

**STUDIES ON SOIL ACIDITY IN COFFEE
GROWING SOILS OF KARNATAKA**

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BANGALORE**

1996

**STUDIES ON SOIL ACIDITY IN COFFEE
GROWING SOILS OF KARNATAKA**

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Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
for the award of the Degree of
Master of Science (AGRICULTURE)
in
SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

BANGALORE

JANUARY 1996

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*Affectionately Dedicated to
My Beloved Parents*

DEPARTMENT OF SOIL SCIENCE & AGRICULTURAL CHEMISTRY
University of Agricultural Sciences
Bangalore

CERTIFICATE

This is to certify that the thesis entitled “ STUDIES ON SOIL ACIDITY IN COFFEE GROWING SOILS OF KARNATAKA” Submitted in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (AGRICULTURE) IN SOIL SCIENCE AND AGRICULTURAL CHEMISTRY of the University of Agricultural Sciences, Bangalore, is a bona-fide record of research work done by MR. M.V. RAVI during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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ACKNOWLEDGEMENT

I am greatly indebted to the Chairman of my Advisory Committee, Dr. R. Ananathanarayana, Associate Professor, Department of Soil Science and Agricultural Chemistry, University of Agricultural Science, Bangalore, for suggesting the problem, valuable guidance and constant inspiring encouragement during the course of investigations, preparation and compilation of the thesis.

I am grateful to Dr. R. Siddaramappa, Professor and Head, Department of Soil Science and Agricultural Chemistry and a member of my advisory committee for his sustained interest in my research work and for providing all facilities in the department.

I am grateful to other members of my advisory committee, Dr. Ramesh Melantha, Professor and Head, Division of Horticulture and Mr. G.N. Gajanan, Soil Physicist, Dryland Research project, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Bangalore for their valuable suggestions and critical evaluation of the manuscript.

I am thankful to Mr. R. Ramamurthy, Soil Chemist and C. Chandrappa, Research Assistant, CRS, Chettalli, for their help in soil sample collection from Kodagu district.

I thank Dr. Jayaram, Head, Department of Soil Science and J.S. Nagaraj, Research Assistant of the CCRI, Balehonur for their help in soil collection from Chikmagalur district.

I take this opportunity to thank the Department of Horticulture, University of Agricultural Sciences, GKVK for providing green house facilities for conducting the Pot Culture experiment.

I express my gratitude to Mr. B.K. Shivanna, Assistant Professor, Department of Entomology, Agriculture College Shimoga, for his constant encouragement during the course of the study.

My Sincere thanks are due to S.J. Jindal Trust, Bangalore for providing financial assistance for my Post Graduate Programme.

I am grateful to University of Agricultural Sciences, Bangalore for permitting me to assist in the project on soil acidity in coffee growing soils.

I express my sincere respect to my beloved parents, G.V. Veeranna and Smt. B.K. Sharadamma for their guidance in my life.

I express my affectionate and heartfelt thanks to my dear brother Suresh and my sisters, Veeramma, Jayamma and Nagarathna, who were an inspiration for me in conducting this research.

I express my sincere thanks to Dr. Sreedara Adiga, Assistant Agriculture Officer, Department of Agriculture, for his help in many ways.

I am thankfull to my Classmates, Senior and Junior friends for their help in conducting the laboratory analysis successfully.

My thanks are also due to all the staff members of the Department of Soil Science and Agricultural Chemistry for their help and co-operation.

Finally I wish to thank Mr. Srinivasa Babu for the neat and speedily execution of typing of the thesis in time.

Bangalore

January, 29, 1996


(RAVI M.V.)

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INTRODUCTION

I. INTRODUCTION

Development of soil acidity has been attributed to climate, parent material and anthropogenic factors. The oxides of aluminium, iron and manganese, particularly the poorly crystallised and micro crystalline forms are the most reactive component of acidic soils. Hydrogen and aluminium are the dominant cations responsible for soil acidity. The elements are initially liberated into solution by acidic weathering of soil minerals and then reprecipitated either locally or after translocation as hydrous oxide species of high specific area and reactivity.

Since aluminium occurs exclusively in trivalent form, only pH and complex formation affect the solubility of its oxides, but with iron and manganese more than one valency state may be involved. Hence redox potential must also be considered in the process of soil acidification. Iron as a contributing factor towards soil acidity has not been studied, extensively in the acid soils of India. This is probably due to the fact that the clay mineral associated with soil acidity contains much larger amount of aluminium than iron. Iron precipitates at a much lower pH than aluminium (Takkar *et. al.*, 1976).

Soils coming under humid and heavy rainfall region become acidic due to the leaching of bases from soil exchange complex. Soil developed from base poor parent material are acidic. Addition of acid forming fertilizers, intensive cultivation and heavy irrigation result in the development of soil acidity.

In Karnataka, coffee is grown in an area of 1,26,363 ha, (Krishnamurthy Rao and Ramaiah, 1993) and of this 63 percent is contributed by Arabica coffee. In Karnataka, coffee is grown mostly in heavy rainfall tracts under tropical humid conditions. Coffee cultivation is primarily confined to three important districts in Karnataka Viz., Kodagu, Chikmagalur and Hassan. Coffee growing soils are generally fine textured, 0.7 to 4 meter deep and well drained. Kaolinite is the dominant clay mineral with intercepts of Smectite and Illite. Coffee growing soils are generally acidic (4 to 6 pH). The reaction of soils in the coffee growing region is extremely important in evaluating its production potentials. pH is a major factor that governs the nutrient availability for optimum growth. The growth and yield of coffee is not normal in coffee growing acid soil due to toxicity of manganese, deficiency of calcium and phosphorus.

Violet D'Souza *et. al.* (1994), opines that soil acidity in coffee growing areas may pose :-

- 1) A decrease in nitrification rate
- 2) Increased phosphorus fixation
- 3) Reduced potassium activity
- 4) Low availability of magnesium
- 5) Release of elements like aluminium and manganese in toxic levels.

Practices such as application of 2 kg lime per bed (1 x 6 m) and use of liming material in the preparation of soil mixture for basket nursery indicates the awareness of coffee growers to the application of lime. Although the researcher at the Central Coffee Research Station, Balehonur is trying to work out the lime need of soil, the approach is based on lime requirement methods only.

It is a fact that potential acidity is contributed by exchangeable hydrogen and aluminium of the soil exchange complex and its dynamics hold key for the nature of soil acidity in soil. Hence unless the nature of soil acidity in the coffee growing soils is well understood, lime recommendations would not be meaningful. Hence this study.

The objectives of the study are

- 1) To characterise the nature of soil acidity in coffee growing soils.
- 2) To study the efficiency of lime requirement methods with respect to soil characterisation.
- 3) To study the inter relationship between lime potential, lime requirement and physico chemical properties of soil.
- 4) To correlate the effect of lime levels on the growth of coffee seedlings.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Soil acidity is an important agricultural problem while evaluating the production potential of most of the crops. The poor growth of crops in acid soils is due to the presence of toxic elements like aluminium, iron and manganese. Lime is applied to the soil for neutralisation of soil acidity and reduce the toxicity of above elements. Liming increases the availability of nitrogen, phosphorus, calcium, magnesium and sulfur in acid soils.

Publications regarding nature of acidity in coffee growing soils is scanty. However characterisation of soil acidity has been done by Ananthanarayana and co-workers from 1970 to 1995 for acid soils in all the districts of Karnataka which supports cereal and oil seed crops. Review of literature relevant to the present investigation has been considered under following heads.

- 2.1 Chemical nature of coffee soils.
- 2.2 Chemical constituents of coffee soils and nutrient uptake.
- 2.3 Nature of soil acidity.
- 2.4 Factors influencing the nature of soil acidity.
- 2.5 Causes for poor plant growth in acid soils.
- 2.6 Measurement of soil acidity.
- 2.7 Amelioration of soil acidity.
- 2.8 Liming.
- 2.9 Influence of lime on soil acidity.
- 2.10 Evaluation of different lime requirement methods.
- 2.11 Effect of lime on the nutrient status of soil.
- 2.1 Chemical nature of coffee soils.

Mathew (1972) reported that coffee soils vary in geological origin, include deeply weathered laterites, as in Brazil, volcanic ash soils as in Columbia, Java and Central America. Lateritic weathered loamy soils derived from lova rocks as in Hawaii and soils

from granite, gneiss and occasionally from basalt and schists as in part of Africa and India.

