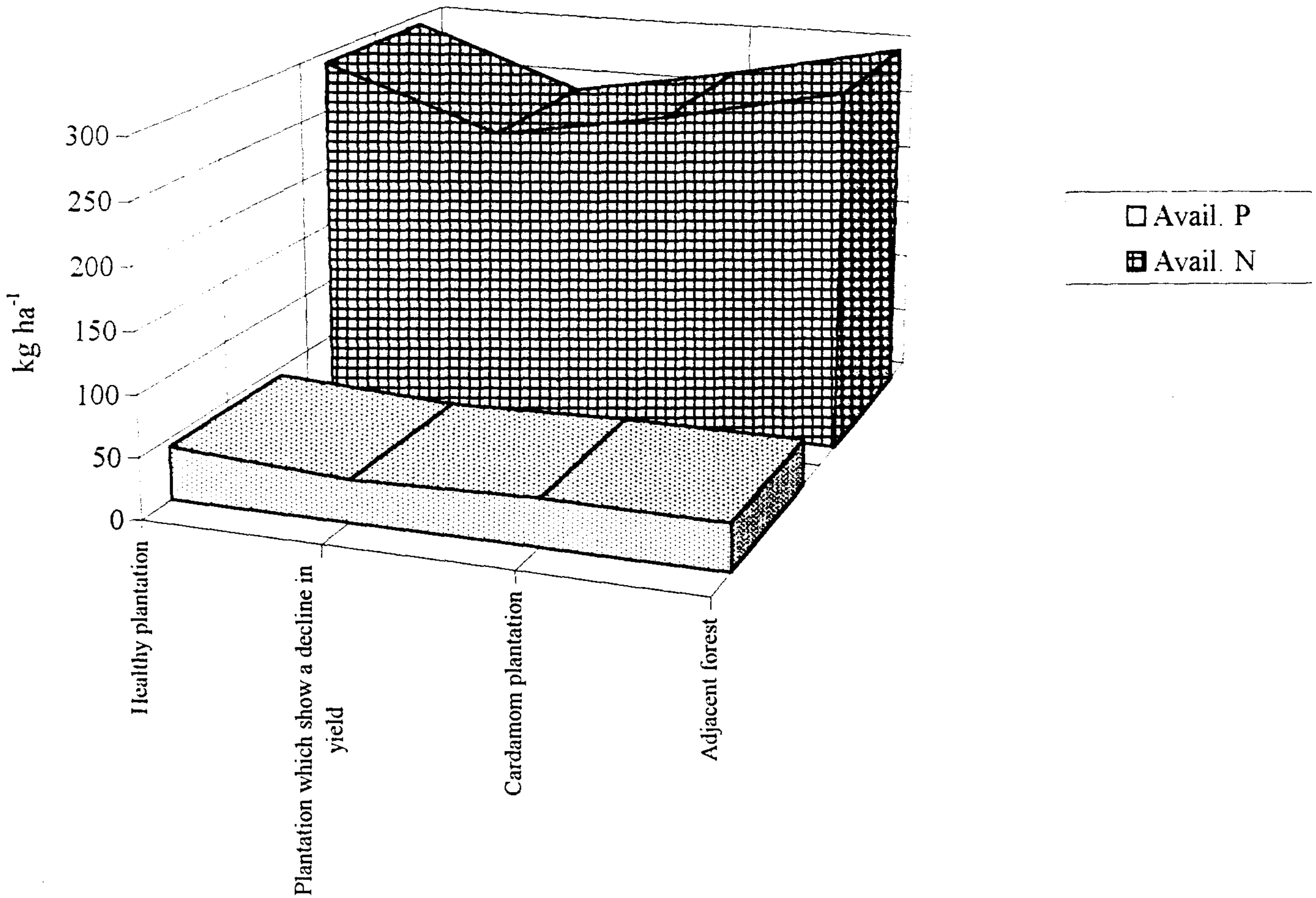

Fig. 6 Comparison of available N and P status of soil of different locations

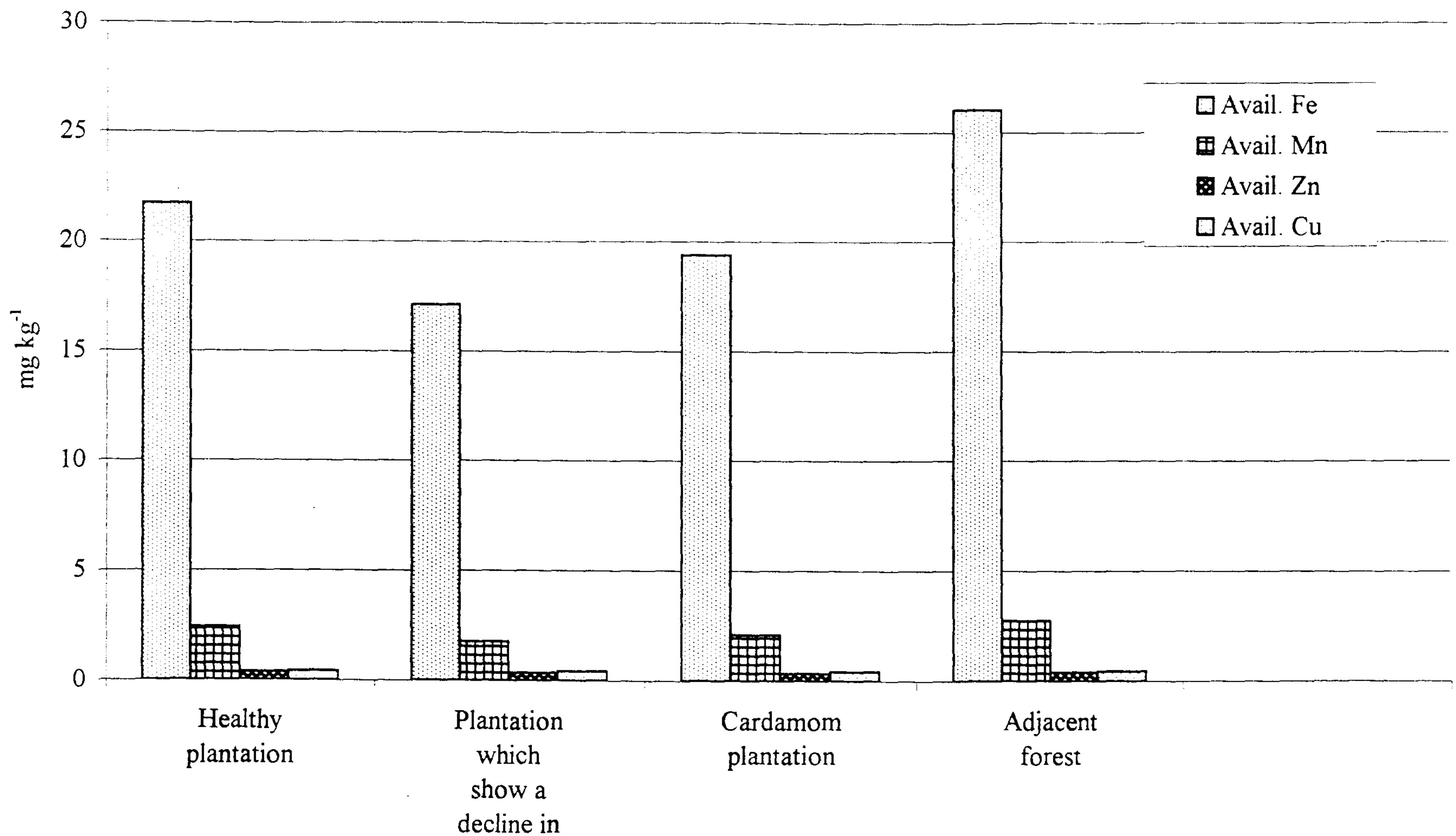

Fig. 7 Comparison of micronutrient status of soils of different locations

Available micronutrients

Although available micronutirent status showed that the micronutrients like Fe, Mn, Zn, Cu were comparatively higher in the soils under adjacent forest, but the difference was insignificant (Fig. 7). The higher organic matter associated with the forest soil may be the reason for such a difference in micronutrient status of soils, since the organic matter plays a key role in the conversion of unavailable form of nutrients to available form by forming soluble chelates. However there was a decreasing trend in the available micronutrients as the depth increased which could be attributed to the relative lowering of organic matter towards lower layers.

