PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF HIGH ELEVATION SOILS WITH REFERENCE TO TEA *(Camellia sinensis)*

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled Physico hemical and b ological properties of high elevation soils with reference to tea *(Camellia sinensis)* is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed 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 Physico chemical and biological properties of high elevation soils with reference to tea *(Camellia sinensis)* is a record of research work done independently by Kum Elizabeth Chacko under my guidance and supervision and that it has not previously formed the basis for the award of any degree fellowship or associateship to her

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INTRODUCTION

Tea the drink that cheers millions of people all around the globe at the dawn and dusk of every day plays a vital role in the economy of independent India Tea obtained from *Camellia sinensis* as two leaves and a bud has been described as the world s most popular and cheapest beverage next to water the Adam s wine

Tea cultivation in India is confined mainly to few states like Assam West Bengal Kerala Karnataka and Tamil Nadu The total area under tea in India is 378 000 ha with an annual production of 650 000 tonnes

Tea Plantations are raised at elevations ranging upto and beyond 2000 m and on slopes of varying steepness The natural vegetation in such forest areas has been replaced and put to monoculture with tea on a commercial basis for the past several years

Since the nature and mode of different agencies responsible for soil formation are governed by the ecosystem the physico chemical and biological characters of the soil of the tea plantations are found to vary widely compared to the natural and other planted forests

Soils of the tea plantations are most likely to show some special features in their physico chemical and biological make up due to the exclusive characteristics of the Tea plant as well as the management practices associated with the plantation The non exclusion of vatious plant species which were originally present and monoculture with tea also bring about appreciable variation in soil properties Since the two leaves and a bud from every shoot are nipped off very frequently the scope for recycling of nutrients is very little compard to other natural forest systems or plantations Besides the annual application of large amounts of inorganic fertilisers coupled with the heavy rainfall makes the soil prone to become more acidic and base different

The behaviour of added nutrients and their availability to the plants and their retention inthe soil will be controlled by the physico chemical and biological properties of these soils Only very meagre studies have been conducted on such characters of high altitude soils with special reference to tea platations

The present investigation has therefore been undertaken with the following main objectives

(1)To study the physico chemical and biological properties of high altitude tropical soils cultivated to tea for a long period

(2)To compare the nature and properties of soils cultivated to tea with the nearby soils not cultivated to tea

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Tea plantations are located in areas having certain special features in terms of temperature rainfall altitude and soil type The tea plantations in South India especially of Kerala are situated in the midland region at an altitude of 350 to 2500 M They are raised on denuded forest soils of high altitude low temperature and put to monoculture with tea *(Camellia sinensis)* for more than hundred years The soils are mainly derived from granite and gneissic rocks

The area is dominated by a slopping and level topography which had witnessed a number of geomorphic cycles punctuated with uplifts followed by prolonged periods of erosion and subsidence Under the impact of monsoon with alternate wet and dry conditions the laterisation processes continues to be active to the present day

The specific impact of tea plantation as a soil forming factor on the soil characteristics in these regions is less understood Only limited efforts have been made to study the nutritional and related aspects of the plantation in relation to the soil physical and chemical properties The literature available on these aspects of the high altitude soils with special reference to tea plantation is reviewed

<u>Vegetation as a soil Forming Factor</u>

Marbut (1932) in his notes on the relation of soil type to environment considered vegetation as the most important soil forming factor and Nikiforoff (1935) identified the importance of plant cover in determining the profile features of a soil

In a discussion on biosphere as a factor of soil formation Joffe (1936) stated that plants acted directly or indirectly as a factor of soil formation He brought out the influence of grassland and timber the physiological functions of the plants and their composition on the constitution of the soil profile

Jenny (1941) recognised vegetation both as a dependent and as an independent variable To illustrate the role of vegetation as an independent variable he studied the prairie timber transition zone and concluded that under equal climatic circumstances a decidious forest cover stimulated leaching and accelerated soil development more than a prairie vegetation

Physical properties

Burges (1917) has reported that the porespace of high altitude soils was generally high and the soils were loose and highly permeable He found the porespace to be high and range from 43 64/ in the plantation soils

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

Costin et al (1952) observed that in alpine humus soils of New South Wales silt and clay were obtained at a maximum altitude between 5500 and 6000 ft decreasing significantly either way They explained this being due to the optimum temperature and moisture conditions prevailing in the region

Mann and Gokhale (1960) have reported that tea soils of S India have a high clay and silt content but in the high ranges the texture is distinctly open They have concluded that the tea soils are derived from gneissic rocks containing a good deal of mica

From a comparitive study of the physico chemical properties of soils under cultivation and forest cover Pathak et al (1964) showed that porosity waterholding capacity and moisture under forest cover were higher than those of the soils under cultivation The forest soils exhibited more aggregation than cultivated soils

Chandrasekharan and Koshy (1970) reported maximum amount of clay in the surface horizon of the soil profile at an elevation of 600 2100 M in the high ranges of Kerala The clay content decreased with depth and downward translocation was maximum at 1200 M

Dey (1971) has reported that substantial deterioration in soil aggregation takes place in the early twenty years of cropping period This is partially or fully regenerated during the period between medium and old age of tea plantations

Harler (1972) has stated that the soils planted to tea are generally red and lateritic and accumulated iron compounds in them

Jose and Koshy (1972) studied the physical properties of teak soils in Kerala These soils showed a higher value for apparent density and absolute specific gravity and lower values for porespace and waterholding capacity The results indicated that the physical condition of the soils has been markedly altered as a result of deforestration and planting with teak The clay content of soils at an altitude of 200 M and cultivated to eucalyptus decreased with increase in depth and varied from 5 8 8 1 percent The bulk density is slightly reduced at higher elevation due to a higher rate of organic matter accumulation The waterholding capacity porespace and moisture equivalent showed an increasing trend with increasing elevation (Krishnamoorthy and Rajamannar 1978)

Iyengar (1977) has observed that the soils under coffee vary in colour from reddish brown to yellowish red with the texture ranging from loam to clay loam They are in general well drained and possess excellent physical properties

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

Physical properties of deodar growing forest soils at an altitude of 2100 - 2700 M were studied by Banerjee and

Badola (1982) They found the soils to be fine textured mildly acidic rich in organic matter and high in water retention properties

Ghosh et al (1984) could observe no abrupt change in texture between top and subsoil layers in the tea soils of Assam However the hydraulic conductivity varied with texture and was correlated with coarse sand silt and water content at 100 and 333 cm of water column suction

Premakumari (1987) while conducting studies on the physico chemical properties of teak eucalyptus and rubber plantations in comparison with natural forests in S Kerala has shown that in all these plantations sand and silt content of soil decreased and clay content increased with depth in the profile The single value constants were found to be positively influenced by the organic matter content of the soil

Soil Reaction

Thomas (1941) has reported that tea is a calcifuge and its preference for acid condition is associated with the generally low calcium status of leached acid soils

Analytical data reported on horizons of tea soils in Ceylon (Lamb 1955) showed a pH value of 5 5 in the top soil He opined that tea dislikes soils of high pH possibly due to an unavailability of manganese and aluminium

From a comparison of young and old forest stands Ovington and Madgwick (1957) suggested that in forest soil the greatest change in soil acidity occurred in the first 25 years after planting

Goletiani (1965) has reported that prolonged application of physiologically acid fertilisers in tea plantations brought the soil pH in the range 3 8 to 4 5 and stimulated the vegetative growth of tea bush Most tea soils in S India show a pH value between 4 5 6 (Mann and Gokhale 1960)

Bhavanandan and Sunderlingam (1972) reported that all nitrogenous fertilizers reduced the soil pH in tea plantations However the reduction in pH was maximum by the use of ammonium sulphate

Harler (1972) observed that the tea plants preferred an acid soil a condition that has resulted from the leaching of lime and other bases In most tea areas the natural pH value of soil is about 5 4

Ranganathan and Swaminathan (1973) had stressed the scope and need for liming of tea soils to bring the pH to greater than 4 5 for a breakthrough in tea production through soil management

Dhir (1976) has reported that high altitude profiles have a very large amount of acidity with much of it present in difficultly exchangeable forms The middle altitude soil profiles also are acidic but the amount of difficultly exchangeable aluminium is negligible and that of mobile sesquioxides are relatively small

Studies on the genesis of well drained laterite soils formed on different parent materials under tropical climatic conditions revealed that though soil acidity of these soils is due to chemical weathering acidity around pH 5 5 can be developed under different climatic conditions depending on the nature of the weathering complex (Gowaikar et al 1976) Rajamannar et al (1979) have reported that high level lateritic soils under *Eucalyptus tereticornis* and *E globulus* are acidic in reaction

<u>Organic matter status</u>

Cooper (1946) has shown that the continual incorporation of tea prunings into the soils increase its nitrogen content The diminution of C/N ratio seems to reflect a change in the nature of C-N linkage due to this policy

Jenny and Ray Chaudhuri (1958) showed that a higher organic matter content is found at higher elevations due to the low temperature prevailing in the high altitude range

Analytical reports of Tolhurst (1961) have revealed that tea soils of Ceylon which are around 2500 ft elevation suffered more severely than others by a loss of organic matter when compared to forest soils where the organic mattercontent increased steadily with a rise in elevation

Ramaswamy (1960) has reported the biochemical nature of the organic matter in tea soils of Ceylon A significant correlation was obtained between the altitude of the soil sampled and total organic nitrogen But the amount of available nitrogen did not show any definite correlation with altitude

Harler (1972) observed that in tea soils there is a depletion of organic matter during the early 20 years of cropping after which the rates slow down leading to a state of equilibrium

Similar observations have been made by Dey (1971) where the organic matter in tea soils are depleted rapidly in the first 20 years of planting Thereafter the rate of decline slows down and ultimately reaches an almost equilibrium level

Weeraratna (1977) has reported that tea prunings on soil increased organic matter content from 2 16 2 49 percent Organic matter content of the subsurface soil indicated that some organic matter has been transported from the surface to subsurface

Ganesan and Ranganathan (1978) studied the organic matter variation in tea soils of S India A declining trend in organic matter content was observed from 1971 to 1977 They attributed it to a lesser return of organic matter to the tea soils Liming of soils had a beneficial effect on improving the organic matter status

Rajamannar et al (1979) have reported that high level lateritic soils under *Eucalyptus tereticornis* and *E globulus* developed under low temperature and high rainfall contained higheramounts of organic carbon (0 44 9 74%) which showed a decrease with depth in the soil profile

Under continuous cropping and manuring in tea nutrients and organic matter are depleted rapidly in the early 20 years of cropping and thereafter the rate of decline slows down reaching a level of equilibrium Nitrogen and organic matter content of the top 30 cm soils are linearly correlated (Dey 1971)

Banerjee et al (1982) studied the physico chemical properties of deodar growing soils at 2100 2700m altitude and reported that the soils are fine textured mildly acidic rich in organic matter well supplied with nitrogen phosphorus potassium and possessed high cation exchange capacity and water retention capacities

Khairy et al (1985) have reported on the balance and dynamics of organic matter under tropical crops like tea and coffee They found that soil under tea contained greater amounts of humic acids than the original soil With continued humification soils under tea produced larger amounts of humic substances compared to coffee plantations

Nutrient status

Studies on forms of phosphate absorbed by soil colloids and their availability to tea plant by Aidinyan (1957) showed that exchangeable phosphorus fixed by soil colloids is the most available form and the decrease in exchangeable form is generally supplemented by the chemically fixed form

Jayaraman and De Jong (1955) analysed tea soils and observed that all of them were highly leached with low levels of bases and that they contained high levels of free oxides of iron and aluminium resulting in a rapid fixation of phosphorus

Conditions of Ceylon tea soils reported by Lamb (1955) revealed that they are highly fertile with 3 5% organic carbon and 0 3% nitrogen Jungle soils contained upto 20% organic matter in the top layer but their nitrogen was only slowly available After a long period of monoculture under tea there were only few signs of deterioration Sharma et al (1956) observed that the organic carbon and nitrogen generally were greater in the high elevation soils of Himachal Pradesh The C/N ratio of soils upto an elevation of 600 ft was around 10 1 and Takkar

(1963) has reported that the total nitrogen and organic carbon content in tea soils of Punjab were in the range of 0 05 2 00 and 0 42 2 50 per cent respectively The available P O varied from 6 45 85 60 ppm

Mahalingam and Durairaj (1968) have reported on the chemical properties of high altitude soils of the Nilgiris They noticed a significant increase in the contents of iron and aluminium and a general tendency for the alkali and alkaline earth metals to decrease with increasing elevation Ikegaya (1971) based on the relations between content of exchangeable bases of soil and growth of tea plants stated that poor growth generally coincided with lower base saturation Growth was best with 25 50 per cent of calcium and magnesium saturation of the clay complex