Mathew (1972) reported that coffee loves a deep, friable, humus rich soils. In India coffee soils vary from sandy loam, rich in organic matter, fairly well supplied with available potassium. Coffee soils are generally low in phosphorus, calcium, magnesium and acidic in reaction, except in parts of Andhra Pradesh. The total soluble salts are below the toxic limit.

Biddappa (1973) and Venkatarao (1973) reported that under South Indian conditions silt increased up to 900 meters while nitrogen content and cation exchange capacity increased with elevation and rainfall. Soluble silica and pH showed a decreasing trend with rainfall.

Gopalakrishna Hebbar (1977) reported that Coffee soils in South Indian conditions are deep, friable, well drained rich soils. When such land is not available, coffee cultivation is often extended to marginal and sub-marginal land called as 'bane' cultivation.

Krishnappa Naik *et. al.* (1988) reported that red loam (Ultisols) and laterite (Oxisols) soils are found in Chikmagalur District. These soils are normally deep and clay content increase down the profile. They are heavily leached, contain large amount of organic matter, gravelly in texture and susceptible for erosion due to high slope.

Raju (1988) indicated the critical levels of soil pH, available phosphorus and available potassium for coffee. Critical soil pH for coffee under south Indian condition is 5.8-5.9. For available phosphorus and potassium the critical value were found to be 7 and 60-80 ppm respectively. No appreciable difference were noticed in the critical test values between Arabica and Robusta plantations.

Krishnamurthy Rao and Ramaiah (1993) observed that soil collected from specific estates of coffee in Karnataka contain 72-75 percent Kaolinite with 12 percent vermiculite and 12 percent mica in a few cases. Soil with low amounts of mica will be extremely poor with respect of exchangeable potassium.

2.2 Chemical constituents of coffee soil and nutrient up take.

Soil in which coffee is grown is derived from granite, gneiss, schist and dibase rocks. In Karnataka coffee is grown in red and non gravelly red loam soils (Krishnamurthy Rao and Ramaiah, 1993). Non gravelly red loams are derived from weathering of sedimentary and metamorphic rocks of schist and shale.

Coffee soils generally contain low acid insolubles ranging from 50 to 70 percent silica, sesquioxide ratio is lower than two (Krishnappa Naik *et. al.*, 1988).

Computation of nutrient required for coffee crop cannot be as precise in the case of perennials as in annuals. This is because of total volume of soil explored by the plant root varies with environmental conditions apart from plant type and density. In coffee the nutrient uptake is also influenced by shade. Shade in coffee is generally considered as an interfering factor between responses and applied nutrients (Krishnamurthy Rao and Ramaiah, 1985, Iyengar and Aswathamani, 1975, Mathew and Krishnamurthy Rao, 1980). Responses under mixed ^{canopy} copy of shade comprising leguminous/non-leguminous trees have been generally non-linear, non-significant and non-consistent (Rao and Ramaiah, 1985). Removal of nutrient in coffee follow the order of $K > N > P > Ca > Mg > S$ (Alwar and Rao, 1991, Krishnamurthy Rao 1988).

2.3 Nature of Soil acidity.

Maurice (1972) reported that pH is an indicator of the degree of acidity in soil. pH is a measure of only a very small part of total soil acidity. Soil acidity has two components (1) Active and (2) Potential acidity (Brady, 1990).

2.3.1 Active acidity.

Active acidity is a measure of H^+ ion activity in the total solution at any given time. Yuan (1963) with reference to pH and its relation with hydrogen and aluminium stated that pH expressed that part of acidity which is present in the equilibrium system with the H^+ ions that have dissociated from soil complex at various degree and hydrolysis of some acid produce in ions such as iron and manganese.

Hydrogen ions produced by hydrolysis react and dissolve soil minerals. This results in an increase in H^+ ion concentration of the soil solution and lower pH (Coleman and Thomas, 1967). Sharma *et. al.* (1990) reported that low base saturation was mostly associated with the soils having low pH (5.3 to 5.8), besides exchangeable H^+ and Al^{3+} , Fe^{3+} and Mn^{2+} and some other hydrolysable ions on the soil exchange complex also contribute to soil acidity upon hydrolysis.

2.3.2 Potential acidity.

It is due to adsorbed H^+ and Al^{3+} ions. Potential acidity is divided into exchangeable and residual acidity.

2.3.2.1 Exchangeable acidity.

It is that portion of soil acidity that can be replaced with neutral buffer salt solutions like KCl, CaCl₂ or NaCl. The exchange acidity is almost entirely due to monomeric Al³⁺ ions. Vietch (1902) showed the presence of the exchangeable aluminium, by extracting the soil with sodium chloride and titrated with a base to phenaphthelein end point. On checking the components, Al³⁺ ions was found to be the dominant component, followed by very small quantities of iron, manganese and zinc.

Schofield (1949) and Chernov (1959) showed that exchange acidity extracted from clay by salt solution contained almost entirely aluminium.

Coleman and Thomas (1967) reported that aluminium is adsorbed both by exchangeable trivalent ions and has hydroxy-aluminium-o-polymer of indefinite size and degree of hydroxilation.

Satyanarayana *et. al.* (1976) used one normal solutions of KCl, NH₄Cl, CaCl₂ and NaCl on acid soil depending on soil pH. They found that one normal potassium chloride to be effective for soils having pH less than 4.5 and the rest for soil having pH greater than 4.5.

Sharma *et. al.* (1990) found that electrostatically bonded hydrogen and electrostatically bonded aluminium comprises 21 and 79 percent of exchangeable acidity.

Das *et. al.* (1991) reported that contribution of exchange acidity to total acidity varies from 2.9 to 7.9 and from 12.7 to 20.9 percent in the lateritic zone of tarai soils.

Kailash Kumar *et. al.* (1995) reported that electrostatically bonded hydrogen and electrostatically bonded aluminium comprises 93.3 and 63.3 percent of exchangeable acidity.

2.3.2.2 Residual acidity.

Residual acidity refers to that portion of soil acidity after active and exchange acidity has been neutralised. Trivalent Al, Al-hydroxy polymers and aluminium bound in organic matter and silicate clays contribute to residual acidity.

Kamprath (1970) reported that BaCl₂. 2H₂O-TEA at pH 8.2 was a measure of total acidity and non-exchangeable acidity and asserted that non-exchangeable acidity can be obtained by subtracting exchangeable from total acidity. He observed that very little exchangeable hydrogen as such exists in mineral soils.

2.3.2.3 pH dependent acidity.

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It is the difference between total potential acidity and exchange acidity. pH dependent acidity increased with increasing iron and aluminium oxides and organic matter in the soil (Misra *et. al.*, 1987).

Coleman *et. al.* (1959) reported that a cecil subsoil which had 5.5 milli equivalents per hundred grams of acidity responsible with BaCl₂-TEA at pH 8.1 had only 0.5 milli equivalent of exchangeable acidity responsible with potassium chloride.

Sharma *et. al.* (1990) reported that the total acidity in Indian soils comprised of pH dependent and exchange acidity which contributes 71 percent of total acidity. This was attributed to the high contents of aluminium on exchange complex and organic matter content of soils.

Das *et. al.* (1991) concluded that tarai acid soils of West Bengal manifested comparatively high total acidity. This is probably due to high percent of organic matter in the soils contributed to the total acidity through their functional groups like Carboxylic - COOH and Phenolic - OH.

2.4 Factors influencing nature of acidity.

Seatz and Peterson (1964) reported that soil acidity is a complex process. The important factors affecting acidity are (1) humus (2) aluminosilicate clay minerals and hydroxides of iron and aluminium. (3) Management practices. (4) Soluble acids.

2.4.1 Humus

Microbial decomposition of organic matter results in the formation of humus. The process may lead to the formation of number of organic acids. Acid humus, like the clay show colloidal behavior which can be characterized by means of potentiometric and conductometric titration.

Mukherjee (1972) and Panda (1987) reported that humus makes the soils acidic is capable of attracting and dissociating the hydrogen ions. The strength of the acid produced depends on the nature of predominant groups. Humus also reacts with iron and manganese to form complexes which may under go hydrolysis to yield hydrogen ions.

Mishra. *et. al.* (1989) opined that exchangeable aluminium is positively correlated with organic matter, which plays an important role in the formation of soil acidity.