Soil and plant nutrients of the leaves of healthy location and location which show a decline in yield

The soils of the healthy cardamom locations was compared with the soils of the location which show a decline in yield. The comparison was done in order to assess whether any soil nutrient factors are involved in the decline in yield in cardamom. From the results on the analyses of leaf samples from the healthy plantation and plantation which show a decline in yield it may be seen that the nutrient status of leaves of healthy plantation was comparatively higher than the other. The variation in the nutrient status of two types of leaves was of a more or less uniform pattern.

Physical properties

The mechanical composition of the soils revealed that the soils of the healthy cardamom plantation contained a significantly higher content of coarse sand, and a lower content of fine sand than the soils of the location which show a decline in yield. Not much variation was noticed between the two locations in silt and clay content (Fig. 1). A higher content of coarse sand may be due to the high rate of coarsening process and the excessive tillage operations followed in the healthy cardamom plantation. A higher amount of coarse sand and lower content of clay may be due to the higher rate of clay translocation or loss of clay particles by soil erosion. The lower clay content was due to the excessive tillage operations in the healthy cardamom plantations as reported by Zachariah (1980).

The bulk density, particle density and WHC of the healthy location and location which show a decline in yield expressed a nonsignificant variation (Fig. 2). The bulk density and particle density of the soils of all the profiles decreased with increase in depth and WHC increased with decrease in depth. Almost the same bulk density, particle density and WHC observed in the two locations may be due to the equal proportion of organic matter content. The organic carbon content of these two locations also showed a nonsignificant variation as observed from the present study.

Chemical properties

The pH of soils of the healthy location and location which show a decline in yield recorded the same pH value of 5.12 and they are more acidic than the other locations. The high acidity may be due to the long and continued leaching of cations these soils are subjected to as evidenced by the downward movement of clay in the profiles. The reason of high acidity may also be due to the low base status of the cardamom plantation soils as a result of crop uptake.

Organic carbon also shows not much variation between the location. But the soils of the healthy locations have a slightly higher content of organic carbon. Higher organic content may be due to the higher rate of litter addition from the shade trees and its decomposition.

The CEC, ECEC and exchangeable acidity of the soils of healthy location and location which show a decline in yield did not vary much in their values (Fig. 3). As seen earlier, the high content of organic matter and management practices like mulching may be the reason for a slightly higher value than the location which show a decline in yield. The higher value of CEC inspite of its lower clay content than the location which show a decline in yield indicates that CEC is mostly contributed by the organic matter. The soils under plantation which show a decline in yield showed a slightly high exchangeable acidity compared to the soils of healthy location well supports the low pH value in the surface soils. Since the plants are healthy, the removal of basic cations from the available pool may be the reason for low exchangeable acidity in the soils of the healthy locations.

Soil and plant mineral nutrients

The results have made it clear that the total N and total K content of the soils of the healthy cardamom plantation and the location which show a decline in yield did not varied significantly but the total P content showed significant variation (Fig. 5). The reason for lower content of P in the plantation which show a decline in yield may be due to the excessive leaching as these soils are more exposed when compared to the soils of the healthy plantation. According to Korikanthimath (1984) leaching of bases result in the reduced soil reaction, thus bring down the availability of P. The available N content of the healthy cardamom plantation was significantly higher than the soils of the location which show a decline in yield. This may be due to the good management practices followed in the healthy plantation. The observations of the present study was in accordance with the findings of Dileep Kumar (1983) who also found no significant difference between the soils of healthy plants and diseased plants in their N and K content. Further, there was no difference in the available P between the soils of healthy plantation and diseased plant location.

Compared to the healthy plants, the nitrogen content of the location which show a decline yield was insignificantly lower, and there was much difference in the P and K content. The comparatively higher Nitrogen content in the leaves of the healthy plantations may be due to the appreciable higher content of both total and available N in the soils. This may be due to the special management practices like mulching adapted in the healthy plantations or increased biotic activity due to the excessive tillage operations. Since the plants in the healthy plantation are vigorous the uptake of nitrogen from the soil was more.