Nutrient status of coffee growing soils was studied by Iyengar (1977) These soils were rich in organic matter during the initial years of planting But during later years the soils got depleted in nitrogen They are generally low in available phosphorus and have a high phosphorus fixing capacity due to the predominance of kaolinite and hydrous oxides type of minerals The soils have moderate reserves of potassium

Ranganathan (1977) has reported that the tea soils are abundant in sesquioxides and low in bases Soils are predominantly kaolinitic and lack fixation sites for potassium The average release of potassium from weathering of rocks has been estimated to be 10 ppm per month and is considered to be not adequate to meet the crop s demand

Dey (1971) has reported the exchangeable and non exchangeable status of potassium of tea soils to be low ranging between 100 200 kg ha Organic phosphorus fractions showed considerable depletion after 40 years of tea cropping

Dhir (1976)has reported that the A horizon of high altitude soils are rich in exchangeable bases and lower horizons contain conceivably large amounts of difficultly exchangeable aluminium

Koyamu and Nambiar (1978) have noticed a reduction in total nitrogen in virgin forest land after a period of eleven years of growing plantation crops Greater reduction in potassium and calcium contents as well as an increase in phosphorus and magnesium was noticed throughout the cropping period

Studies on tea latosols in S India by Ram (1980) revealed that their CEC is low and have no fixation sites for potassium He stressed the need for high levels of nitrogen to support the large crops produced in S India

Bhattcharya and Dey (1984) have reported that soluble phosphorus applied to tea soils are mostly adsorbed as aluminium and iron bound phosphates which are only sparingly soluble

Krishnamoorthy (1985) has identified potassium as a limiting nutrient in most tea growing soils of S India It is ephemeral in nature as the soil lacks potassium fixing capacity

Crop Nutrient Studies

Jayaraman and Peter De Jong (1955) have reported that application of nitrogenous and potassic fertilisers increased the yield of tea by influencing the rate of shoot development

Goletiani (1958) has observed that the presence of 5 meq/100 g aluminium in the soil promoted the growth of tea plant along with fertilizers like ammonium sulphate and potassium phosphate

Willson (1975) from his studies on the mineral nutrition of tea reported that the response of tea to nitrogen fall off as the nitrogen application levels rise This has been attributed to a limited availability of other nutrients when an excessive amount of nitrogen is applied

He also reported that mature tea will absorb phosphate and give positive yield response when there is an undisturbed mulch layer on the soil surface

Ranganathan (1978) has reported that the efficiency of nitrogen and potassium is highest when the calcium concentration is optimum in soils Tea plants also contain larger quantities of potassium and silicon at a pH of 5

Effects of aluminium on growth and nutrient absorption in tea plants has been reported by Matsuda et al (1979) Considerable amount of aluminium accumulated in the roots and were transported to the top At 15 ppm of aluminium concentration the phosphorus content of tea plants increased while levels of nitrogen and iron in the roots showed little change

In a study of the micro distribution of aluminium and manganese in the leaf tissues Memon et al (1981) have reported that tea plants contained a very large amount (4457 ppm) of aluminium in their older leaves despite the low level of exchangeable aluminium in the soil X ray micrographs showed that aluminium was densely deposited in the cell walls of the adaxial epedermis and palisade parenchyma of old leaf tissues

Jayman and Sivasubramaniam (1975) have stated that root exudates of young tea plants contained malic acid which are capable of solubilising phosphorus iron and aluminium from rock phosphate Immobilised iron and aluminium phosphate is released by the use of malic acid as a chelating agent

Aiyadurai and Sivasubramaniam (1977) have shown a higher phosphorus uptake high nitrogen and potassium contents of leaves and stem as well as a higher dry matter content for tea plants receiving a fertiliser mixture containing ammonium phosphate

Yamada and Hattori (1977) observed higher levels of aluminium and fluorine in tea plants compared to other elements They attributed this to the absorption of aluminium fluorine complexes from the soil

Biological properties

Microbial Count

Daraseliya (1960) has reported the presence of Azotobacter in red acid tea soils near Batum in Ceylon They were numerous in organically manured soils Daraseliya (1960) has further reported that the kransnozen soils of tea plantations of Georgia contain many ammonifiers few nitrifying and aerobic cellulose decomposing bacteria and many fungi

The data collected from the analysis of an acid tea plantation soil from Alathiyur in Tamil Nadu showed that bacterial actinomyctes and fungi population decreased with soil depth which was more marked in the case of fungi than in bacteria and actinomyctes (Rangaswamy et al 1967)

Susamma and Sam Raj (1973) have reported that the tea soils of Ponmudi at 300m above MSL contained the highest population of bacteria fungi and actinomyctes in the surface soil A steady decrease in population was noted in the lower layers

Ayanaba and Omayuli (1975) reported that microbial population of acid tropical soils are claracterised by few nitrifiers denitrifiers and aerobic cellulose decomposers

Acidity has a great influence on the densities of the microbes examined

Lundgren et al (1983) studied the bacterial numbers in a fine forest soil in relation to environmental factors Different patterns of fluctuation in bacterial numbers were found for every three years There was significant correlation between bacterial number and moisture content

Grunda (1984) has identified aerobic and anaerobic bacteria and actinomycetes in the horizons of a clay loam soil under oak Aerobic bacteria showed peaks in May and October while actinomycetes in July and October Ammonifiers were numerous but nitrogen fixers absent

From a study of the soil microbial population in forest ecosystem subjected to artificially induced soil compaction Smeltzer et al (1986) reported that the total number of fungi bacteria and nematodes were significantly higher in control than in compacted plots

<u>Biochemical Activities</u>

1 Urease activity

Hoffmann and Hoffmann (1954) have reported that urease activity is greater in the rhizosphere and is dependent on the particular plant species

Roberge and Knowles (1965) studied the transformation of urea in plots of black spruce fertilized with urea and control plots They observed that ureolysis was rapid immobilisation small and nitrification negligible in urea treated plots

Margaret et al (1968) analysed New South Wales soil profiles under pasture and obtained a highly significant positive correlation between urease activity and organic carbon

Seetharaman (1968) has observed that soils high in organic matter had a high urease activity though he had not established any correlation between the two

Bhavanandan and Fernado (1970) studied the urease activity in tea soils They observed that it varied with location depth season and form of nitrogen fertilizer used It was also observed that there was always sufficient urease activity in the soil to hydrolyse the usual units of added urea

Zantua and Bremner (1976) observed that addition of urea to Iowa soils did not induce urease activity They found that soil constituents protected urease against microbial degradation and other processes leading to the inactivation of the enzyme

Sahrawat (1980) has reported that urease activity in the flood water of rice soils is enough to hydrolyse part of the urea applied on the surface water but its contribution seems to be far less than that of soil urease Correlation analysis of urease activity with properties of wetland rice soils differing widely in pH texture and organic matter indicated that urease activity was correlated significantly with organic carbon and total nitrogen but was not significantly correlated with CEC clay and pH (Sahrawat 1983)

Baruah and Mishra (1984) have reported that urease and dehydrogenase activities were generally higher in flooded rice soils than in upland rice soils Enzyme activities were negatively correlated to bacterial numbers and increased with increasing organic carbon total nitrogen and moisture content of soil

Rao and Ghai (1985) have reported low levels of urease and dehydrogenase activity in alkali soils However after their reclamation by chemical and biological methods enzyme activity was high and was positively correlated with organic carbon and nitrogen and negatively with pH and calcium carbonate content

Nitrogen fixation

Roskoski (1980) has reported nitrogen fixing activity inthe hardwood forests of the US Nitrogen fixation was found to be higher in the youngest (4 yrs) and oldest (over 200 yrs) plantations Nitrogen fixed in deadwood during the first 20 years following clear cutting was able to replace only a modest fraction of the amount lost as a result of the cutting and product removal

Studies in a 120 year old Scots Pine forest in Sweden showed that nitrogenase activity in needle litter increased and was obviously correlated with the stage of decomposition Annual contribution by nitrogen fixation in litter was estimated to be 1 5 mg/ha compared to 0 3 kg ha for the stand as a whole (Lindberg & Berg 1982) Lower rates of nitrogen fixation in roots of field grown maize than on soil were detected Most probable numbers of nitrogen fixing bacteria was estimated to be $7x10^6$ cells/dgw of roots (Mwawa et al 1986)

Nitrification Activities

Sandanam et al (1978) studied the nitrification of ammonium sulphate and urea in an acid red yellow podzolic tea soil in Srilanka Compared to the bareplots adjoining the tea fields nitrification was appreciable in tea fields A higher pH substantially increased nitrification in tea soils

Walker and WickramaSinghe (1979) isolated pure cultures of autotropic nitrifying bacteria from acid soils of tea estates *Nitrosospira sp* caused nitrification in situ in these acid soils of pH 4 1

Phosphatase activity

Nair and Subha Rao (1977) have reported two efficient phosphate solubilising micro organisms *Pseudomanas sp* and *Aspergillus niger* in the rhizocphere of coconut and cocoa These fungi were capable of dissolving about 50 percent of the inorganic phosphates

Gupta and Tripathi (1986) have found the population of phosphate solubilising bacteria to be higher in the A horizons than in B in some soils of N W Himalayas under varying biosequence and climosequence They have identified four species of phosphorus dissolving bacilli from these soils

The phosphomonoesterase activity in forest soils was found to be highest in the forest floor and decreased up to 60 cm depth in mineral soil horizon (Pang and Kolenko 1986) The study also demonstrated that phosphomonoesterase activity depended on soil geographic location and depth

Thomas and Santharaman (1986) have observed that solubilisation of inorganic phosphate in coconut plantations in laterite soils recorded maximum solubilisation of 54 percent of the insoluble phosphorus with *Micrococeus roseus*

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study entitled Physico Chemical and Biological properties of high elevation soils with reference to Tea has been made by carrying out a detailed analysis of soil and plant samples from typical tea plantations

Location

Sampling sites were located in the Jayasree Tea Estate Ponmudi in Trivandrum district The plantations are of 60 years old and situated at an altitude of 1500 to 2000 metres above MSL

Collection of soil samples

Soil profiles to a depth of 1 25 M were exposed in six different locations in the tea plantation In each of these locations an adjacent area not planted to tea was also selected and profiles exposed in a similar manner Since horizon differenciation was not marked in any of these profiles soil sampling was done at three arbitrary depths of 0 to 15 (d1) 15 to 30 (d2) and 30 to 45 cm (d3)

Undisturbed soil samples at these depths were also collected using a core sampler In addition to the soil samples from these profiles 12 surface (0 15 cm) and subsurfaces (15 30 cm) samples each were also collected randomly from the same locations

Plant sample

Leaf samples from the tea bushes were collected from where the soil samples were collected

Soil Analysis

Preparation of soil sample

The air dried soil samples were gently powdered with a wooden mallet and passed through 2 mm sieve and stored in air tight containers for subsequent studies

Physical properties

The physical properties such as bulk density particle density water holding capacity and pore space were determined in the undisturbed core samples by adopting standard analytical procedures as detailed below The texture of the soil samples was also determined by standard procedures

Bulk density Particle density Water holding capacity and pore space	Troell s method by using Keen Raczkowskii box	Wright (1939)
Texture	Mechanical Analysis by Bouyoucos Hydrometer method	Black (1965)

Chemical properties

The chemical characters like pH total acidity exchangeable acidity total and available nitrogen and phosphorus total and exchangeable potassium exchangeable calcium magnesium iron aluminium organic carbon sesquioxides cation exchange capacity and phosphorus fixing capacity of the soil samples at the three depths were determined by methods indicated below

PH	in 1 2 5 soil water suspension using pH meter	Jackson (1973)
Total acidity exchangable acidity and exahangable aluminium	Titration method after extraction with IN KCl	Yuan (1959)

Total nitrogen	Microkjeldahl method	Jackson (1973)
Available nitrogen	Alkaline permanganate distillation method	Subbiah and Asija (1956)
Total phosphorus	Chloro Stannous reduced molybdo phosphoric blue colour method in H SO_4 system in H SO_4 extract	Jackson (1973)
Available phosphorus	Dickman & Brang s molybdenum blue method after extraction with Bray 1 reagent	
Total potassium	In H_2SO extract using flamr photometer	
Exchangeable potassium	In neutral normal ammonium acetate extract using Flame photometer	
Exchangeable calcium and magnesium	Neutral normal ammonium acetate extract by using Atomic Absorption Spectrophotometer at a Wavelengths of 422 7 nm and 285 2 nm for calcium and magnesium respectively	
Cation Exchange	Ammonium acetate method	

capacity		
Organic carbon	Walkley and Black s titration method	Piper (1950)
Phosphorus fixing capacity	Waugh & Fitts	Nad et al (1975)
Sesquioxides	By precipitation from hydrochloric acid extract and ignition	Sankaram (1966)