Pal *et. al.* (1991) working on the Sundarban areas (Typic Haplaquepts) reported that the humus is one of the possible factors for both exchange and hydrolytic activity.

2.4.2 Aluminium silicates, hydrous oxides of iron and aluminium.

Aluminosilicate clay minerals contain alumina (Al_2O_3) and silica (SiO_2) components. They exhibit charges which may be separated into permanent and pH dependent charges.

Goates and Adherson (1956) reported that permanent charges resulted from the isomorphous substitution within the lattice frame work and pH dependent charge might be due to several sources like the ionisation of H^+ from Si-OH groups.

Thomas (1988) reported that, among the clay minerals the ratio of exchange acidity to total acidity is highest for montmorillonite, intermediate for dioctohedral vermiculite and lowest for kaolinite.

Misra *et. al.*, (1989) and Ananthanaraya and Veerabhadra Rao (1994) reported that the exposed octahedral Al/Fe and /or X Al-O-SIX groups of the oxides of iron and aluminium may be responsible for pH dependent acidity.

Adhikari and Si (1991) found that pH dependent acidity of the soil was positively correlated with organic matter, clay contents and free oxides in the soil ($r= 0.416, 0.026$ and 0.213 respectively). With decrease in soil pH, the release of iron and aluminium increases the overall soil acidity. This is due to hydrolytic products of iron and aluminium.

2.4.3 Management Practices.

Ganeshmurthy and Mongia (1989) have observed an increase in soil acidity when the lands were brought under cultivation, there was an increase in exchangeable, extractable and water soluble aluminium on bringing virgin lands under cultivation. This is due to the non recycling of basic cations like calcium and magnesium.

Deepak Kher and Minhas (1991) revealed that nitrification process is essentially a proton donating activity. Hence, mineralization of organic matter, transformation of nitrogenous fertilizers, produce protons leading to acidity in injurious proportions for plant growth.

2.4.4 Soluble acids.

Due to intense biological activity in soil there will be significant fluctuation in pH. In long term biological activity leads to leaching of calcium, magnesium and development of soil acidity.

Moorman (1963) reported that production of high concentration of sulfuric acid and very low pH when soils containing ferrous sulfide are drained and exposed to oxidising conditions.

Mortenson (1963) reported in case of podzols organic acids dissolved from litter give rise to acid soils.

2.4.5 Other factors contributing for soil acidity.

Acid soils are formed from acid parent material like granite. Soils formed from basic parent material can become acidic under very high rainfall and vegetation.

Acid soils will also be formed if soils are rich in sulfur. The sulfur in soils might originate from organic matter. Soils containing sulfide on air drying after water logging will lead to oxidation of sulfide. This will lead to the formation of sulfate and sulfuric acid (Subramoney, 1971) and also there will be depletion of lime leading to extremely acidic conditions of soil.

Westerman(1981) studied the effect of ammonical nitrogen and monoammonium phosphate on soil acidity under winter Wheat cultivation. Upon addition, monoammonium phosphate hydrolysed to di-calcium phosphate and phosphoric acid.

2.5 Causes for poor plant growth in acid soils.

The chemical environment of acid soils is not conducive for optimum plant growth. This is due to the toxic concentrations of hydrogen, aluminium, manganese and deficiency of calcium, magnesium, phosphorus, sulfur, molybdenum and retarded microbial activity.

2.5.1 Hydrogen and aluminium toxicity.

Jackson(1967) reported that variation in H^+ ion concentration have a significant influence on the adsorption of many inorganic ions provided the soil reaction does not fall below pH 4.0. Exchangeable aluminium is a major cation in many of the acid soils particularly at pH 4.5 or less. This occupies a large proportion of the effective cation exchange capacity in other acid soils. Aluminium toxicity is a problem in many soils in the tropics.

Kamprath (1970) opines that the interacting factors of aluminium, calcium and hydrogen concentration in a complex manner affects plant growth, principal effect of aluminium toxicity is the effect on root growth.

Pierie (1974) reported that at 20 percent aluminium saturation of the exchange complex, nodulation in groundnut was reduced and there by the groundnut yields also decreased.

Addition of fertilizers to highly leached acid soils rises the soil solution ionic strength with a reduction in pH and enhancement of aluminium solubility (Ananthanarayana and Veerabhadra Rao, 1994). Their work proved, that if ratio law is simply a consideration of solubility, equilibria of sparingly soluble solids can result in increased ionic strength which will give rise to increased levels of soluble aluminium even without the necessity of a concomitant decrease in pH.

2.5.2 Manganese toxicity

Manganese toxicity is one of the major constraints in crop production in acid soils. Terley *et. al.* (1975) investigated the toxicity of manganese on leaf cell multiplication, expansion and dry matter yield of Sugar beet. When the manganese content in the culture solution was 30 to 40 mg. per litre the dry matter yield was reduced to 50 percent.

Tveitnes and Svads(1989) concluded that the toxicity of manganese reduced by the application of lime and increased soil exchangeable calcium and magnesium.

2.5.3 Calcium deficiency

In acid soil calcium is deficient. This deficiency due to dominance of hydroxides of aluminium, manganese, iron and leaching of calcium in soils.

Kamprath (1967) stated that calcium as much as not a growth limiting factor but it is the toxic levels of aluminium, iron and manganese that has to be considered. Application of fertilizers rich in potassium and manganese aggravate calcium deficiency.

Imbalance of calcium solution concentration with magnesium, ammonium and potassium ions can create calcium availability. Problem under certain circumstances and calcium availability is than a function of the ratio of calcium to other cation in soil solution (Panda, 1987).

2.5.4 Phosphorus deficiency

Acid soils are known to contain greater proportion of hydrous oxides of iron and aluminium which react with phosphorus and form hydroxy phosphates which have low solubility. Thus, phosphorus is rendered unavailable for plants in acid soils.

Bouma (1975) reported on the effect of some metabolic phosphorus compounds was lower in leaves from phosphorus deficient plants. Photosynthesis was increased when deficient leaves were placed in solution containing 0.7 to 6.00 millimolar phosphorus solution.

Memory *et. al.* (1976) observed that ten days of phosphorus deficiency resulted in a decrease in number of flowers. In Inceptisols and Alfisols there was dominance of aluminium phosphorus where as in Entisols there was dominance of iron phosphorus on submergence but submergence decrease, calcium and reductant soluble phosphorus (Pattanayak and Misra, 1989).

Das *et. al.* (1991) observed negative significant correlation between available phosphorus and pH of soil. As the total potential acidity increases the available phosphorus, iron and aluminium.

2.5.5 Molybdenum deficiency

The presence of aluminium, iron and manganese in acid soils will suppress the activity of aluminium. Pal and Mandal (1975) reported that an increase in molybdenum content in acid soil on liming might be attributed to the release of MoO_4^{2-} from complex due to liming. The increased molybdenum content in soil on liming may also be due to probable decomposition of $\text{Fe}_2(\text{MoO}_4)_3$ and $\text{Al}_2(\text{MoO}_4)_3$ compounds present in acid soils, leading to formation of $\text{Fe}(\text{OH})_3$ and $\text{Al}(\text{OH})_3$ with the dissolution of molybdenum in soil. Addition of lime also favour the formation of $\text{Fe}(\text{OH})_3$ and $\text{Al}_2(\text{OH})_3$ with the dissolution of molybdenum in soil. Addition of lime also favour the formation of CaMoO_4 , a compound of higher solubility causing an increase in the content of available molybdenum in the soils.

2.5.6 Retarded microbial activity

Most of the microbes thrive well around neutral pH. In acidic soils, due to low pH the microbial activity is retarded. The processes of nitrogen fixation and organic matter mineralization principally occur due to microbes which are very active only under neutral pH range. When such soils are limed, favourable pH conditions helped the microbes to hasten the processes of nitrification, organic matter mineralization and nitrogen fixation (Rangaswami, 1967; Sha and Mandal, 1980; Weier and Gillam, 1986).

2.6 Measurement of soil acidity.

The three most common ways of measuring this parameter is by, (1) Titration

with base or equilibration with lime. (2) Leaching with a buffered solution followed by the analysis of the leachate for the amount of base consumed by reaction with the soil. (3) Subtracting the sum of exchangeable bases from the effective cation exchange capacity.

Titration with base or equilibration with lime.