The exchangeable K, Ca, Mg and Na content of soils did not vary much between the healthy cardamom plantation and plantation which show a decline in yield (Fig. 4). This may be due to the presence of same parent material and similar climatic conditions prevailed in the cardamom plantations.

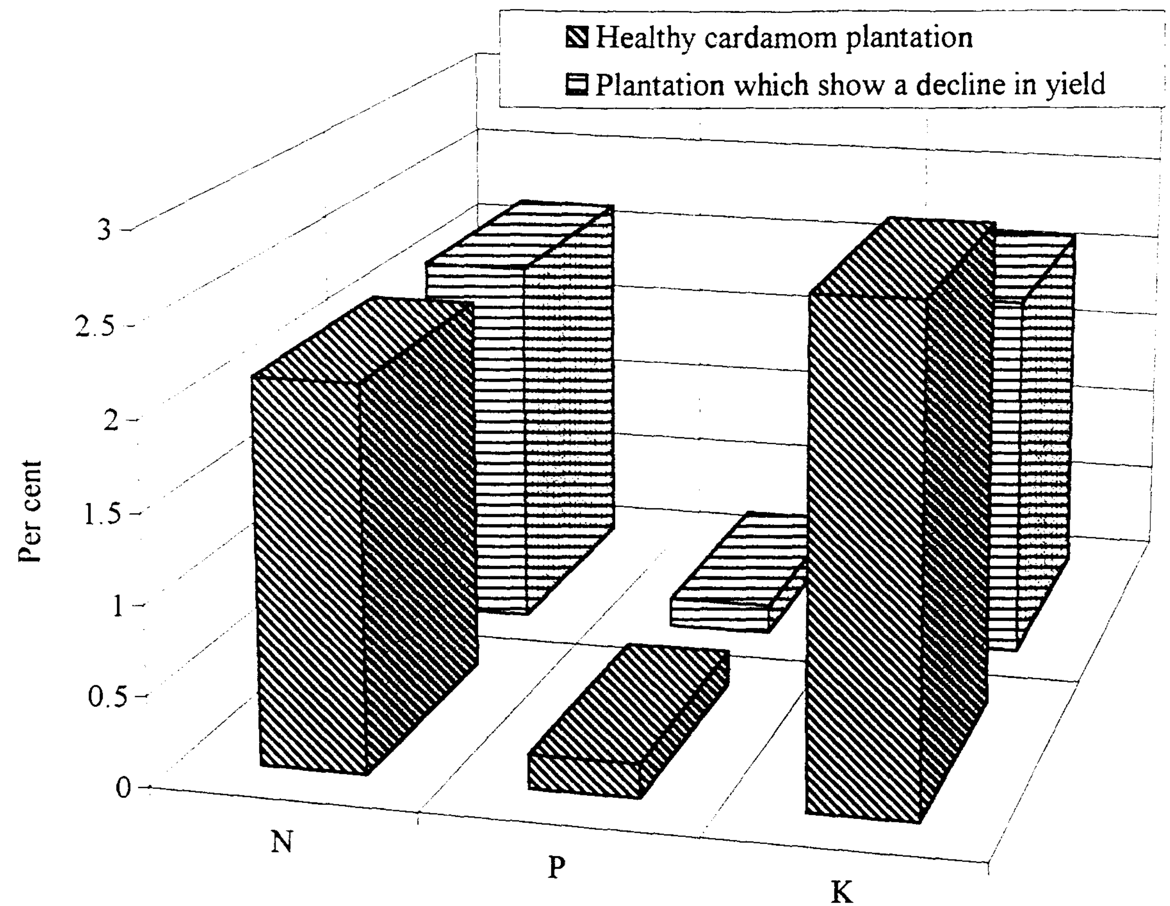

Fig. 8 Comparison of NPK content of leaves of healthy plantation and plantation which show a decline in yield

The micronutrients present in the soils have nonsignificant difference between the healthy cardamom plantation and plantation which show a decline in yield.