The surface and subsurface soils were also analysed for total nitrogen available phosphorus exchangeable potassium calcium and magnesium by the methods described above and results are given in appendix VII

Biological properties

Biological properties like total microbial count urease activity phosphorus solubilising capacity and nitrogen fixing capacity were studied by the following methods

Total microbial count

Total microbial count was determined by the soil dilution and plate count method (Timonin 1940)

A dilution of 1 10^6 was prepared for each of the soil and 1 ml each of the diluted solution was separately plated in triplicate petri dishes each containing specific media for bacteria (soil extract agar) fungi (streptomycin Rose bengal Agar) and actinomyctes (Kenknights media) The composition of the respective media is given in Appendix I

After seven days incubation at room temperature the number of colonies formed in each plate was counted averaged and the total number of each organism in one gram of the soil was calculated

Urease Activity

The Hoffmann Teicher method (1961) with slight modifications was followed In this method 5 g of the soil was placed in a 100 ml volumetric flask and 1 ml toluene added After fifteen minutes 10 ml of sodium citrate citric acid buffer (pH 6 5) and 10 ml of 10 per cent urea solution was added The flasks were incubated for 24 hours at 30oC A control in which 10 ml of distilled water substituted for urea was run simultaneously for each soil sample

After incubation the contents of the flasks were diluted to 100 ml with distilled water the toluene forming an immiscible layer above the graduation mark The flask was shaken well and the contents filtered through a Whatman No 5 filter paper The ammonia released by the enzymic hydrolysis of urea was determined in an aliquot of the filtrate by distillation in a micro kjeldhal distillation unit Urease activity was reported as mg of ammoniacal nitrogen released per gram of urea added

Phosphate solubilising capacityl

20 g of the soil was moistened with 5 10 ml of the medium (Appendix II) mixed with 1 g of tricalcium phosphate spread in a petridish and incubated for three weeks at room temperature After three weeks the soil was extracted with Bray s reagent I and the available phosphorus estimated Control for each soil was maintained in a similar condition without the addition of tricalcium phosphate

Nitrogen fixing capacity

One gram each of the surface soil from the profiles of soils cultivated to tea and not cultivated to tea was incubated with 25 ml of Jensens media (Appendix III) for

21 days at room temperature At the end of 21 days the total nitrogen of the medium plus soil was estimated by the modified kjeldahl method (Allen 1953) Nitrogen fixing capacity of the soil was estimated by subtracting the total nitrogen of the soil from the above values and expressed as mg of nitrogen fixed per gram of sugar oxidised

Analysis of plant samples

The fresh leaves were dried in an air oven at 60±5°C powdered in a Sumeet dry grinder and used for further analysis

1 g each of the powdered sample was digested with a mixture of concentrated H_2SO_4 and H_2O_2 (Jackson 1973) The digest was filtered and made upto 100 ml with distilled water Known aliquots of the extract were used for the determination of nitrogen phosphorus potassium calcium and magnesium by adopting standard analytical procedures as detailed below

Nitrogen	Microkjeldahl distillation method	Jackson (1973)
Phosphorus	Vanadomolybdo phosphoric yellow colour method in nitric acid system by using	

	klett summerson Photoelectic colorimeter
Potassium	By using flame photometer
Calcuim and Magnesium	By using Alomic Absorption Spectro photometer (Model PE 3030) and the Spectrum of absorption was determined at wavelengths 422 7nm and 285 2 nm respectively for calcuim and magnesium

Statistical analysis

Data pertaining to the various characteristics were analysed statistically by applying the technique of analysis of variance Simple correlations were worked out between different soil characteristics from the analytical data as given below

ANOVA

Source	DF
Between soils (T)	1
Between depth (d)	2
T x d	2
Error	30
Total	35

RESULTS AND DISCUSSION

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The results of the study and salient findings on the physical chemical and biological properties of high elevation soils and the specific effect of tea plantations are presented and discussed in this chapter

Physical properties

Mechanical Composition

The distribution of the different sized particles at various depths in the soils of tea and non tea areas of the plantation (Table 1) do not depict any significant difference either between the soils or at their different depths The soils are of a uniform clay loam texture indicating the dominance of clay compared to the silt and sand fractions

The similarity in their texture and lack of appreciable difference in the content of the particles of different size at various depths in the soils indicate a uniformity in the factors leading to the formation and distribution of the inorganic soil constituents The high clay content of 30 32 per cent especially in the lowest horizon indicates a higher rate of weathering and clay formation as well as its

Physical Properties

Table 1 Mechanical Composition of Soils cultivated to Tea (T)

and Non tea (NT) areas (per cent)

Soil particles	Soils	Depth d	d_2	d_3	Mean S
Coarse Sand	T	23 57	23 63	23 23	23 48
	NT	23 62	22 38	26 77	24 26
Mean d		23 4	23 01	25 00	
Fine Sand	T	19 63	16 20	17 03	17 62
	NT	20 62	14 87	14 98	16 82
Mean d		20 13	15 53	16 01	
Silt	T	24 65	26 98	24 62	25 92
	NT	26 12	27 43	24 4	25 98
Mean d		25 38	27 20	24 5	
Clay	T	30 88	30 97	32 53	31 46
	NT	29 72	30 67	32 57	30 98
Mean d		30 30	30 82	32 55	

downward migration

This observation is in accordance with the findings of Pathak et al (1964) from their comparative studies of the physical and chemical properties of soils under cultivation and forest cover A higher accumulation of clay with increasing depth indicates migration of clay towards lower layers The particle size distribution of soils under teak plantations also showed a higher amount of silt and clay in the deeper zone while the sand content decreased (Alexander et al 1981 Similar reports on increase in clay content with depth due to downward migration from surface has been reported for teak rubber and eucalyptus plantations in the forests of Kerala (Prema kumari 1987)

Single value constants

The mean values for the single value constants of the soils are given in tables 2 3 4 and 5 and the analysis of variance in appendix IV

Bulk density

The bulk density in both tea and non tea soils doesnot appear to differ significantly However the lowest value

(1 10 gcm ⁻³) is observed in the third horizon of non tea soil and the highest in the same horizon of tea soil The results obtained in this study is in agreement with the general findings from the study of forest and plantation soils (Prema kumari 1987) where there is an increase in bulk density with depth in the soil associated with a decrease in its organic matter content

Table 2 Bulk density (gcm)

Soil	d	d_2	d_3	Mean	S
Tea	1 14	1 22	1 29	1 22	
Non Tea	1 13	1 12	1 10	1 11	
Maen d	1 12	1 17	1 19		

In the present context eventhough there is a decrease in organic carbon level with depth(Table 10) it is not reflected in a significant increase in bulk density This may be due to the comparatively lower content of organic carbon (0 81 1 31/) in the soil which may not impart any significant influence in altering its bulk density

Even though slight differences are noticed between the particle density of the soils of tea and non tea areas at various depths these differences are not appreciable the mean values being 2 14 and 2 08 gcm^{-3} respectively for the tea and non-tea soils However a slight increase in particle density is noted with increase in depth of the profile in the two soils A similarity in the mean values of particle density of the tea and non tea soils suggest a uniformity in the nature and pattern of distribution of the mineral and rock fragments The laterite soils of the Western Ghats sloping westward in Kerala in general are found to be dominated by kaolinite with small qnantities of quartz in the clay fraction (Gowaikar 1972)

Table 3 Particle Density gcm ¬

Soil	d	d_2	d_3	Mean S
Tea	1 88	2 17	2 36	2 14
Non Tea	2 09	2 11	2 03	2 08
Maen d	1 98	2 14	2 19	

Increase in particle density with depth of the soil at the same time might probably be due to the influence of compaction of the underlying soil layer

Such instances of compaction and fragipan formations at 30 90 cm depth are encountered in tea plantations of Nilgiris especially at the centre of high plateaus leading to secondary consolidation (Ranganathan /1982)

Water Holding Capacity

It may be seen from table 4 that water holding capacity is maximum in the top layer in both the soil types and it shows significant variation between the three layers of tea and non tea profiles

Table 4 Water holding capacity (per cent)

Soil	d	d_2	d_3	Mean S
Tea	40 99	33 82	35 60	36 77
Non Tea	38 48	31 92	30 88	33 76
Maen d	39 73	32 88	33 19	

CD between depths 5 2

Water holding capacity of a soil is known to be governed by the nature of the predominant clay type as well as the content of the organic matter Since the soils of the tea plantations are lateritic and the clay is kaolinitic (Gowaikar 1972) which is a non expanding type the influence of organic matter appears to be more significant in determining the water holding capacity of the soil

It may be noted from table 10 which presents the data on organic carbon that there is a singnificant decrease in the organic matter content with depth in both soils

A higher water holding capacity for the tea soils compared to the non tea soils may be due to its higher organic matter content It may be further observed that while a correlation is lacking between water holding capacity and clay there is a positive though not significant correlation (r 0 1946) between organic matter and water holding capacity

Shukla and Ray Choudhari (1965) based on their studies of some foot hill soils of Himalayas have observed higher values for water holding capacity and volume expansion which was attributed to the higher organic matter content This is again supported by Banerjee and Badola (1982) in their studies on deodar growing forests where the soils are fine textured rich in organic matter and show high water retention

Pore Space

The mean values for porespace presented in table 5 show a decreasing tendency with increasing depth Pore space is highest (50 4 per cent) in the surface soil of non tea soils and lowest (44 6 per cent) in the middle layer of tea plantations

Table 5 Pore Space (per cent)

Soil	d	d	d₃	Mean S
Tea	47 5	46	44 6	46 1
Non Tea	50 3	50 4	46 9	49 2
Maen d	48 9	48 2	45 75	

The amount of pore space in a soil is determined largely by the nature of solid particles In soils with a higher sand content the movement of air and water is very rapid due to the predominance of macropores which makes the pore space high The soils of tea plantations have a higher clay content (31 46 per cent) when compared with sand (23 48 per cent) The clay loam texture of the soil thus leads to a decrease in pore space due to predominance of clay rather than sand The decrease in pore space with depth may be attributed to an increase in clay content eventhough the sand content do not vary appreciably This finding is in agreement with that observed in teak plantations of Kerala (Jose and Koshy 1972) where they reveal lower values for pore space

Chemical properties

Soil reaction (pH)

The values of pH in table 6 reveal that the soils are highly acidic The PH ranges from 4 1 to 4 3 and it is higher in the subsurface soil compared to the surface soil There is no marked variation in pH of soil between tea plantations and areas not cultivated to tea

Table 6

pH of soil

Soil	d	d	d_3	Mean s
Tea	4 1	4 3	4 3	4 18
Non Tea	4 2	4 2	4 3	4 16
Maen d	4 15	4 25	4 30	

Soil acidity

The mean values of total acidity in the soils cultivated to tea and not cultivated to tea at various depths are presented in table 7 Total acidity is significantly higher (3 99 cmolp kg soil) in the tea soils and no significant difference is noted between the three horizons of the two profiles Total acidity is maximum at a depth of 15 30 cm in the tea plantation

Table 7 Total acidity (Cmolp+Kg Soil)

Soil	d	d_2	d_3	Mean b
Tea	3 43	4 69	3 85	3 99
Non Tea	3 75	2 88	2 98	3 20
Maen d	3 59	3 78	3 42	

CD (between soils) 0 611

CD (combination between soils and depth) - 1 058

Exchangeable aluminium and hydrogen are considered to be the two important factors contributing to soil acidity (Black 1973 Sanchez 1976)