The best known titration procedure is the one explained by Seatz and Peterson (1964) where increments of calcium hydroxide are added to the soil suspension which are then aerated to precipitate excess of $\text{Ca}(\text{OH})_2$ added to reach that condition being equivalent to soil acidity.

Extracting the soil with strong electrolyte like potassium chloride and then titrating it by versene method gives a reliable estimate of the lime needs of acid soils. Puri, (1964) termed it, exchangeable calcium or titrimetric method and it was statistically proved to be the best under Indian acid soil conditions (Patil and Ananthanarayana, 1989).

Leaching with buffered solution followed by analysis of the lechate.

Liming methods commonly employ buffer solution and they extract many components of soil acidity. This is the principle behind $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ -TEA (Peech, 1965) method, which has been used to separate soil acidity into exchangeable and weak acid components.

According to Peech (1965) $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ -TEA extraction is a measure of pH-dependent acidity. In this, extractable acidity results from the replacement of hydrogen and aluminium and from the dissociation of acidic groups neutralized by free triethanolamine buffered to pH 8.2. The barium ion in addition to replacing the hydrogen ion also increases the extent of hydrolysis of adsorbed aluminium ions and degree of dissociation of hydrogen on clay surfaces.

Adams and Evan (1962) method was considered to be a rapid procedure with relatively high degree of accuracy for determining lime requirement of soils with low cation-exchange capacity and having smaller amounts of 2:1 type of clay minerals.

Subtracting the exchangeable bases from the cation exchange capacity.

Subtracting the exchangeable bases from the cation exchange capacity would give precisely the same values for exchange acidity as do the corresponding leaching methods (Pratt and Bair, 1961).

2.7 Amelioration of soil acidity

Soil acidity hinders plant growth and has got influence on plant nutrient availability. So it is necessary to ameliorate soil acidity by using different amendments. The amelioration of soil acidity would be done by using different liming materials, organic matter addition and by using other amendments.

2.8 liming

Soil acidity is considered to be one of the important limiting factor of low productivity in acid soils. In order to provide an optimum condition for plant growth, liming is an important aspect of soil management practices in an acid soils. Addition of appropriate quantities of lime ensures not only neutralize soil acidity but also supply of calcium to plant growth. Lime in agriculture, essentially means calcium oxide, although other material, like ground limestone, dolomite, calcium hydroxide, several byproducts of steel industries and chalk have neutralizing effect on soil acidity.

2.8.1 Liming materials

Liming materials such as calcium oxide ground limestone, dolomite, calcium hydroxide and several byproducts of steel industry are being used as liming materials.

Figuera and Torres (1978) reported that dolomite as a source of calcium and magnesium for coffee. Dolomite (21% MgO) applied each year to two year to arabica coffee, cv. caturra Amarilla, at 500 g/plant correlated mg. deficiency and raised the leaf Mg level from 0.17 to 0.32 percent. Leaf calcium level was also raised from 0.71 to 0.92 to 1.21 to 1.29 percent.

The efficiency of liming materials is determined by the neutralizing value of the liming material concerned (Ananthanarayana and Hanumantha Raju, 1994).

2.9 Influence of lime on soil acidity

Ratan Singh and Singh (1985) indicated that liming increased soil pH, calcium saturation, base saturation percentage and availability of nutrients like nitrogen and phosphorus. They also found reduction in soil acidity. Among the various sources of lime calcite limestone was found to be superior in reducing soil pH, calcium saturation and percent base saturation with increment upto 100 percent, lime requirement decreased exchange acidity from 17 percent to 3.8 me. per 100 grammes of soil raised soil pH from its initial value of 5.3 to 7.51 and base saturation from 34.5 to 82.0 percent.

Halder and Mandal (1987) studied the effect of calcium carbonate on extractable Al^{3+} content and they applied ten mg. of CaCO_3 to ten grammes of soil corresponding to one fifth of actual lime requirement value of soil. It brought about the marked increase in pH value and decrease in aluminium content of soil.

Jarvis (1987) reported when acid soil having pH 4.2 treated with CaCO_3 resulted in the leaching of aluminium and reduction in soil aluminium content by fifty two percent.

Sahu and Pal (1987) reported that application of lime at 0.25 lime requirement (LR) (1500 kg/ha) proved to be optimum dose for an acid clay loam soil. They found increase in pH, exchangeable calcium, and magnesium and reduction of exchangeable H^+ and Al^{3+} of soils.

Bishnoi *et. al.* (1988) reported that the application of lime increased the effective CEC base saturation percentage and lime potential and decreased exchangeable acidity and toxic elements Al^{3+} , Mn^{2+} and Fe^{3+} in soils.

Gupta *et. al.* (1989) studied the effect of lime application on soil characterization. Liming increased the pH, effective CEC and lime potential and decreased the iron and aluminium, aluminium saturation and free acidity.

As the neutralization reaction proceeds the first ion to move out of the soil are hydrogen ions followed by monomeric aluminium. In general few monomeric aluminium ion exists in soils having pH 5.5 or more. The product of a complete liming reaction are exchangeable calcium, magnesium, aluminium hydroxide and iron hydroxide. The soil pH under such condition is 8.3 and the soil is said to be completely base saturated. However under field conditions this is not so. Thus soils are not limed beyond pH 6.5 (Mathur *et. al.*, 1991)

Patiram *et. al.* (1989) found that liming the acid soils significantly decreased the available iron and exchangeable manganese and toxic effects of these nutrients were reduced by liming. Application of lime in the dolomitic limestone form at rates twice the exchangeable aluminium almost completely neutralized the exchangeable Al^{3+} by raising the soil pH to more than 5.5 and decreased Al^{3+} saturation of the soils.

Makaya and Bishnoi (1990) observed that addition of lime in an incubation study increased the soil pH significantly from first day of incubation. The concentration of Al^{3+} , Mn^{2+} and Fe^{3+} were markedly and significantly suppressed by lime application. This was due to the precipitation of trivalent aluminum as well as $\text{Al}(\text{OH})_3$ in presence of high concentration of OH^- ions.

When an acid soil has reacted with calcium carbonate to reach pH 6.5 much of the calcium and magnesium from the limestone has become exchangeable and soil acidity has been neutralized (Ananthanarayana and Hanumantha Raju, 1993).

2.9.1 Studies on liming to coffee

Biddappa (1973) investigated the lime requirement of 33 high level laterite soil of west coast where coffee is being grown. The lime requirement of these soils varied from 0.50 to as high as 5.4 tons/acre as CaCO_3 depending upon the soil acidity, exchangeable bases and exchangeable hydrogen and aluminum content. A prediction equation has been established between pH and the lime requirement to calculate the quantity of lime to be applied to similar acid soils.

Raju and Krishnamurthy Rao (1978) reported that soils of pH 4.2 and 5.6 were treated with calcium carbonate ranging from 0.3 to 10 tons/acre to result in varying pH levels and incubated for three months with moisture at field capacity. Analysis of soil sample after incubation period indicated that the varying amounts of calcium carbonate had practically no effect on the organic carbon content, cation exchange capacity and available potassium in the soils studied. Total exchangeable bases and exchangeable Ca^{++} ion was found to increase with increasing amount of added lime.

Krishnamurthy Rao et. al., (1979) reported that the effect of five different liming rates on growth and chemical composition of seedlings of four cultivars of Arabica coffee (*Coffea arabica* L.) grown in polythene bags 6:2:1, under nursery conditions. The pH of the soil increased from 7.0 to 7.2, 7.6, 7.7, 8.0 and 8.3 with increased liming rates at the end of fifteen months. Heavier application of lime adversely affected the height, the number of primaries and leaves. The available phosphorus status of the soil decreased with increasing rates of lime while the available Potassium status remained unaffected. Leaf phosphorus, potassium, magnesium and iron levels were not influenced. Leaf calcium content increased with increase in the level of lime applied while leaf manganese content decreased with increased lime application. This study has shown that lime need not be used with jungle soil of normal reaction for raising seedlings in the nursery.

Violet D'Souza et. al., (1994) reported that liming as a tool for better fertilizer use efficiency in coffee soils.