It is revealed from the analysis of leaves that the content of both macro and micronutrients was comparatively higher in the leaves from the healthy plantation compared to the plantation which show a decline in yield. Much variation was noticed for P, K, Ca, Mg and micronutrients but the nitrogen content of the two types of leaves insignificantly varied (Fig. 8). The higher nitrogen in the healthy plantation may be due to the higher nitrogen in the soil than the plantation which show a decline in yield. Total and available nitrogen are more in the soils of healthy plantation compared to the plantation which show a decline in yield and therefore more nitrogen was present in the available pool. According to Rao (1977) the healthy leaves contain more nitrogen content in the healthy leaves than the diseased leaves. The significantly higher content of nitrogen may be due to high organic matter addition and lesser rate of decomposition in the soils and a higher uptake of by cardamom plants of the healthy plantation. The observation of the present study is in accordance with the findings of Dileep Kumar (1983) in his studies on nutrient status of plant and soil to the incidence of chenthal disease of cardamom and he conducted that N, P, Ca, Mg, Fe, Mn, Zn were more or less similar in the healthy and diseased leaves and no nutrient factor could be ascribed as the predisposing factor for the incidence of the disease.

SUMMARY

SUMMARY

The investigation entitled "comparative study of the soils of cardamom plantations and virgin forests" was taken up at the College of Agriculture, Vellayani, during 1994 - 96. The study has been made on the soils of cardamom plantations of the Idukki district of Kerala with a view to assess and compare physico-chemical and nutritional status of cardamom cultivated soils and virgin forests. A comparison was also made between healthy cardamom plantation with those where a decline in yield is observed. For this, surface soil samples and soil profiles excavated from various selected locations were subjected to detailed chemical analysis. The plant samples were also collected from the cardamom plantations and subjected to chemical analysis to find out whether any plant nutrient factors are involved in the decline in yield in cardamom.

The important conclusion drawn from the study are summarised below:

1. Considerable variation in the physico chemical properties of the soils of adjacent forest did not take place as a result of cardamom plantation.
2. The cardamom plantation soils have higher sand content and lower clay content compared to the soils of adjacent forests. The coarse sand content was significantly higher in cardamom plantations while there was not much difference in the fine sand, silt and clay content when compared to adjacent forest.
3. Healthy cardamom plantations contained a significantly higher content of coarse sand and lower content of fine sand than the soils of the location which show a decline in yield.

4. In all the profiles of the locations the sand and silt decreased and clay content increased with depth indicating a higher migration rate for clay from surface downwards. Translocation of clay to the surface soil in the cardamom plantations was steady and more rapid rate than the soils of adjacent forest.

5. A higher content of clay in the plantation which show a decline in yield indicating a higher degree of weathering and clay formation in these soils.

6. Not much significant variation was noticed between the cardamom plantation and adjacent forest in the case of single value constants. In all the soils including adjacent forest the bulk density and particle density showed a tendency to increase with depth while the values for WHC showed a reverse order.

7. Almost similar values for bulk density and particle density were observed in the healthy cardamom plantation and plantation which show a decline in yield.

8. There was no significant difference between the cardamom plantation and adjacent forest in pH, organic carbon and exchangeable properties like CEC, ECEC and exchangeable acidity. Similarly no significant variation was observed in these properties between cardamom plantation and plantation which show a decline in yield.

9. Organic carbon and total nitrogen were higher in the surface soils of natural forests. It indicates a slow rate of decomposition and a higher rate of accumulation made possible by grater extent of canopy closure in the natural forests.

10. Among the exchangeable bases, exchangeable K content of adjacent forest soils was significantly higher than that of the soils of cardamom plantation.
11. Low total P and K content of soil profile samples were observed in the cardamom plantation when compared to the adjacent forest.
12. Inspite of comparatively same content of total N, the available N content of the adjacent forest soils were significantly higher than the cardamom plantation soils.
13. The total P content of the soils of healthy cardamom plantation was significantly higher than that of the location which show a decline in yield. Not much variation was observed between the two locations in the content of total N, K and available N and P.
14. Soils of the cardamom plantation, adjacent forest, healthy cardamom plantation and plantation which show a decline in yield showed more or less similar values for available micronutrients.
15. The P, K, Ca, Mg and micronutrient content of the leaves of the healthy plantation was significantly higher than that of the leaves of the location which show a decline in yield. No significant variation was observed between the two locations in the N content of leaves.
16. The soil nutrient factors are not a single factor for declining the yield of cardamom but the plant nutrient factors are also responsible for the decline in yield.