The contribution of these two factors towards

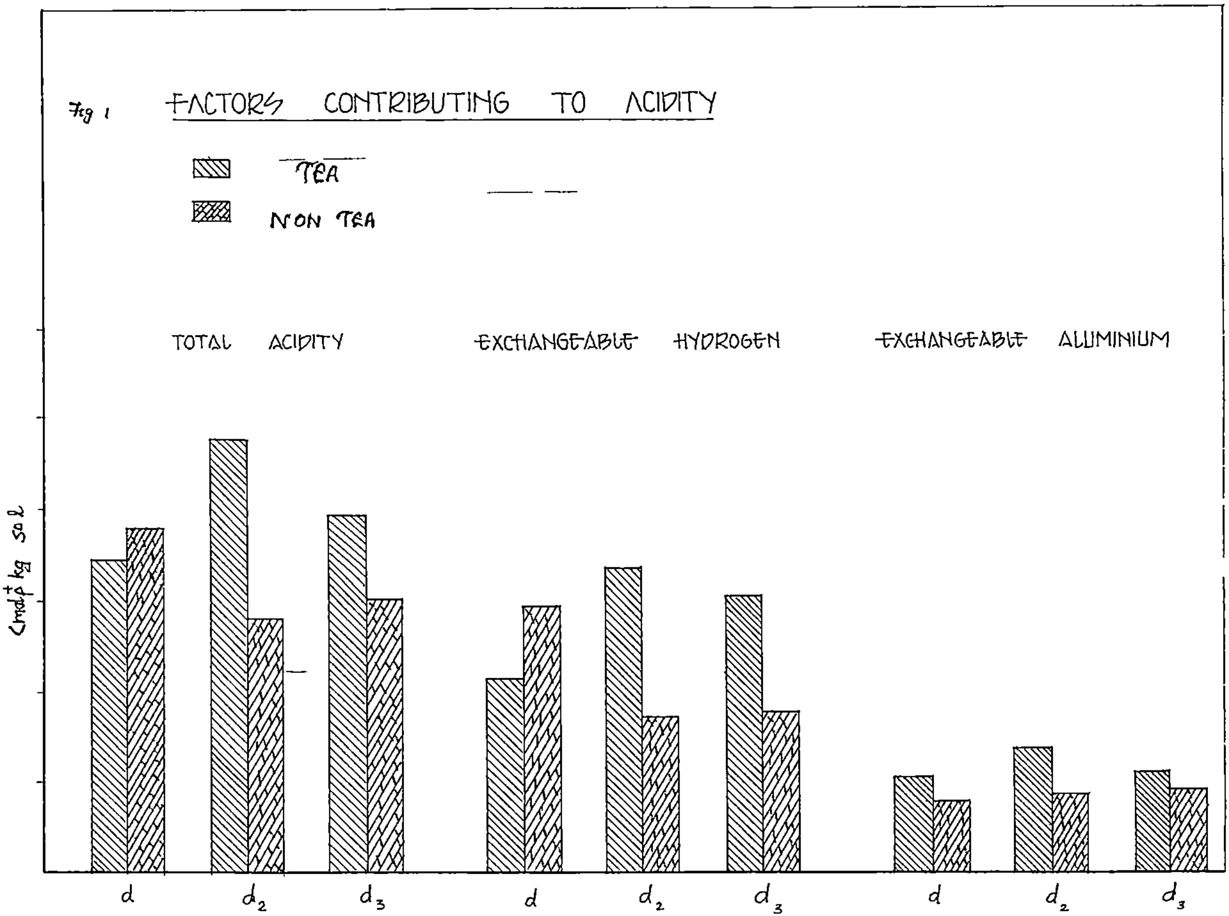


Fig 1
FACTORS CONTRIBUTING TO ACIDITY
TEA
NON TEA
TOTAL ACIDITY
EXCHANGEABLE HYDROGEN
EXCHANGEABLE ALUMINIUM
Cmol p+ kg soil
d
d2
d3
d
d2
d3
d
d2
d3

present context may be due to a higher acidity of the soil associated with a greater weathering of soils and an abundant use of acid forming fertilizers

The high values for exchangeable aluminium in these soils show the possibility of exchangeable aluminium acting as a potential source of soil acidity At the same time a perusal of table 9 shows that a considerable part of the total acidity of the soils of tea plantations is represented by exchangeable hydrogen rather than exchangeable aluminium

Table 9 Exchangeable hydrogen(Cmol$_p$ Kg of Soil)

Soil	d	d₂	d₃	Mean S
Tea	2 10	3 33	3 02	2 81
Non Tea	2 87	1 65	1 79	2 10
Maen d	2 48	2 49	2 40	

CD (between siols) 0 594

CD (between depths) 0 727

CD (combination between soil & depth) 1 028

Exchangeable hydrogen is significantly higher in the soils of tea plantations compared to that of non tea soils

It is highest (3 33 cmol(p+)kg) in the tea soils at a depth of 15 30 cm and lowest at the same depth of non tea soil The interaction between the values of exchangeable acidity in the three horizons and two soil types is also significant

Since the tea plantations of Ponmudi are located at an altitude of 1000 3000 m and at a moderateto steep slope and have an annual rainfall of 150 cm/a the loss of bases through leaching and runoff assumes great significance The exchange sites of the clay which are not saturated by the cations have thus become sites for holding the hydrogen ions thereby making the soils highly acidic

It is also possible that the strongly acidic nature of the soils may be due to the nature of parent material from which these soils have developed Granite and gneiss are known to form parent material for the tea areas of South India occuring in the high altitude range (Mann and Gokhale (1960)

Cation Exchange Capacity

The mean values for CEC of the tea and non tea soils presented in table 10 are similar In both situations the surface soils record a higher CEC which show a tendency to decrease in the subsurface soils The CEC of the soils may be rated as low as per the classification proposed by Barbur and Rockwell (1972)

Table 10 Cation Exchange Capacity (Cmol(p)Kg of Soil)

Soil	d	d_2	d_3	Mean S
Tea	8 53	8 15	7 63	8 07
Non Tea	8 33	7 85	8 03	8 07
Maen d	8 43	8 00	7 73	

CEC is a concept arbitrarily defined (Russel 1961) and gives the sum of cations held by the permanent negative charges on the clay particles and the cations held by organic matter The low CEC of these soils may be due to the predominance of kaolinitic clay minerals which themselves are characterised by a low CEC The contribution from organic matter may not be so appreciable in view of its low content

A slight decrease in CEC with increase in depth inspite of the slightly higher content of the clay in deeper horizon may be due to a decrease in the content of organic matter Such a decrease in organic matter and consequent depletion of cationic nutrients has been observed with continuous cropping of *Pinus radiata* in Australia (Florence 1967) The tea latosols of South India have reported to be of a low CEC with no fixation sites (Ram 1980)

Organic Carbon Nitrogen, C/N ratio and available nitrogen

Organic Carbon

The organic carbon contents of the soils of tea plantation (Table 11) is significantly higher than that of the non tea soils In the tea soils it ranges from 1 05 per cent in the lowest horizon to 1 56 per cent inthe surface soil Here the organic carbon significantly decreases with an increase in depth of the soil while such a gradation is not seen in the non tea soils

Table 11 Organic Carbon (per cent)

Soil	d	d	d	Mean S
Tea	1 56	1 33	1 05	1 31
Non Tea	0 86	0 21	0 72	0 80
Maen d	1 21	1 07	0 88	

CD (between soils) 0 123

CD (between depths) 0 157

Eventhough the tea plantation of Ponmudi are situated at a high altitude where organic matter decomposition is likely to be less due to the prevalence of a lower temperature appreciable accumulation of organic matter has not taken place The tea soils generally lack a surface cover of weed plants and the only source of organic matter is the prunings of the tea plant received from time to time This may not be sufficient to build up a formidable levelof organicmatterin these soils

The tea soils of South India are generally considered to be low in organic matter The tea soils of Ceylon which are around 2500 ft elevation are also low in organic matter and suffered more severely than natural forests by a loss of organic matter (Tolhurst 1961)

Similar observations have been reported by (Dey 1971) who found that organic matter content in tea plantations depletes rapidly in the initial years of planting and thereafter reaches a state of equilibrium

Generally a higher content of organic matter is found in the natural forests compared to the plantation soils Thus (Lundgren 1978) has reported a higher organic matter content in the soils under naturalforest than the plantations The eucalyptus plantations at Kadassery also have a relatively lower content of organic carbon compared to natural forests Balagopalan and Alexander (1983) Prema kumari (1987) has observed a higher organic matter in natural forests compared to teak eucalyptus and rubber plantations where there is a greater exposure of the soil organic matterto chemical and biological process

The decreasing trend of organic matter with depth in the soil profile may be attributed to a lesser rate of incorporation of organic matter in these soils The absence of a grass cover which normally adds appreciable amounts of organic matter through the sloughing off of old roots may be one reason for this observation in addition to a greater exposure of the surface soil

The total nitrogen content of the tea soils (Table 12) s at a significantly higher level than the corresponding non-tea soil and in both cases appreciable decrease in nitrogen content with depth is evident A high content of nitrogen and a low status of organic matter has given rise to a very narrow C/N ratio of 14 to 17 in (Table 12) these soils A decrease in C/N ratio with depth has been pointed out earlier in teak plantations by Jose (1968) and in eucalyptus plantations by Balagopal and Jose (1983) fig 2 FACTORS CONTRIBUTING TO ACIDITY

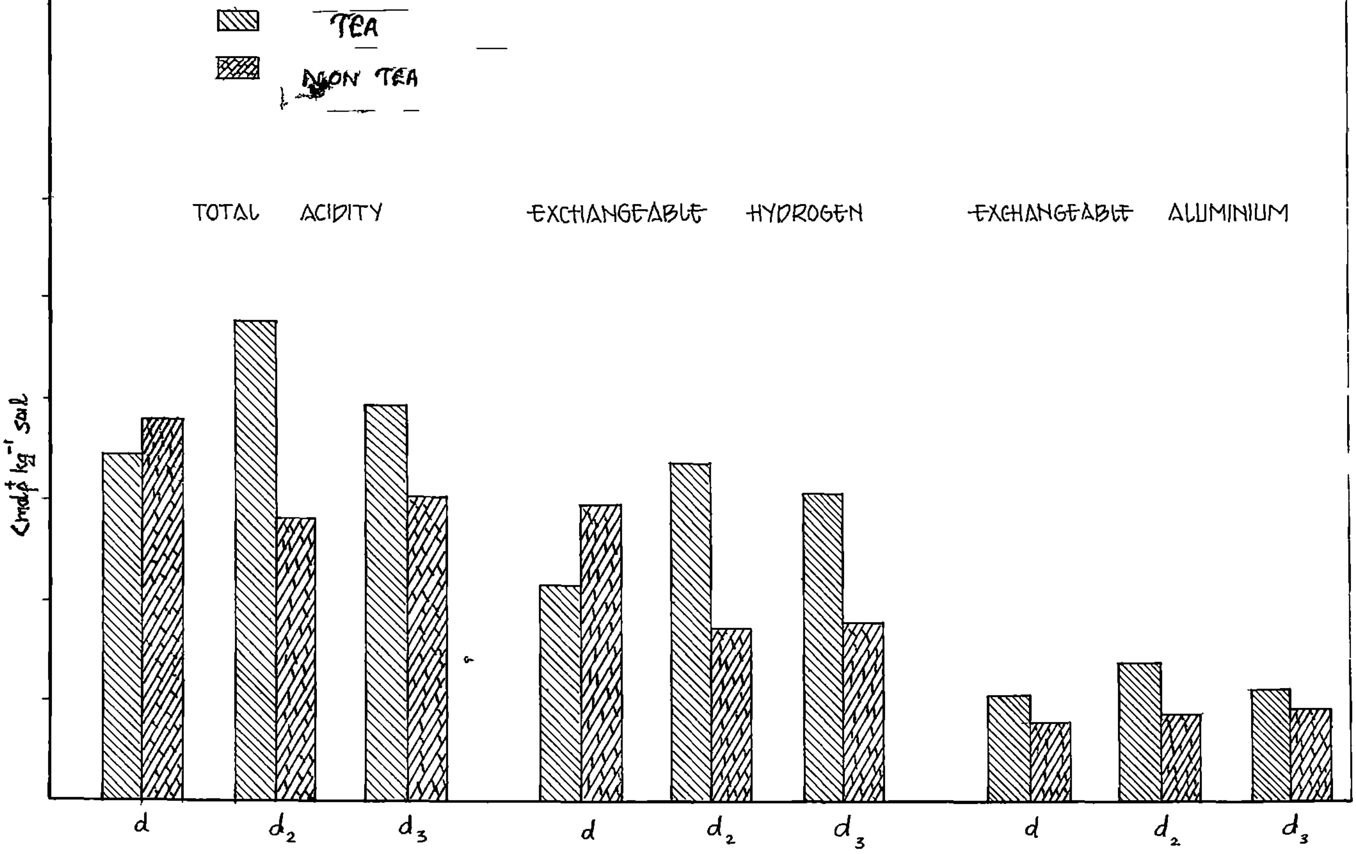


Table. 12 Total nitrogen (per cent)

Soil	d_1	d_2	d_3	Mean S
Tea	0.090	0.078	0.069	0.079
Non-Tea	0.063	0.048	0.047	0.053
Mean d	0.077	0.063	0.058	