2.10 Evaluation of different lime requirement methods

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Raju and Krishnamurthy Rao (1977) evaluated six different methods, viz., Shoemakers, Ca(OH)_2 incubation, Wood ruff's, Brown's, Adams and Evans and BaCl_2 -TEA were evaluated in a laboratory incubation study to determine the lime requirement of Oxisol cropped to coffee. The soils were sandy clay loam with organic carbon content of 2.5 percent and cation exchange capacity of 10 me/100 g. It was found that liming the soil to pH 4.2 according to Shoemakers method and liming at the rate of 40 percent of lime requirement value determined by BaCl_2 -TEA method brought the pH to the desired value of around 6.5. For the soil of pH 5.0 liming at the rate of half the lime requirement value of Shoemakers method could shift the pH to the desired level while other methods indicated either too much or too little lime requirement. For the soil of pH 5.6 all the method tried excepting Adams and Evans proved efficient to change the initial soil pH to around 6.5. Liming of only 1/3 and 1/2 lime requirement value was found sufficient to shift the pH of the soil from 5.6 to 6.5, suggesting that only smaller quantities of lime were required if the initial pH of soil is neutral. The study also indicate the reaction between liming material and the soil matrix would be completed in the months time provided the material is or very fine texture and thoroughly mixed with soil and adequate mesh is maintained.

Raju *et. al.*, (1978) studied the efficacy of few liming material and rock phosphate of different particle size at varying soil moisture level to raise the pH of a soil cropped to coffee at pH 6.5. The material tested were burnt lime, limestone, dolomite, basic slag and rock phosphate at soil moisture level of 0, 10, 20, 30, 40 and 60 percent water holding capacity of the soil. Soil moisture played a dominant role in raising the pH and moisture level of 60 percent water holding capacity was necessary for complete reaction. Soil reaction resulting in the pH change occurred in a week's time. The efficacy of the liming material tested was placed in the order burnt lime > lime stone > dolomite > basic slag.

2.10.1 Lime requirement versus calcium saturation.

Liming of acid soil, based on lime requirement would just neutralize soil acidity but may not supplement the calcium needs of the crop. Addition of lime based on calcium saturation of the cation exchange capacity of the soil would take care of calcium nutrition of the crop besides neutralizing soil acidity. Such approaches were successfully tried by Bheemaiah and Ananthanarayana (1984) and Gajanan *et.al.*, (1991) with groundnut as a test crop.

2.11 Effect of lime on nutrient status of soil

2.11.1 Available nitrogen

Pal and Mandal (1985) reported that the application of lime increased the availability of nitrogen in the soil. Increase in nitrogen is due to liming may be attributed to the higher rate of mineralization of soil organic matter as a result of greater microbial activity in the limed soil.

Patil and Ananthanarayana (1989) reported that application of lime at incremental levels increased the available nitrogen upto 1.5 Lime requirement (410.03 kg/ha) over control (332.5 kg/ha). It is attributed to the greater nitrogen fixation, and higher ~~rate~~ mineralization of organic matter as a result of greater microbial activity in the limed soils.

2.11.2 Available phosphorus

Solankay *et. al.*, (1971) reported that available phosphorus increased by 25 percent at pH 6.4 beyond which there was no effect of liming. Pal and Mandal (1985) studied the phosphorus effect of application of lime to the acid soils. An increase in available phosphorus of the soils due to liming may be attributed to the decrease of Al and Fe.

Gupta *et. al.*, (1989) reported that available phosphorus increased from 8.2 to 14.7 ppm due to the inactivation of Fe and Al in the soil, by lime.

Patil and Ananthanarayana (1989) reported that addition of lime increases the availability of Phosphorus to certain extent. The increase in available phosphorus of soils due to liming may be attributed to the release of native phosphorus, solubalization of Fe and Al bound P as a result of increase in OH⁻ ion concentration and precipitation of Fe and Al into their insoluble forms of hydroxides and thereby decreasing their activity in soil solution.

2.11.3 Available potassium

There is difference of opinion about the effect of liming on the availability of Potassium. Type of clay materials, bonding energies of dominant clay associated and antagonistic cations are the principal factors involved in the availability of Potassium. Håbebullah *et. al.*, (1977) reported that exchangeable Potassium decreased in increasing levels of calcium saturation. This was due to higher solution concentration of calcium and displacement of Potassium from the exchange complex.

Bishnoi *et. al.*, (1988) noticed an increase in available Potassium status of acid soils by liming can be explained on the basis that release of Potassium from non exchangeable fraction to available pool, get accelerated when acid soils are limed.

2.11.4 Exchangeable calcium

Bheemaiah and Ananthanarayana (1984) reported that exchangeable calcium content in soil increased with increasing calcium saturation levels. Bishnoi *et. al.*, (1988) revealed that exchangeable calcium increased by 31.1 percent with liming. This increase in calcium may be the direct effect due to increase in base saturation of acid soils on liming and higher amount of calcium moved from lime particle to the exchange sites of the soils.

Patil and Ananthanarayana (1989) reported that increase in exchangeable calcium was in direct proportion with increase in lime level. This is due to increase in charge density and greater affinity for higher valent ions. Thus calcium being divalent cation and its higher solution concentration due to liming increased its concentration exchange complex.

2.11.5 Exchangeable magnesium

Grimme *et. al.*, (1977) reported that higher calcium addition to the soil resulted in higher solution concentration with respect to calcium. This might have adverse effect on Mg in the soils. Bheemaiah and Ananthanarayana (1984) found that high calcium saturation level in field experiment decreased the availability of exchangeable magnesium content in soil. This can be attributed to the sorption of calcium on the exchange complex with concomitant release of magnesium to the solution phase.

Patil and Ananthanarayana (1989) reported that increase in exchangeable magnesium at lower lime level indicates synergistic effect on magnesium and explained that at lower levels of lime addition the increase in charge density on exchange surface might have also preferred the small amounts of magnesium present in lime. The decrease of exchangeable magnesium is due to higher solution concentration with respect to calcium which might compete with magnesium for the exchange sites.

2.11.6 Available sulfur

Venkata Rao *et. al.*, (1976) reported that the influence of pH on sulfate adsorption was seen at pH 5.7. The adsorption of sulphate was maximum at pH 3.7 and subsequently decreased with the increase in soil pH. Korentajer *et. al.*, (1983) revealed that the amount

of SO_4 released increased with increase in liming rate which may be attributed to the increase in the rate of mineralization due to liming and/or to increase solubility of sparingly soluble soil SO_4 compounds which have been postulated to be present in very acid soils. Patil and Ananthanarayana (1989) reported that sequential increase in available sulfur with incremental addition of lime over fertilizer treatment. Availability of sulfur increase due to mineralization of organic matter.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

Coffee cultivation is primarily confined to three important districts viz., Kodagu, Chikmagalur and Hassan. Agroclimatically Kodagu comes under the hilly zone. It is located in South West part of the state. It lies between 12° 00' and 15° 40' North latitude and between 74° at East to 76° East longitude. The annual rainfall varies from 1500 mm to 2000 mm, the major portion of which is received during the South West monsoon month of June, July and August. The North East monsoon rains are received from mid October to December. The blossom shower are received during March-April. The mean annual temperature ranges from 10°C - 36°C.

Chikmagalur stands first in coffee producing districts of the country (60%) of total production. The district comprises of Southern transitional, hilly and central dry zone. It is located in South West part of the state. It lies between 12°55' and 13°54' North latitude and between 75°57' and 76°87' East latitude. It receives high rainfall ranging from 1500 mm to 2500 mm. The mean annual temperature ranges from 12°C during winter and 35°C during summer.

Hassan district of Karnataka state is located in the Southern West part of the state. It lies between 75°6' to 76°18' East longitude and between 12°5' to 14°5' North latitude. The district comprises of Southern transitional and hilly zones. The mean annual temperature ranges from 15°C to 30°C. The district has got a benefit of receiving maximum rainfall during South West monsoon. The district receives rainfall ranging from 900 mm to 1000 mm.

3.1 COLLECTION, PROCESSING AND STORAGE OF SOIL SAMPLES

In order to study the different forms of acidity, lime requirement methods and their relationship between the soil properties, one hundred and seventy representative acid surface soil samples of coffee growing areas were collected at 22.5-45 cm depth. The soil samples were collected from North Kodagu, South Kodagu, Madikeri, Somarpet taluks. The soils of Kodagu district belongs to sandy loam to clay loam texture with colour varying from light gray to deep red texture. These soils belong to Ultisol and Inceptisol.