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(* original not seen)

APPENDICES

Appendix - I

Plantation - I

Table 1 Growth characters of plants from the healthy location

Sl. No	Crop stand	Age (Yrs)	No. of suckers	Height (m)	No. of tillers	Yield / plant (g)
1	Healthy	7	5	5.09	45	676
2	Healthy	7	5	6.71	47	656
3	Healthy	7	5	4.95	38	649
4	Healthy	7	5	5.34	42	660
5	Healthy	7	5	5.25	48	676
6	Healthy	7	5	4.94	39	627
7	Healthy	7	5	5.90	45	668
8	Healthy	7	5	4.60	43	653
9	Healthy	7	5	4.75	39	641
10	Healthy	7	5	5.26	51	687
11	Healthy	6	4	4.38	46	671
12	Healthy	6	4	5.74	48	669
13	Healthy	6	4	4.81	51	674
14	Healthy	6	4	6.00	55	660
15	Healthy	6	4	5.90	39	639
16	Healthy	6	4	4.25	48	663
17	Healthy	6	4	5.20	51	673
18	Healthy	6	4	5.60	53	684
19	Healthy	6	4	4.80	49	681
20	Healthy	6	4	4.85	46	675
Mean		7	5	5.22	46	671

Plantation - I

Table 2 Growth characters of plants from the location which show decline in yield

Sl. No	Crop stand	Age (Yrs)	No of suckers	Height (m)	No. of tillers	Yield / plant (g)
1	Poor	13	4	3.97	34	449
2	Poor	13	4	3.94	39	451
3	Poor	13	4	3.31	45	481
4	Poor	13	4	4.12	40	469
5	Poor	13	4	3.85	33	417
6	Poor	13	4	4.36	35	459
7	Poor	13	4	4.22	34	457
8	Poor	13	4	3.96	40	474
9	Poor	13	4	4.15	43	467
10	Poor	13	4	4.09	41	453
11	Poor	13	4	4.15	38	455
12	Poor	13	4	4.22	34	427
13	Poor	13	4	3.91	40	470
14	Poor	13	4	3.85	36	448
15	Poor	13	4	3.39	31	410
16	Poor	13	4	3.45	33	436
17	Poor	13	4	3.96	31	408
18	Poor	13	4	3.87	37	445
19	Poor	13	4	3.54	36	451
20	Poor	13	4	4.09	34	420
Mean		13	4	3.92	37	447

Appendix - II

Plantation - II

Table 1 Growth characters of plants from the healthy location

Sl. No	Crop stand	Age (Yrs)	No. of suckers	Height (m)	No. of tillers	Yield / plant (g)
1	Healthy	13	4	4.04	42	696
2	Healthy	13	4	5.83	38	662
3	Healthy	13	4	3.95	46	677
4	Healthy	13	4	4.28	43	683
5	Healthy	13	4	3.99	43	693
6	Healthy	13	4	4.13	44	698
7	Healthy	13	4	4.38	41	655
8	Healthy	13	4	3.92	43	665
9	Healthy	13	4	4.67	44	679
10	Healthy	13	4	3.97	46	675
11	Healthy	13	4	3.88	38	632
12	Healthy	13	4	3.83	39	629
13	Healthy	13	4	4.11	45	663
14	Healthy	13	4	3.85	45	669
15	Healthy	13	4	3.30	37	648
16	Healthy	13	4	4.34	39	634
17	Healthy	13	4	3.91	47	648
18	Healthy	13	4	4.22	49	665
19	Healthy	13	4	4.51	44	660
20	Healthy	13	4	3.99	49	685
Mean		13	4	4.16	43	666

Plantation - II

Table 2 Growth characters of the plants from the location which show decline in yield