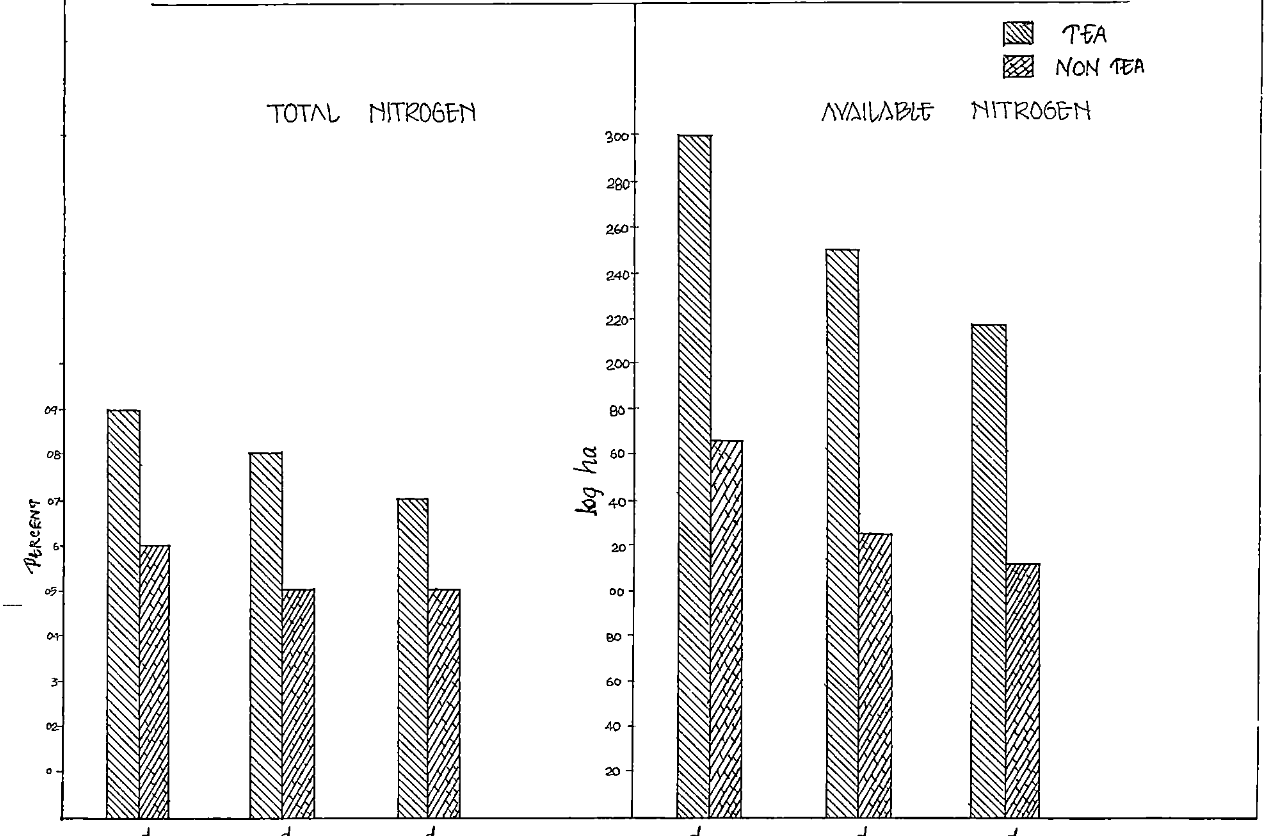
CD (between soils) - 0.0066
CD (between depths) - 0.0081

A very narrow C/N ratio of 1.5 to 25.4 has been reported for the forest soils of the Chakrata division where the total nitrogen varied from 0.013 to 0.427 and organic carbon from 0.172 to 8.130 (Yadav, 1963).

Table. 13 C/N Ratio

Soil	d_1	d_2	d_3	Mean S
Tea	17	16	15	16
Non-Tea	14	16	15	15
Mean d	16	16	15	

Fig 3 DISTRIBUTION OF TOTAL NITROGEN AND AVAILABLE NITROGEN



Similarly a very narrow C/N ratio of 5 to 13 has been obtained (Premakumari 1987) for the teak eucalyptus and rubber plantations in the Kulathupuzha range of forests in Kerala In these plantations the C/N ratio has been a steady downward decrease due to a reduction in the content of both organic carbon and nitrogen

The narrow ratio between carbon and nitrogen suggest a very great scope for mineralisation reactions to proceed at a rapid rate making the status of available nitrogen in the soil very high

Table 14 Available nitrogen (Kg ha)

Soil	d	d	d	Mean S
Tea	296 9	246 2	212 9	251 9
Non Tea	165 8	123 6	111 1	133 5
Mean d	231 4	184 9	162	

CD (between soils) 52 71

The data on available nitrogen presented in table 14 eventhough indicate a significantly higher values (251 9 kgha) for the tea soils compared to only (133 5 kgha) for the non tea soils based on the ratings of the Soil

Testing Laboratories is only medium for tea soils and low for non tea soils Similarly the tendency of available nitrogen to decrease with depth in soil profiles inspite of the constancy in the ratio between carbon and nitrogen is a matter to be discussed This may probably be due to a greater resistance to mineralization of the organic nitrogenous compounds in the lower soil layers

Total and Available Phosphorus

Table 15 Total phosphorus (per cent)

Soil	d	d_2	d_3	Mean S
Tea	0 118	0 090	0 052	0 087
Non Tea	0 050	0 055	0 082	0 062
Mean d	0 084	0 073	0 067	

The mean values of the total phosphorus content in tea plantations and soils not cultivated to tea (Table 15) are 0 087 and 0 062 per cent respectively None of these soil types show marked variation in total phosphorus content between the three horizons

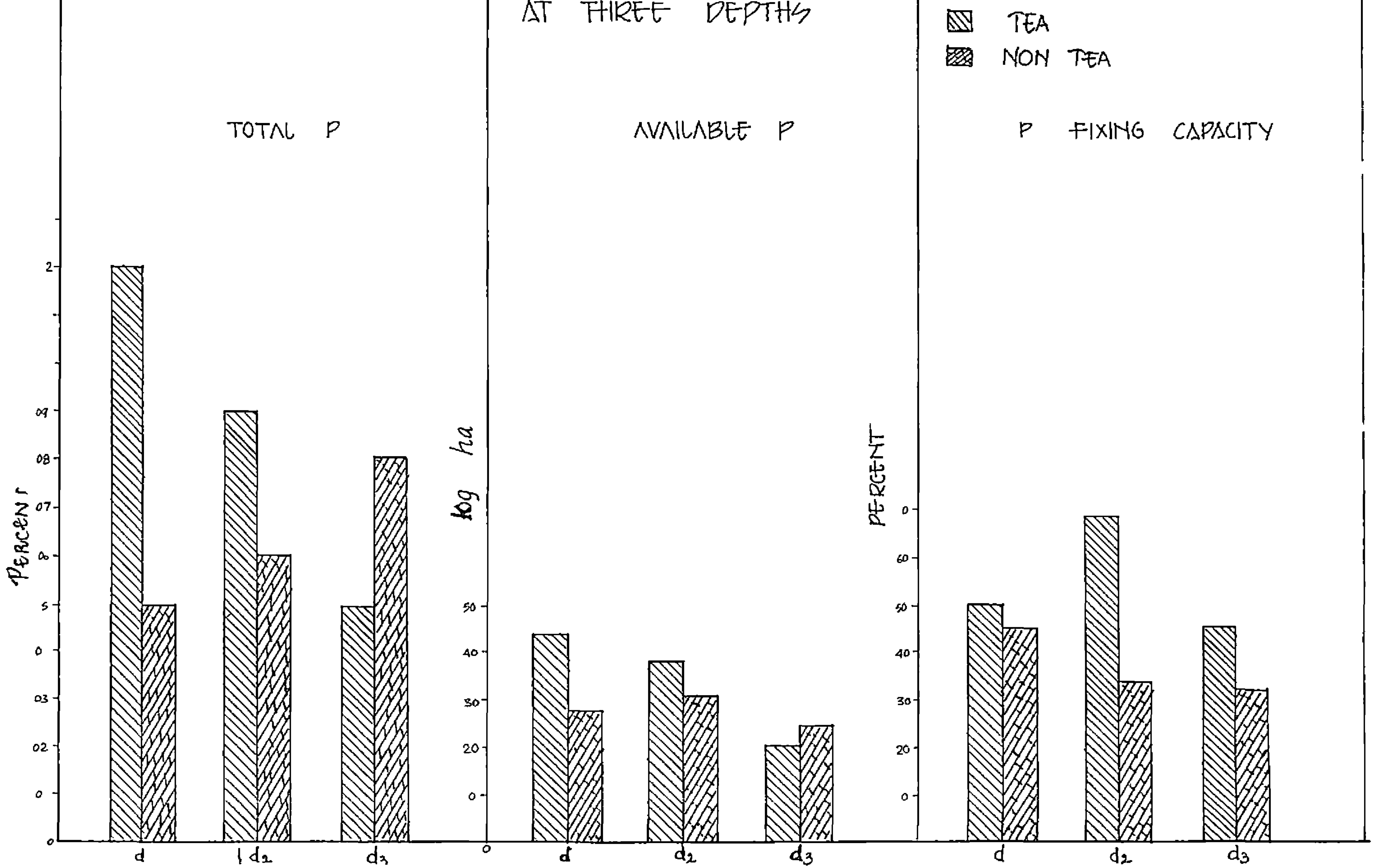
Table 16 Available phosphorus (Kgha)

Soil	d	d	d	Mean S
Tea	43 5	37	21 4	33 9
Non Tea	18 0	30 1	24 5	24 2
Mean d	30 7	33 6	22 9	

The mean values for available phosphorus (table 16) show that both soil types have only a low status Eventhough the difference in total and available phosphorus between tea and non-tea soils is not significant statistically tea soils appear to be comparatively richer in both these constituents It may apparently be due to a higher content of organic matter in tea soils compared to the non tea soils and the decrease in phosphorus with depth in the profile may similarly be due to a lower content of organic matter in deeper soil layers In addition to this the annual application of phosphatic fertilizers to the tea plantations might have resulted in a build up of this element leading to its higher content in the tea than non tea areas

The correlation between available phosphorus and phosphorus fixing capacity of soils which is found to be

Fig. DISTRIBUTION OF TOTAL AND AVAILABLE PHOSPHORUS P FIXING CAPACITY AT THREE DEPTHS



positive though not significant may indicate phosphorus fixation reactions as being responsible for the low status of available phosphorus in these soils

Bhattacharya and Dey (1984) have reported considerable fixation of phosphorus applied to tea soils Fixation of phosphorus by the kaolinitic clay minerals in the coffee plantations of Karnataka has been observed (Iyengar 1977)

Phosphorus fixing capacity

Table 17 Phosphorus fixing capacity (per cent)

Soil	d	d	d	Mean S
Tea	49 78	67 68	45 33	54 26
Non Tea	44 60	33 10	32 40	36 70
Mean d	47 19	50 39	38 87	

CD (between soils)	7 37
CD (between depths)	9 03
CD (soils x depths)	12 77

The data in table 17 reveal that phosphorus fixing capacity of the soils is rather high and vary significantly between soil types In the tea plantations the second horizon registers maximum phosphorus fixing capacity While that of the top and bottom layers are on par The variation in the phosphorus fixing capacity at three depths between the soil types also shows significant difference Phosphorus fixing capacity is lowest in the bottom layer

The phosphorus fixing capacity of soils bears a positive and significant correlation between total acidity (0 505) and the relationship with sesquioxides and clay content though positive is not significant

Generally the phosphorus fixing capacity of a soil is governed by the content of sesquioxides and nature and amount of clay minerals (Ray Chaudhari and Mukherjee Patel and Viswanath 1946) Both sesquioxides (10 20 to 18 52 per cent) and clay (29 72 to 32 57 percent) are rather high in these soils indicating the probability for a greater influence of these factors in increasing the phosphorus fixing capacity

A greater correlation with total acidity than these factors on the otherhand indicates the direct influence of acidity in releasing iron and aluminium in soluble forms for precipitating the soluble phosphates leading to their consequent fixation

The factors contributing to phosphorus fixation such as total acidity sesquioxides and clay content are higher in tea soils than in the non tea soils justifying the existence of a higher phosphorus fixing capacity for the tea soils

A higher level of free oxides of iron and aluminium leading to a rapid fixation of phosphorus in tea soils has been reported (Jayaraman 1955) The high P fixation rates observed in the tea plantation of Ponmudi may also be explained on the above basis

Table 18 Sesquioxides (per cent)

Soil	d	d	d_3	Mean S
Tea	17 75	17 27	11 38	15 47
Non Tea	18 52	12 58	10 20	13 97
Maen d	18 13	14 93	11 09	