The taluks of Chikmagalur district from where, soil samples collected are Mudigere, Narasimharajapura, and Chikmagalur taluk. Generally these soils are red loam (Ultisol) and lateritic (Oxisols). The red loam soils are naturally deep and clay content increases with depth.

In Hassan soil samples were collected from Sakalaleshpura (Hilly zone). These soils belong to red sandy loam, red sandy clay and loamy sand. Taxonomically these soils are grouped into Ultisols, Inceptisols, Entisols with suborder Ustalfs, Tropents and Fluvents.



Figure01: Geographical location of Karnataka from where the soil samples were collected.

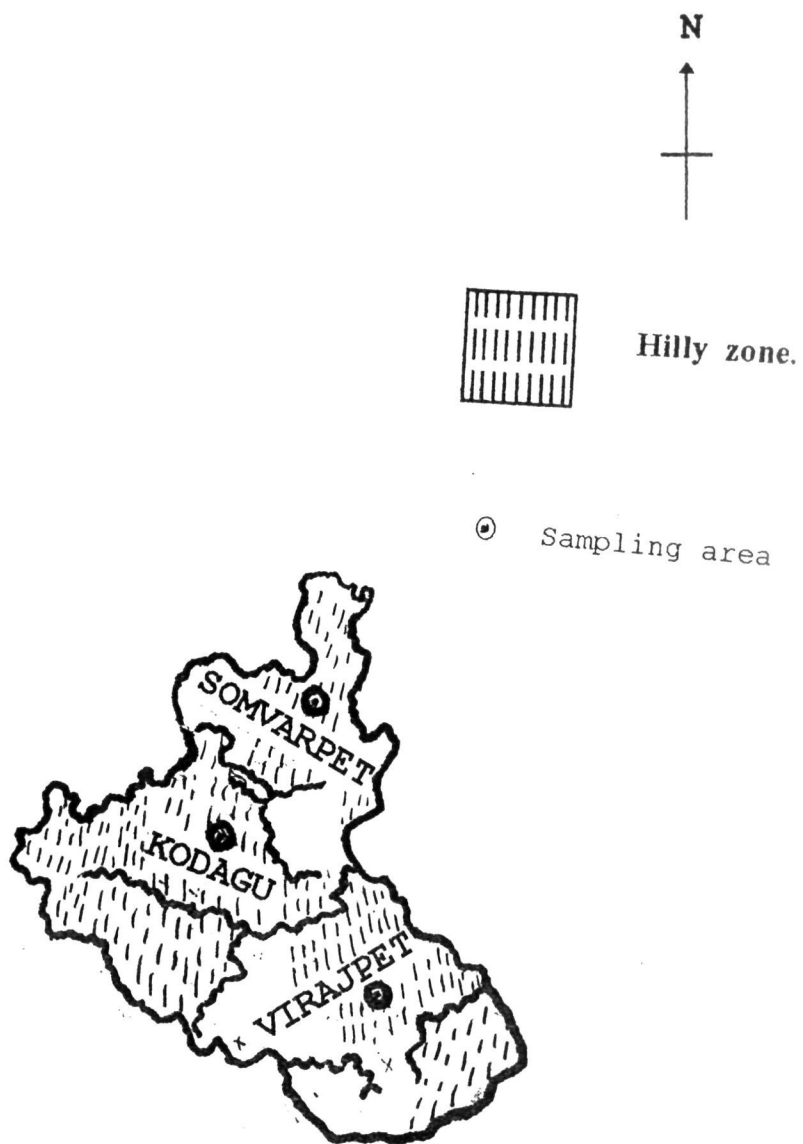


Figure 02 : Geographical location of Kodagu from where the soil samples were collected.

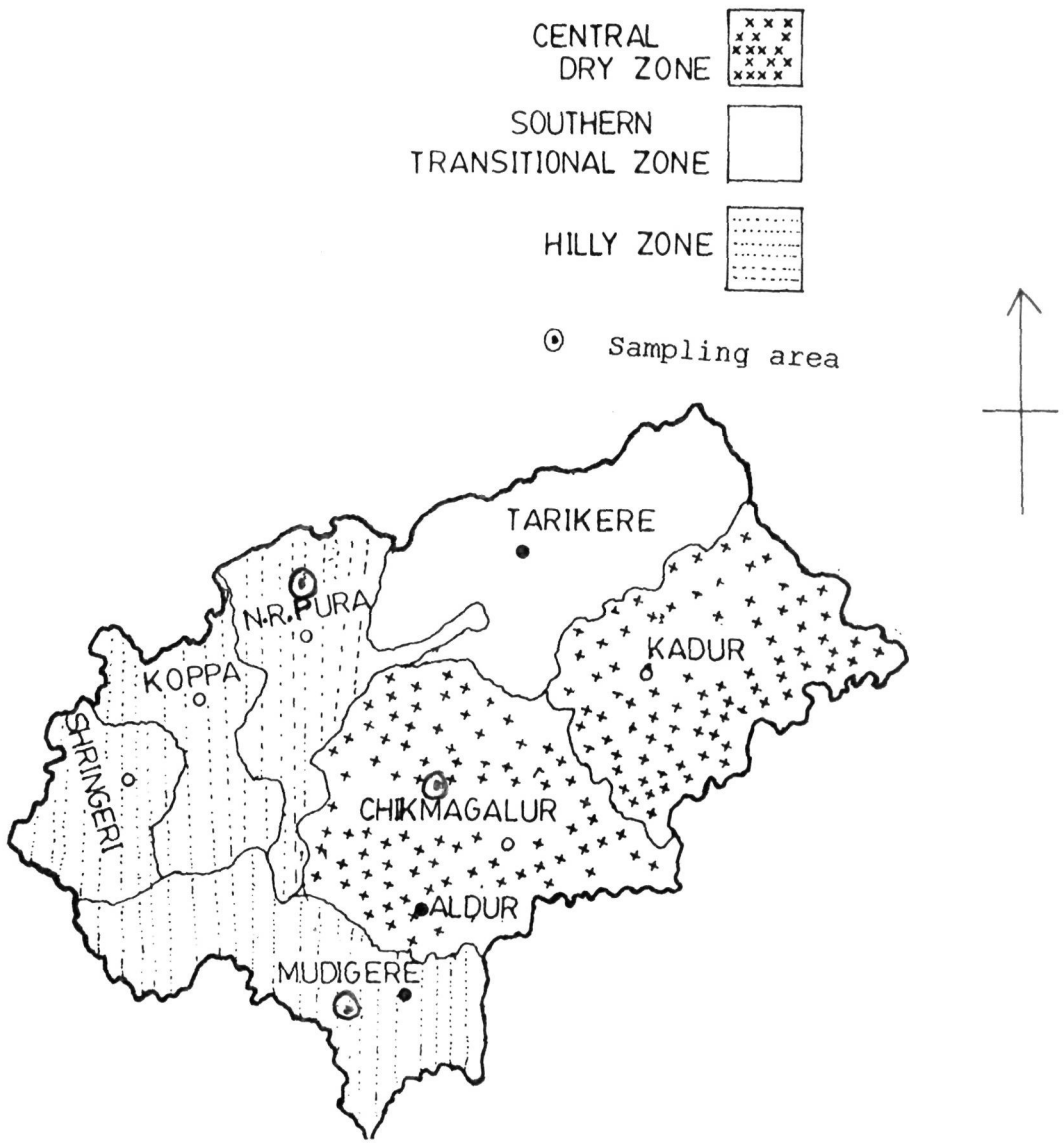


Figure 03 : Geographical location of Chikmagalur from where the soil samples were collected.