Sl. No	Crop stand	Age (Yrs)	No of suckers	Height (m)	No. of tillers	Yield / plant (g)
1	Moderate	9	4	4.34	35	535
2	Moderate	9	4	3.81	32	518
3	Moderate	9	4	4.80	38	521
4	Moderate	9	4	4.72	39	519
5	Moderate	9	4	4.50	43	549
6	Moderate	9	4	3.97	42	544
7	Moderate	9	4	5.04	49	555
8	Moderate	9	4	4.85	51	556
9	Moderate	9	4	3.78	43	539
10	Moderate	9	4	3.61	47	527
11	Moderate	9	4	3.90	41	524
12	Moderate	9	4	4.07	48	538
13	Moderate	9	4	4.80	49	545
14	Moderate	9	4	5.20	33	559
15	Moderate	9	4	5.32	44	545
16	Moderate	9	4	4.38	37	517
17	Moderate	9	4	4.24	48	546
18	Moderate	9	4	3.83	36	526
19	Moderate	9	4	4.71	49	551
20	Moderate	9	4	4.40	46	539
Mean		9	4	4.41	44	538

COMPARATIVE STUDY OF SOILS OF CARDAMOM PLANTATIONS AND VIRGIN FORESTS

By

GLADSON D' CRUZ

ABSTRACT OF THESIS
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ABSTRACT

The investigation entitled "comparative study of the soils of cardamom plantations and virgin forests" was taken up at the College of Agriculture, Vellayani, during 1994 - 96. The study has been made on the soils of cardamom plantations of the Idukki district of Kerala with a view to assess and compare physico-chemical and nutritional status of cardamom cultivated soils and virgin forests. A comparison was also made between healthy cardamom plantation with those where a decline in yield is observed. For this, surface soil samples and soil profiles excavated from various selected locations were subjected to detailed chemical analysis. The plant samples were also collected from the cardamom plantations and subjected to chemical analysis to find out whether any plant nutrient factors are involved in the yield decline in cardamom.

A study of the soils of cardamom plantations in comparison with adjacent forests has shown that considerable variation in the physico-chemical properties of the forest soils did not take place due to the influence of the cardamom plantations.

In all these soils, the sand and silt content decreased and clay content increased with depth. The soils of cardamom plantations have higher sand content and lower clay content compared to the soils of adjacent forests. A higher content of the clay in the forest soils compared to cardamom plantation indicates a greater degree of weathering and clay formation. Healthy cardamom plantation soils contained a significantly higher amount of coarse sand and lower content of fine sand than the soils of the location which show a decline in yield.

The physical properties such as bulk density, particle density and WHC and exchangeable properties such as CEC, ECEC, exchangeable acidity were found to be positively influenced by organic matter content of the soils and were more or less similar in all the locations.

Total P and K content of soils of the cardamom plantations were low when compared to the adjacent forest indicates inefficient bio-cycling associated with the cardamom plantation and loss of bases from the system by leaching and soil erosion. A lower P content of the soils of the cardamom plantation which show a decline in yield when compared to the healthy plantation is due to the inherent properties of the former.

Inspite of the similarity in the content of total nitrogen, the available N of the adjacent forest soils was significantly higher indicating a rapid rate of mineralisation of organic matter in the soils of adjacent forest. The total P content of the soils of the healthy cardamom plantations was significantly higher than that of the location which show a decline in yield. The specific influence of the plantations in making more of available P from the unavailable pool is evident.

The total and exchangeable potassium status in the soils of the cardamom plantation recorded a lower value than the soils of the adjacent forest. This situation may indicate a lower release as well as grater uptake of this element. The content of micronutrients such as Fe, Mn, Zn and Cu were more or less same in the soils of cardamom plantation and adjacent forest indicating the same parent material and similar climatic conditions prevailed in the locations under study.

The analysis of plant leaves showed a higher content of P, K, Ca, Mg, Fe, Mn, Zn and Cu in the leaves of the healthy cardamom plantation. This point to a situation where the soil nutrient factors are not a single factor for declining the yield of cardamom but the plant nutrient factors were also responsible for the decline in yield.