CD (between depths) 3 19

The sesquioxide content presented in table 18 shows a decreasing tendency with increase in depth in the tea cultivated soils as well as in the non tea soils They show marked variation between depths the highest content (18 52 per cent) being observed in the surface layer soils of non tea areas and lowest (12 58 per cent) in the middle layer of the soils of the same area

Total and Exchangeable Potassium

The status of total potassium (table 19) in tea plantations is considerably higher (0 059 per cent) However no significant difference is observed between the content of total potassium among the soil horizons

Table 19 Total potassium (per cent)

Soil	d	d	d	Mean S
Tea	0 082	0 053	0 043	0 059
Non Tea	0 013	0 012	0 038	0 021
Maen d	0 048	0 033	0 041	

CD (between soils) 0 034

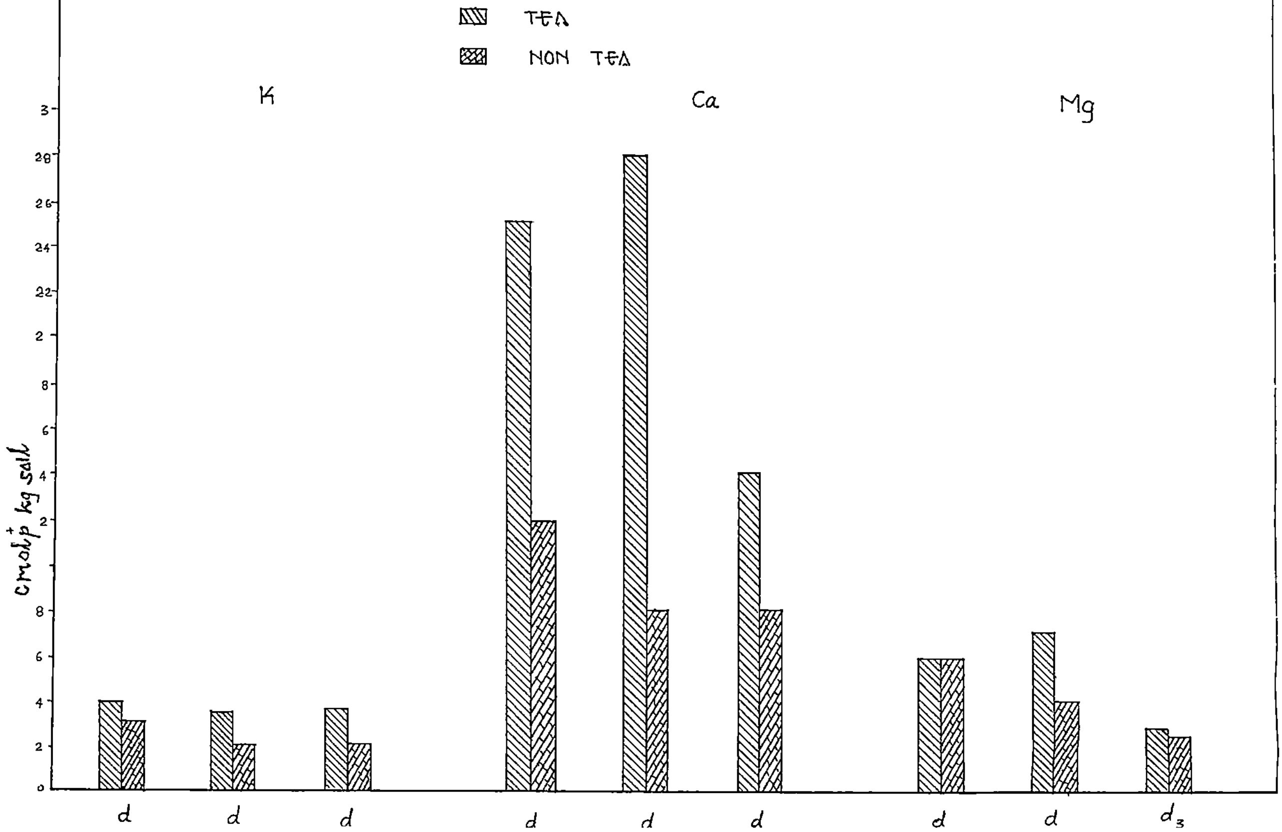
Similarly the exchangeable potassium content of the soils (table 20) is low though the tea soils record a higher value compared to the non-tea soils With regard to the distribution of exchangeable potassium in the different horizons of the soil profile a steady decrease with depth is observed

It may be noted that the soil of the tea plantations have a comparatively higher amount of total potassium than the eucalyptus (0 143 per cent) teak (0 109 per cent) and rubber (0 119 per cent) plantations as reported by Premakumari (1987) The exchangeable potassium status is also similarly higher for tea plantation than the other forest vegetation Lack of fixation sites for potassium in tea soils of S India as reported earlier by Ranganathan (1977) and Ram (1980) as well as the annual application of large amount of potassic fertilizers might probably account for a low rate of potassium fixation resulting in a higher status of exchangeable potassium in these soils

Table 20 Exchangeable potassium (C mol P^+ kg^{-1} of soil)

Soil	d_1	d_2	d_3	Mean S
Tea	0 40	0 34	0 34	0 36
Non Tea	0 29	0 23	0 23	0 24
Mean 1	0 34	0 29	0 28	
CD (between soils)				0 046

Fig v DISTRIBUTION OF EXCHANGEABLE BASES AT THREE DEPTHS



A higher content of nitrogen phosphorus and potassium in the soils of tea plantation compared to the eucalyptus teak and rubber plantations may be the consequence of a build up these elements through annual application of fertilizers The tea plantations receive an annual application of 90 120 kg N 50 60 kg P O and 45 50 kg K_2O Unlike the other plantations and natural forests which sustain by nutrient recycling the tea plantations are fully dependent an added fertilizers since the two leaves and a bud are nipped off and a considerable part of the soil nutrients are removed through them

Exchangeable Calcium, Magnesium and Base saturation

Table 21 presents the values for exchangeable calcium in the soils cultivated to tea and not cultivated to tea A significantly higher content of exchangeable calcium is present in the tea plantations compared to the non tea soils The middle layer of the tea soil (15 30 cm) has the highest calcium content of 2 78 cmol p kg soil which is significantly higher than the calcium content at the other depths The lowest layer of non tea soils register the lowest amount (1 03 cmol p+kg 1) soil of exchangeable calcium

Table 21 Exchangeable calcium (Cmol$_{p}$Kg of soil)

Soil	d	d_2	d	Mean S
Tea	2 53	2 78	1 42	2 24
Non Tea	1 24	1 03	0 88	1 05
Maen d	1 88	1 90	1 15	

CD (between soils) 0 538
CD (between depths) 0 659

The results in table 22 reveal that there is no significant variation in the exchangeable magnesium content of the tea plantations and areas not cultivated to tea The middle layer of tea soils record the highest content (0 71 cmol$_{p}^{+}$kg) and the contents of magnesium in the other two layers are on par

Premakumari (1987) has reported values for exchangeable calcium and magnesium as ranging between 0 202 to 1 055 and 0 148 to 0 478 cmol$_{p}$kg respectively with a base saturation from 14 4 to 32 9 in the eucalyptus rubber and teak plantations

Table 22 Exchangeable magnesium (cmol$_p$ kg)

Soil	d	d	d_3	Mean S
Tea	0 60	0 71	0 28	0 513
Non Tea	0 60	0 40	0 27	0 423
Maen d	0 577	0 552	0 277	

CD (between depth) 0 223

The presence of appreciable amounts of exchangeable calcium and magnesium in the tea soils which are highly acidic and register high values of total and exchangeable acidity is rather surprising

The build up of bases like calcium and magnesium in a highly acidic soil which has become so more by the leaching action of water during heavy rainfall is also not common in soils occurring in similar situations

Eventhough tea is long regarded as a calciphobic or calcium hating plant and thriving well in acid soils compared to neutral soils definite response in terms of yield to calcium application in acid soils of pH below 4 8 and low in calcium status has been reported (Ranganathan 1978)

The highly acidic tea soils annually receive heavy application of rockphosphate which contain 18 to 24 per cent of calcium as tricalcium phosphate The rock phosphate gradually becomes soluble under the influence of soil acidity and releases calcium and phosphorus which are taken up by the tea plant and the remainder is accumulated in the soil The regular use of rockphosphate thus leads to a build up of total and exchangeable calcium which is more than compensated by the leaching and runoff losses

Table 23 Base Saturation (per cent)

Soil	d	d	d	Mean S
Tea	40 93	46 87	35 88	41 22
Non Tea	25 13	21 72	17 45	21 43
Maen d	35 03	34 29	26 67	

CD (between soils) 9 207

The per centage base saturation is found to be higher in the tea soils where it ranges from 35 86 to 46 87 per cent and only 17 45 to 25 13 per cent in the non tea soils Variation in base saturation between depths is not significant A greater base saturation in the tea soil is associated with their higher content of exchangeable calcium and magnesium compared to the non tea soils

Biological properties

The bioligical properties of the soils of tea plantations such as total microbial count including thatof bacteria fungi and actinomycetes as well as biochemical activities such as phosphate solubilisation urease activity and nitrogen fixing capacity have been studied The results thereof are presented and discussed here

Total microbial count

The total number of microorganisms obtained by the dilution plate method are presented in tables 24 to 26

It may be noted from the tables that the bacterial count is higher and there is a general decrease in their number with increase in depth of the soil profile eventhough the differences are not statistically significant

Table 24 No of bacteria x 10 g soil

Soil	d	d	d_3	Mean S
Tea	8 8 (2 7)	6 0 (2 6)	3 3 (2 5)	6 06(2 66)
Non Tea	7 5 (2 4)	8 8 (2 5)	4 8 (3 0)	7 06(2 66)
Maen d	8 17(2 6)	7 41(2 6)	4 08(2 7)	

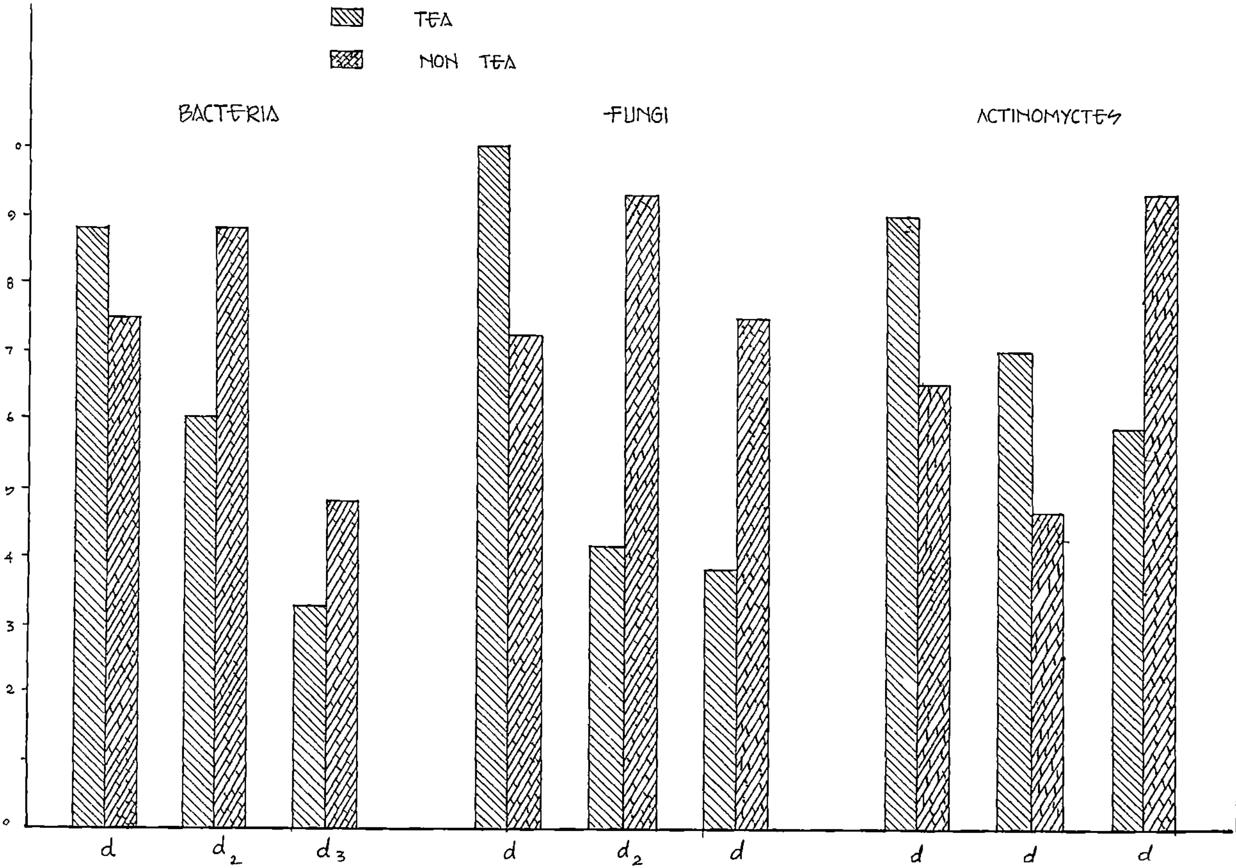
(Values in parenthesis are transformed values by square root transformation)