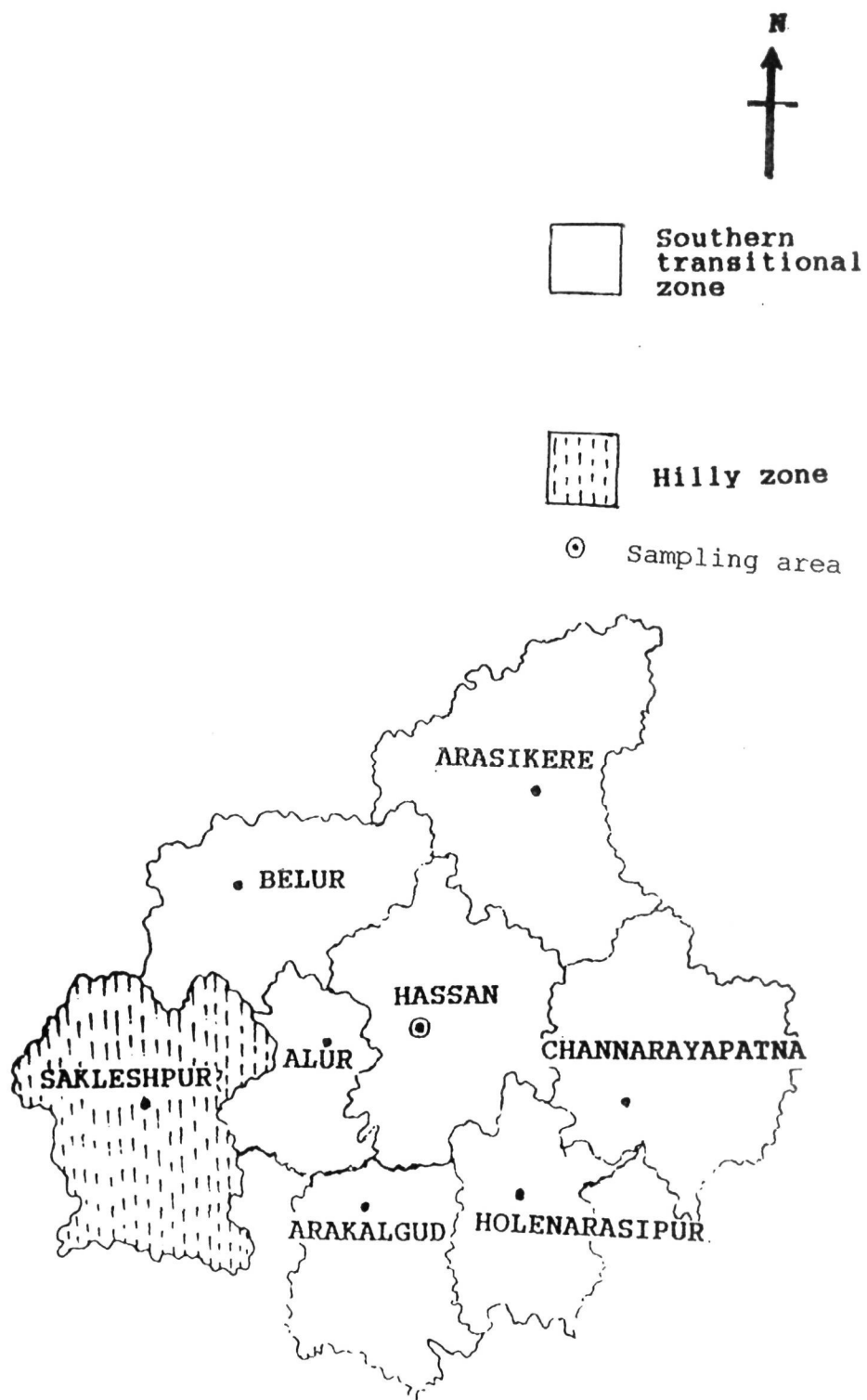


Figure 04 : Geographical location of Hassan from where the soil samples were collected.

For pot culture study, representative bulk sample having pH in acidic range (4.86-5.26) was collected from the unlimed fields of Madikeri.

Profile samples were collected from Madikeri, Chettalli (CRS), Teralu, Bettageri, in Kodagu district and Balehonur in Chikmagalur district.

The representative soil samples were air dried, crushed to pass through 2 mm sieve. The samples were stored in the polythene covers in the moisture and fumes free conditions. These samples were used for the laboratory analysis. For pot culture study, bulk sample was sieved through 4mm sieve before filling into earthen pots . For profile sample analysis the soil samples collected depth wise based on colour and texture, passed through 2mm sieve and stored for analysis.

3.2 LABORATORY EXPERIMENT

The processed soil samples were analysed for physico-chemical properties viz., mechanical analysis, pH, electrical conductivity, organic carbon, barium chloride-Triethanolamine extractable acidity, cation exchange capacity, lime potential, exchangeable bases and lime requirement based on two standard methods, viz., Puri's (exchangeable calcium method) and Adams and Evans buffer method. Multiple correlation analysis was done to study the interrelationship between soil parameters and with lime requirement methods.

3.3 POT CULTURE EXPERIMENT

Bulk samples from coffee growing area in Madikeri was collected and representative soil samples were processed and analysed for physico-chemical properties like mechanical analysis, field capacity, pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, sulfur and exchangeable cations like calcium, magnesium and potassium, properties of acid soils, lime requirement methods (Table-1). Lime requirement of soils were estimated by exchangeable calcium method and lime was applied on the basis of calcium saturation of soils.

Table-1 : Physico-Chemical properties of soil used for the pot culture.

CHARACTERISTICS	VALUES	
	1	2
A. SOIL PROPERTIES		
<u>Physical properties</u>		
Mechanical Analysis:		
Coarse Sand (Percent)		29.9
Fine Sand (Percent)		13.8
Silt (Percent)		6.3
Clay (Percent)		48.8
Textural Class		SC
Soil Taxonomy		Ustic palehumults
<u>Chemical properties</u>		
pH (1:2.5, Soil : water suspension)		4.87
pH (in KCl)		4.23
Electrical conductivity (1:2.5, Soil : water extract at 20°C) dsm^{-1}		0.11
Organic Carbon (Percent)		2.05
<u>Forms of Acidity {c. mol (p⁺)kg⁻¹}</u>		
Total potential acidity		38.4
Exchange acidity		9.18
pH dependent acidity		29.22
<u>Exchangeable cations {c. mol (p⁺)kg⁻¹}</u>		
Calcium		1.3
Magnesium		0.8
Potassium		0.53
Sodium		0.02
Extractable Aluminium {c. mol (p ⁺)kg ⁻¹ }		9.18
Effective cation exchange capacity {c. mol (p ⁺)kg ⁻¹ }		11.83
Aluminium saturation (Percent)		77.6

(Cont'd ...)

Table - 1 (Cont'd)

	1	2
<u>Nutrient Status</u>		
Available Nitrogen (Kg/ha)		459.0
Available Phosphorus (Kg/ha)		33.6
Available Potassium (kg/ha)		463.0
Available Sulfur (ppm)		32.5
 <u>Lime Requirement (Tons/ha)</u>		
a) Exchangeable Calcium method		4.15
b) Adams and Evans method		2.94
 B. LIMING MATERIAL		
a) Calcium (Percent)		28.2
b) Magnesium (Percent)		-
c) Purity (Percent)		68.0

Treatment details are as follows:

- T1 Absolute control
- T2 NPK alone
- T3 NPK + 0.25 Lime requirement
- T4 NPK + 0.5 Lime requirement
- T5 NPK + 1.0 Lime requirement
- T6 NPK + 1.5 Lime requirement
- T7 NPK + 2.0 Lime requirement
- T8 NPK + 25 percent calcium saturation
- T9 NPK + 50 percent calcium saturation
- T10 NPK + 75 percent calcium saturation
- T11 NPK + 100 percent calcium saturation

Altogether there were eleven treatment combinations, replicated four times. The pots were laid out in completely randomised design. Burnt lime (68 percent calcium) was used as a liming material. Earthen pots were used for the experiment. Each pot was filled with four kg of 4 mm sieved air dry soil. Lime as per the treatment and amount required for four kgs soil was mixed with the soil and moisture was maintained at field capacity of the soil. One and half year old seedling coffee (*coffea arabica* L.,) var. Cauvery was used as an experimental crop. Fertilizer dosage applied during the course of the study were :

Dosage	Fertilizer for 4 kg soil (g.)	Time
40:30:20	0.23:0.13:0.1	July
15:10:15	0.06:0.5:0.06	October