The total microbial count in soils is generally influenced by the environmental factors especially the soil reaction availability of organic matter and other plant nutrients as well as the physical properties which decide the availability and movement of air and water

Table 25 No of fungi x 10 g of soil

Soil	d	d	d	Mean S
Tea	11 (3 2)	4 1 (2 8)	3 7 (2 1)	6 26(2 69)
Non Tea	7 3 (2 6)	9 3 (2 9)	7 5 (2 7)	8 03(2 75)
Maen d	9 15(2 9)	6 7 (2 81)	5 6 (2 4)	

Fig vi TOTAL NUMBER OF MICRO ORGANISMS $\times 10^6$ g soil



A perusal of the physico-chemical properties of these soils reveal that they are well supplied with the plant nutrients organic matter and maintain a satisfactory physical condition for sustaining a high microbial activity However the soil reaction as indicated by the pH values is highly acidic and not conducive for the general growth of bacteria and actinomycetes which are sensitive to acidic conditions and are in equilibrium with the environment The actinomyctel population however is least and is similar to that of fungi As one may expect a comparatively higher population of fungi is not observed in these soils inspite of the highly acidic situation where they can be good competitors with bacteria and actinomyctes The fungi characteristically inhabit the organic layers of woodlands and forest soil where they are better adapted to more resistant carbonaceous compounds

Table 26 No of actinomyctes x 10 g soil

Soil	d	d	d	Mean S
Tea	9 (3 3)	7 0 (2 69)	5 8 (2 52)	7 2 (2 85)
Non Tea	6 5 (2 4)	4 66(2 2)	9 5 (2 77)	6 89(2 47)
Maen d	7 7 (2 87)	5 83(2 46)	7 65(2 65)	

The tea plantations are not characterised by a surface layer of organic matter as in the natural forests and other plantation crop soils and this may account for the absence of a very high population of fungi in these soils

Locations in the plantation which are not planted to tea also exhibit a similar population of microorganisms as these soils do not appreciably differ in many respects with the soils planted to tea

Phosphate solubilisation

The results presented in tab e 27 reveal that phosphate solubilisation greatly differs between tea and non tea soils It is significantly higher in tea soils (62 00 mg g) and comparatively much lower (35 42 mg g) in the non tea soils

Table 26 Phosphate solubilisation (mg g

Soil	d	d_2	d_3	Mean S
Tea	77 36	54 46	54 44	62 00
Non Tea	46 88	34 5	24 89	35 42
Maen d	61 99	44 48	39 67	

CD (between soils) 10 17

Cd (betweeen depths) 12 14

In both soils the phosphorus solubilisation decreased significantly with depth indicating only lesser phosphorus solubilisation in the subsoils The observation is in agreement with the findings of Gupta anf Tripathi (1986) who have noticed a higher phosphorus solubilisation capacity in the A horizon compared to B horizon in the soils of North West Himalayas under varying biosequence and climosequence

The soil microorganisms are known to bring about a number of transformations of soil phosphorus Chief among them is their ability to alter the solubility of insoluble inorganic phosphates leading to their greater availability in soil Phosphorus solubilisation may be achieved through the direct action of phosphate dissolving microorganisms especially in the vicinity of plant roots or through the indirect action of several autotropic and heterotropic microorganisms in the soil (Alexander 1978)

Phosphate solubilising organisms such as *Pseudomonas Sps* and *Aspergillus niger* have been isolated from the rhizosphere of coconut and cocoa which were capable of dissolving nearly 49 50 per cent of the inorganic phosphates (Nair and Subba Rao 1977)

In the present study no specific effort has been made to isolate the phosphate solubilising bacteris from the soil and only the indirect effect of soil microorganisms on this property was studied The presence of a very large number of bacteria actinomyctes and fungi inspite of the highly acidic nature of the soil maintains a high biochemical activity by which solubilisation of inorganic phosphates is also possible The relationship between phosphorus solubilisation and the total number of bacteria and fungi is found to be positive though not significant At the same time a greater correlation between total acidity of soil and phosphorus solubilisation has been obtained which points to a greater impact of soil acidity on phosphorus solubilisation The presence of species of *Pseudomonas* and *Aspergillus* in the tea plantations of Ponmudi has been reported earlier (Susamma Philip 1971) These species of fungi predominating in the acidic tea soils might have been responsible to a great extent in directly solubilising the inorganic phosphates along with a microflora which do so by indirect action

Urease Activity

Table 28 Urease Activity Mg of NH_4 g urea

Soil	d	d_2	Mean S
Tea	0 30	0 15	0 23
Non Tea	0 13	0 13	0 13
Maen d	0 22	0 14	

CD (between soils)	0 065
CD (between depths)	0 065
CD (soil x depths)	- 0 092

Urease activity is significantly higher in the tea plantations (0 23 mg of NH_4 g soil) than in the adjacent non tea areas The top soil register a higher value and towards the lower layers the activity decreases and it ranges from 0 13 to 0 30 mg of ammoniacal nitrogen per gram of urea only

Urease activity in soils is known to vary with location depth season and forms of nitrogenous fertilisers used (Bhavanandan and Fernado 1970) Soils rich in organic matter are generally considered to possess a high urease activity (Seetharaman 1968 Margaret and Mcgarity 1968) and

Bhavanandan and Fernado (1970) have observed sufficient urease activity in soils to hydrolyse the usual units of added urea

It is believed that soil constituents protect urease against microbial degradation and other processes leading to the inactivation of enzymes and every soil has a stable level of urease activity determined by the ability of its constituents to provide the protection (Zaintua and Bremner 1976)

Like the capacity for phosphate solubilisation urease activity is also restricted to a small group of urease bacteria (Alexander 1978) eventhough many non specific microorganisms are active in producing the enzyme urease

The tea soils of Ponmudi have sufficient urease activity This may be attributed to the population of bacteria fungi and actinomyctes active in the soil and the higher content of clay (30 32 per cent) in soil which may provide protection to the urease enzyme

Nitrogen fixing capacity

The results of the incubation studies to estimate nitrogen fixing capacity of the tea soils have revealed that there soils do not possess to any appreciable extent the capacity for nitrogen fixation The results are not surprising in view of the high soil acidity which completely eliminates the population of common nitrogenfixing species of Azotobacter (Tripathi et al 1982) Soil acidity is recognised as a primary factor restricting the growth and activity of nitrogen fixing organisms (Venkataraman 1982) and it is only natural that the highly acidic soils of the tea plantations do not support their growth and functions

Nutrient composition of tea leaves and nutrient removal

The composition of tea leaves and the approximate annual removal of nutrients from a hectare of the plantation based on an annual production of 2000 kgha of commercial tea is presented in table 29 It may be noted that the tea leaves contain a high content of nitrogen and phosphorus compared to that of eucalyptus teak and rubber plantations although the contents of potassium calcium and magnesium are comparable (Premakumari 1987) The aluminium content of tea leaves is comparatively much higher than that of iron The nutrient composition of the plant is found to be positively correlated to the status of these nutrient elements in the soil

Table 29 Nutrient composition of tea leaves and nutrient removal

	N	P	K	Ca	Mg	Al	Fe
Nutrient composition (per cent)	2 48	0 24	0 18	0 13	0 25	0 71	0 03
Nutrient removal Kg ha a	49 6	4 8	3 5	2 6	5 0	14 2	0 6

Memon et al (1981) have reported a high content of aluminium (4457 ppm) in tea leaves The level of aluminium obtained in the present study is however much higher than this reported figure Considerable amount of aluminium is known to be accumulated in the roots and transported to the top (Matsuda et al 1979) A much higher content of aluminium than the other mineral nutrients might be due to their deposition in the cell walls of the adaxial tissues as evidenced from the X ray micrograph studies of tea leaves (Memon et al 1981)

Based on the nutrient composition of tea leaves nutrient removal through processed tea appears to be much less than the quantity of nutrients annually received through fertilizers The tea plantations at Ponmudi receive an annual application of 90 120 kg N 50 60 kg P_2O_5 and 45 50 kg K O

The higher nutrient status of the tea soils as against the natural forests and other plantations is justified by a constant and high input of nutrient elements than that is actually removed

* personal communication from M/s Jayasree Estate Ponmudi

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Studies have been made on the soils of tea plantations in Ponmudi Kerala State to depict their specific physico chemical and biological properties in comparison with adjacent soils not cultivated to tea

Samples for the study were collected from the different horizons of profiles exposed at different locations in the tea and adjacent non tea areas Plant samples were also collected from these locations and subjected to detailed chemical analysis

The important conclusions drawn on the basis of the above studies are summarised below

1 The texture of the soil is of a uniform clay loam type indicating the dominance of clay compared to silt and sand Soils of tea and non tea areas show a similarity in texture with a higher content of clay ranging from 30 32 per cent in the deeper layers A higher clay content in the soils indicate a high rate of weathering and clay formation and its greater accumulation in the lower horizons its downward migration The values for sand and silt content show a decreasing trend in the deeper layers

2 Higher values for bulk density and particle density (1 22 and 2 14 gcm) noticed in the soils of tea plantations compared to non tea areas The values show a tendency to increase with depth in the soils cultivated to tea than in the non tea soils

3 The top soil of the profiles where there is a greater amount of organic matter record a higher water holding capacity (36 77 per cent) Both the tea and non tea soils registered a decrease in their property towards lower layers

4 The soils of the tea plantation tend to be highly acidic and register a pH value ranging from 4 1 to 4 3 compared to non tea areas in tea plantations The total acidity in both soils is found to be higher Exchangeable aluminium and hydrogen which are the factors contributing to soil acidity were more or less similar in the two soils The highest value of exchangeable aluminium (1 37 c+mol p kg) is noticed in the soils of the tea plantations The exchangeable hydrogen (2 81 c mol p kg) of soils cultivated to tea is also very high The high acidity of these soils may be due to the intense weathering and leaching of bases characteristic of the humid tropical conditions

5 The cation exchange capacity of the soils cultivated to tea and non tea areas is found to be low (8 07 $c(p^{+})$ mol kg^{-1} of soil) Correlation studies have shown that the contribution of organic matter towards CEC is negligible and is more influenced by the presence of kaolinitic clay minerals which themselves possesses only a low CEC

6 Even though the organic matter and total nitrogen is found to be higher in tea plantations than in the nearby non tea soil their content is ~~not~~ appreciable as in the case of natural and planted forests This is obviously due to a lack of build up of organic matter consequent to the greatest exposure of the soil to the tropical climate

7 The comparatively higher content of nitrogen and lower content of carbon has resulted in a narrow C/N ratio in these soils This narrowing of C/N ratio is found to be more prominent in the deeper layers

8 The available nitrogen content of tea soils is high (251 9 kg ha^{-1}) compared to non tea areas (133 5 kg ha^{-1}) The narrow ratio between carbon and nitrogen generally permits a rapid rate of mineralisation making the status of available nitrogen in the soil rather high

9 There is no marked variation in the content of total phosphorus in both soils Maximum amount of available phosphorus is noticed in the surface layer of tea plantation The high content of P is apparently due to the annual application of heavy dose of phosphatic fertilizers

10 The phosphorus fixing capacity of the soils is found to be high and ranges from 36 7 to 54 26 per cent The factors contributing to phosphorus fixation such as total acidity sesquioxides and clay content are higher in tea soils than in the non tea soils

11 The content of total and exchangeable potassium in soil is cultivated to tea is higher than the adjacent non tea soils Lack of fixation sites for potassium in tea soils as well as the annual application of potassic fertilizers might probably lead to a higher status of exchangeable potassium The bottom layers of both soils record the lowest amount of exchangeable potassium

12 The soils of tea plantations show a higher content of calcium and magnesium The build up of these elements in such amount in the highly acidic tea soils is rather surprising The regular use of rockphosphate might have lead to the build up of these basic elements in the soil compensating for the losses sustained through leaching and nutrient removal

13 The soils of the tea plantations have a higher base saturation of 35 46 per cent soils compared to only 17 25 per cent in the non tea soils

14 The total microbial count including that of bacteria fungi and actinomycetes in the tea and non-tea areas is appreciable Inspite of the highly acidic condition the bacterial count is rather high and it ranges from 6 26x10^{6} g of soil It is possible that the bacteria have adapted themselves to the prevailing acidic conditions The actinomycete population is found to be the least

15 The tea soils possess a significantly higher capacity for solubilization of insoluble inorganic phosphates (62 mg g 1) compared to the non-tea soil where it is only 35 mg g 1 In both these soils this property decreased with depth in the soil profile and is related to the total number of bacteria and fungi as well as soil acidity

16 The urease activity is also found to be appreciable in the tea soils and it shows a significant decrease with depth

17 The soils of the tea plantations did not show any capacity for nitrogen fixation The high acidity of the soils might be critical to the acid sensitive nitrogen fixers

18 An analysis of the tea leaves indicate a comparatively higher content of nitrogen and phosphorus than the other nutrient elements Nutrient removal is maximum for nitrogen and not appreciable in the case of others

The annual application of large amounts of NPK fertilizers and the comparatively lesser removal of nutrients through processed tea has resulted in a rather high fertility status of the tea soils Thus the tea soils differ from natural forests and planted forests in high altitude areas which maintain a rather low nutrient status by biological and geological recycling processes alone

Table 30

Correlation between plant nutrient

and soil nutrient status

Nutrients in plant	Nitrogen	Phosphorus	Potassim	Calcium	Magnesium	Alumini
Nutrients in soil						
Total Nitrogen	0 313					
Available Nitrogen	0 314					
Total Phosphorus		0 575				
Available Phosphorus		0 136				
Tital Potassium			0 105			
Exchangable Potassium			0 0018			
Exchangable Calcium				0 373		
Exchangable Magnesium					0 599	
Exchangable Aluminium						0 253

CORRELATION TABLE

* 5% ** 1 5%	Total Acidity	Sesquioxides %	Org carbon %	Total N_2 %	Av N_2	Av P	P fixing capacty	Bulk density	Particle density	Water Holding	Bacteria	Fungi	P solubilisation	Clay content
Total Acidity							* 505						?406	
Sesquioxides %							309							
Org carbon %				**7387	**6025		**492	3339	0524	1946	0661	0442	**6788	
Total Nitrogen %			**7387											
Av Nitrogen				**7129										
Av Phosphorus							1084							
P fixing capacity	**505	309	**492			1084								022
Bulk density			33?9											
Particle density			0524											
Water holding capacity			1946											
Bacteria	0808		0661										0409	
Fungi	0 0122		0442										0802	
P Solubilisation	2406										0409	0802		
Clay constant							022							

Exchangeable K in C mol Kg of soil
Locations

		1		2		3		4		5		6	
		S	SS	S	SS	S	SS	S	SS	S	SS	S	SS
	1	47	19	317	410	27	501	374	202	297	167	61	20
T	2	44	27	291	374	35	27	25	23	276	19	435	27
	3	410	18	350	39	41	31	28	20	374	22	401	25
	1	16	23	31	174	25	33	27	13	19	14	210	18
NT	2	23	19	37	18	36	21	31	17	183	15	19	14
	3	19	25	23	173	21	19	25	15	180	14	183	12
Exchangeable Ca in C mol Kg of soil													
	1	2 10	31	2 01	47	1 13	97	2 13	79	1 4	68	98	53
T	2	2 13	21	1 62	25	2 01	75	1 75	65	87	45	53	35
	3	1 7	40	1 15	21	83	53	1 03	43	1 01	31	87	21
	1	1 01	43	1 04	52	33	21	53	21	50	30	97	25
NT	2	97	37	98	47	53	25	31	19	19	15	53	35
	3	1 2	25	40	40	31	19	33	20	25	17	37	19

Exchangeable Mg in C mol Kg of soil

Locations

	1		2		3		4		5		6	
	S	SS	S	SS	S	SS	S	SS	S	SS	S	SS
1	43	27	73	50	31	19	39	27	38	25	65	29
T 2	51	40	81	73	87	22	25	19	41	30	37	20
3	30	21	73	48	53	18	18	15	33	21	53	19
1	38	19	51	45	23	17	21	20	50	38	31	18
NT 2	21	16	63	39	54	20	24	35	32	27	27	21
3	26	21	42	25	48	19	18	21	25	19	25	23

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* Originals not seen

APPENDICES

APPEDIX I

Composition of media for isolating microorganisms
Media for isolation of bacteria
Soil extract agar (Taylor and Lochead,1938)

Soil Extract (Stock)	1000 ml
Tap Water	900 ml
Glucose	1 g
K_2HPO_4 –	0 5

1000 g of sieved garden soil is mixed with 1000ml of top water and steamed in the autoclave for 30 minutes A small amount of calcium carbonate is added and the whole is filtered through a double filter paper Dissolve the agar in 900 ml of water by steaming it for an hour or more add 100 ml of the stock soil extract solution Add glucose and pH adjusted to 6 8 using IN Na OH

2 Media for isolation of fungi

Peptone dextrose agar with Rose Bengal and Streptomycin (Martin 1950)

Dextrose	10 g
Peptone	5 0
K_2HPO_4	1 0
$MgSO_4$	0 5
Agar	15 0
Rose Bengal	to give colour
Streptomycin	30mg
Distilled water	1000 ml

3. Media for isolating actinomyctes

Kenknights medium (Anonymous 1957)

Glucose	1 0 g
K H PO_4	0 1
MgSO	0 1
KCI	0 5
FeSO 2H O	0 01

Distilled water 1000ml

pH adjusted to 6 8 7 00 by using IN NaOH

APPENDIX II

Media for studying phosphate solubilisation

Pikovskya s Medium (Modified by Sundara Rao and Sinha 1963)

Glucose	10 g
Tricalcium phosphate	5 g
$(NH\ )\ SO_4$	0 5 g
KCl	0 2 g
$MgSO_4$ 7H O	0 1 g
Mn SO_4	trace
FeSO	trace
Yeast Extract	0 5 g
Distlled water	1000 ml

APPENDIX III

Media for studying Nitrogen fixing capacity

Jensen s Medium (1952)

Sucrose	20 g
K HPO	1 g
$MgSO_4$ 7H O	0 5 g
NaCl	0 50 g
FeSO	0 10g
Na MnO_4	0 005g
$CaCO_3$	2g
Agar	15g
Distilled water	1000ml

ANALYSIS OF VARIANCE

APPENDIX IV

PHYSICAL PROPERTIES OF SOIL

SOURCE	df	MEAN SQUARE							
						SINGLE VALUE CONSTANTS			
		Course Sand	Fine Sand	Silt	Clay	Bulk Density	particle Density	Water Holding Capacity	Pore Space
TREATMENTS	5	13 46	34 77	10 55	7 53	*0 033	151	90 76	31 64
BETWEEN SOILS (T)	1	5 41	5 76	2 89	2 05	0 0979	0 0324	81 42	87 44
BETWEEN DEPTH (d)	2	12 57	76 51	22 77	16 66	0 016	0 145	*180 11	17 09
SOILS x DEPTH	2	18 37	7 54	2 16	1 15	0 020	0 214	6 068	18 29
ERROR	30	62 10	23 35	14 01	47 86	0 0124	0 101	37 65	54 26

* SIGNIFICANT AT 5/ LEVEL

** SIGNIFICANT AT 1/ LEVEL

ANALYSIS OF VARIANCE

APPENDIX - V

CHEMICAL PROPERTIES OF SOIL

MEAN SQUARE

SOURCE	df	pH	Total acidity	Exchangeable aluminium	Exchangeable acidity	Cation exchange capacity	Sesquioxide	Organic carbon	Total nitrogen	C/N Ratio	Available nitrogen	Total phosphorus	Available phosphorus	Phosphorus fixing capacity	Total potassium	Ex. potassium	Exchangeable calcium	Exchangeable magnesium
NUTRIENTS	5	045	*2 60	**184	2 96	754	*73 37	*04	**0017	0 77	**31534 5	00044	509 51	**100 81	0041	027	3 87	*92
SOILS (T)	1	*0023	5 57	*514	4 52	000	*20 25	2 35	*0062	13 02	**20333	0053	85 48	**2776 24	*013	**1	*2 7	072
DEPTH (d)	2	073	07	03	020	3	**149 4	**337	**00	3	49 7 75	00095	364 88	*424 53	0006	0 3	*2	*33
S L x D	2	033	3 45	101	**5 13	37	24 16	088	00006	8 9	682	0075	033 14	**096 87	003	0000002	10	1
ERROR	30	50	806	597	76	915	14 73	035	00009	1 8	5997 38	0032	447 16	7 31	0025	004	624	071

* - SIGNIFICANT AT 5% LEVEL

** - SIGNIFICANT AT 1% LEVEL

Base Saturation

**

** 813 5

3525 39

200 46

69 73

162 99

APPENDIX VII

Nutrient content of surface and subsurface soil samples

A Total nitrogen (per cent)

S Suface soil
SS Subsurface soil

Locations

		1		2		3		4		5		6	
		S	SS	S	SS	S	SS	S	SS	S	SS	S	SS
	1	09	07	1	07	09	09	03	05	13	10	05	05
T	2	12	04	16	05	04	02	05	02	07	04	062	03
	3	12	05	09	06	06	04	1	01	12	05	11	08
	1	06	04	09	06	07	04	06	07	08	05	07	06
NT	2	08	03	07	04	03	02	02	03	03	04	02	02
	3	05	031	09	05	05	03	04	01	04	02	03	02
B Avilable Phosphorus (kg ha)													
	1	84	14	22 4	5 6	24 6	8 4	11 2	11 2	10 6	42 6	72 8	42 6
T	2	56	27 44	40 3	22 4	39 2	16 8	42	31 4	33 6	56	38 1	56
	3	50 4	24 6	67 2	156 8	89 6	78 4	56	24 6	22 4	33 6	62 7	23 4
	1	95 2	62 7	43	32 7	42 8	32 3	40 8	36 9	27 8	36 9	43 4	48 8
NT	2	28	142	20 3	26 3	31 7	24 8	33 8	26 1	19 3	21 4	20 8	33 4
	3	50 4	22 4	18 3	43 8	52 3	21 3	18 9	15 4	14 7	24 8	28 7	30 2

PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF HIGH ELEVATION SOILS WITH REFERENCE TO TEA *(Camellia sinensis)*

BY

ELIZABETH CHACKO

ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS

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ABSTRACT

A study has been made on the Tea plantations in Ponmudi in Kerala State with a view to determine the extent to which the physical chemical and biological characters of these soils are affected by the plantation

Samples for the study were collected from soil profiles exposed at different locations in the tea and adjacent non tea areas Plant samples were also collected from these locations and subjected to detail chemical analysis

The mechanical composition of the soil of tea plantations did not depict any [illegible] differen[illegible] h[illegible] compared to non tea soil [illegible] th these soil the sand and silt content d[illegible] rea[illegible] [illegible] n increased with depth [illegible] ofile H[illegible] w[illegible] r a higher content of clay observed in the [illegible] ea oi[illegible] rdi ates a greater degree of weathering and clay formation

The bulk density and particle density of the tea and non tea soils increased with depth The surface soil of the profiles which contained a greater amount of organic matter recorded a higher water holding capacity The CEC of soils

was found to be low and is likely to be influenced by the predominance of kaolinitic clay minerals

The soils of the tea plantations were highly acidic Exchangeable aluminium and hydrogen which are the factors contributing to soil acidity were more or less similar in the tea and non tea soils

The tea plantation recorded a highercontent of total and available nitrogen compared to non tea areas

The soils cultivated to tea though contained only a lower amount of total phosphorus registered a higher content of available phosphorous The high content of phosphorus is apparently due to the annual application of heavy doses of phosphetic fertilizers Total acidity sesquioxides and clay content were higher in the tea soils and contributed to a greater P fixing capac ty

The contents of total and exchangeable potassiumm as well as exchangeable calcium and magnesium in soils cultivated to tea were higher than the adjacent non tea soils Lack of fixation sites for potassium in the tea soils might have probably lead to a higher status of exchangeable potassium

The total microbial count including that of bacteria fungi and actinomyctes in the tea and non tea areas was appreciable The tea soils possesed a higher capacity for solubilisation of insoulble inorgnic phosphates which was related to the total acidity

These soils did not show any capacity for nitrogen fixation and urease activity was comparatively low

Chemical analysis of the tea leaves showed a higher content of nitrogen and phosphorus than other nutrient elements The annual application of fertilizers and a lesser removal of nutrients through processed tea has resulted in a rather high fertlity status of the tea soils