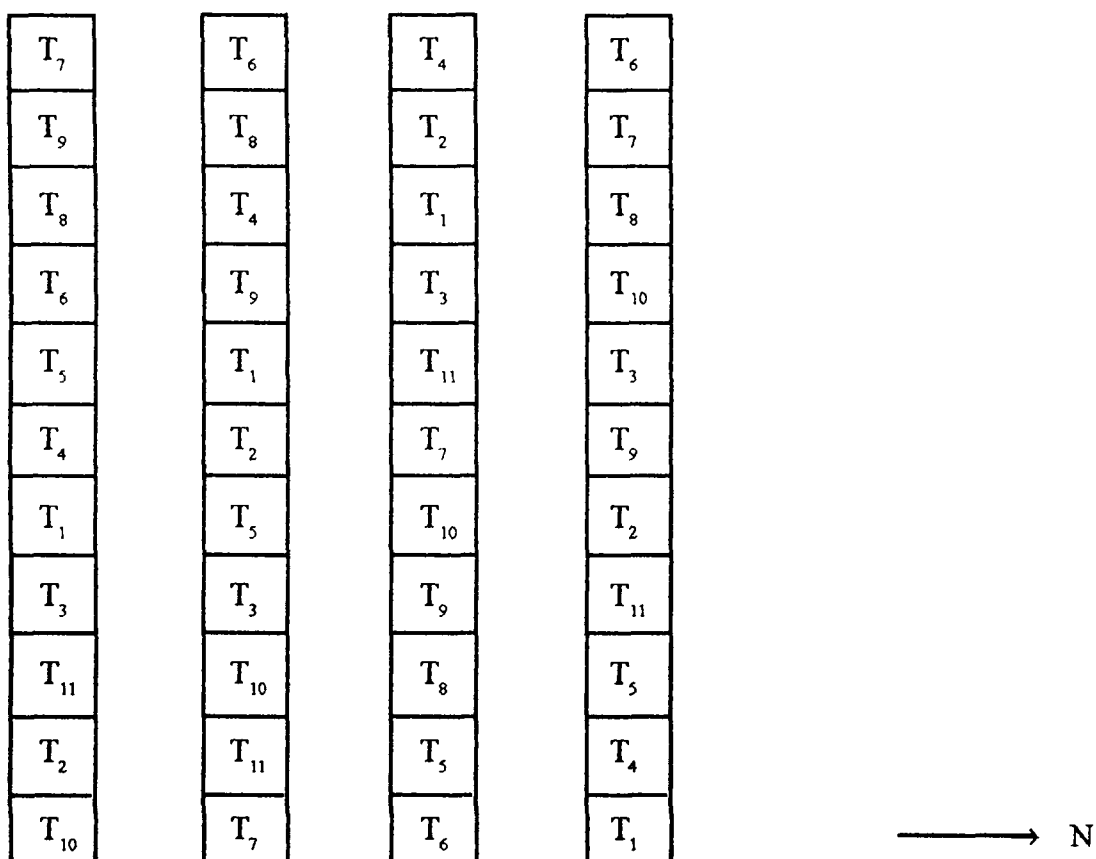


Fig. 5 : LAYOUT OF THE POT CULTURE EXPERIMENT

Treatment details

T ₁	Absolute Control
T ₂	NPK alone
T ₃	NPK + 0.25 LR
T ₄	NPK + 0.50 LR
T ₅	NPK + 1.00 LR
T ₆	NPK + 1.50 LR
T ₇	NPK + 2.00 LR
T ₈	NPK + 25% CS
T ₉	NPK + 50% CS
T ₁₀	NPK + 75% CS
T ₁₁	NPK + 100% CS

* LR : Lime Requirement

* CS : Calcium Saturation

N:P:K fertilizers were given in the form of diammonium phosphate, urea and muriate of potash. Plant protection measures were taken as per recommendation and pots were weeded as and when weeds grew in pots. After one hundred fifty days the plant height, number of leaves was recorded. Two to three pairs of leaves from the bottom were collected for analytical purpose. The leaves were washed with tapwater, teapol, dilute acid, water and distilled water to remove adhered soil particles, before analysis of nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. Soil samples were taken at thirty days interval from all the pots. Samples were air dried, crushed and passed through 2 mm sieve for laboratory analysis. Soil samples were analysed for pH in water, pH in KCl and total potential acidity.

3.4 Methods of soil analysis

3.4.1 Mechanical analysis

The particle size analysis was done by Bouyoucos soil hydrometer method (Piper, 1966)

3.4.2 Field capacity

Field capacity was determined by cylinder method as outlined by Piper (1966).

3.4.3 Soil reaction (pH)

Soil pH was determined in 1:2.5 soil water ratio by potentiometric method using glass electrode (Jackson, 1973).

3.4.4 Electrical conductivity

Electrical conductivity was determined in the supernatant solution of 1:2.5 soil:water suspension using conductivity bridge (Jackson, 1973).

3.4.5 Lime potential

10 g of 2 mm sieved soil was made to react with 20 ml CaCl_2 (0.01 M) for 30 minutes and pH of the suspension was measured in pH meter. Lime potential is given as

$$\text{Lime potential} = \text{Measured pH} - 1.14 \text{ (Hasse, 1973)}$$

3.4.5 Organic carbon and C:N ratio

Organic carbon was determined by Walkley and Black wet oxidation method and C:N ratio was calculated based on (1:10) ratio.

3.4.7 Exchangeable cations (Ca, Mg, Na, K)

The soil was leached with neutral normal ammonium acetate. In the leachate calcium and magnesium were determined by versenate titration using appropriate indicators. Exchangeable potassium and sodium were estimated by feeding the leachate to flame photometer (Jackson, 1973).

3.5 ACIDITY

3.5.1 Exchangeable acidity and Aluminium

Aluminium was extracted with 1 N ammonium acetate (pH 4.8) and the amount was determined by adapting thioglycolic acid method involving aluminon reagent as an indicator (Mclean et.al., 1958). This is considered as exchange acidity (Hesse, 1973).

3.5.2 Total potential acidity

Ten grams of soil sample was made to react with Bariumchloride-Triethanolamine buffer solution adjusted to pH 8.2 for about half an hour and then leached with replacement solution containing $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ and buffer mixture. The leachate was titrated against 0.2 N HCl using bromocresol green-methyl red mixed indicator (Chapman and Pratt, 1961).

3.5.3 pH-dependent acidity

It is the difference between total potential acidity and the amount of H^+ and Al^{3+} exchanged with one normal potassium chloride solution.

3.5.4 Percent contribution of pH dependent acidity

It is the percentage of pH dependent acidity divided by cation exchange capacity expressed in terms of percentage.

3.5.5 Cation exchange capacity (CEC)

After leaching the soil with replacement solution for total potential acidity, soil on the filter paper was washed with 10 percent CaCl_2 solution. In the filtrate the amount of barium adsorbed was determined colorimetrically at 425 nm (Chapman and Pratt, 1961).

3.5.6 Effective cation exchange capacity (ECEC)

Effective cation exchange capacity is the summation of exchangeable calcium, magnesium, potassium, sodium and extractable aluminium.

3.5.7 Available phosphorus

Bray's No.1 extractant was used for extracting available phosphorus in acid soils. In the extract, phosphorus was determined by chloromolybdic acid and stannous chloride method using Spectronic-20 (Jackson, 1973).

3.5.8 Available sulfur

Available sulfur, extracted with sodium acetate and acetic acid mixture was determined by turbidometric method using gum accasia as a stabilizing agent (Black, 1965).

3.6 LIME REQUIREMENT

3.6.1 Adams and Evans buffer method

Twenty ml. of distilled water was added to twenty grammes of soil taken in one hundred ml. beaker and the mixture was stirred continuously for one hour with a glass rod and the pH was recorded. To this suspension twenty ml. of concentrated buffer solution was added.

The buffer solution was prepared by mixing 10 g. paranitrophenol, 7.5 g. boric acid, 37.0 g. of potassium chloride and 10.25 g. of potassium hydroxide and the volume was made upto one liter with distilled water. The resulting solution will have a pH of 8.0 ± 0.1 .

The soil buffer solution was stirred twice at an interval of ten minutes and the pH was measured. Lime requirement was read directly from the appropriate table by using pH values of soil-water and soil-buffer for a desired pH of 6.5 (Adams and Evans, 1962).

3.6.2 Titrimetric method

Ten grammes portions of soil in duplicate were weighed into two conical flasks. One of the samples was treated with one g. of CaCO_3 . 50 ml. of distilled water was added to each flask and the system was left overnight. Next day the contents in the flasks were treated with 0.2 N KCl solution saturated with CaCO_3 , filtered with the leaching solution to collect two hundred and fifty ml. of the filtrate.

Calcium content in both the samples were determined and also in the leaching solution. Milliequivalent values of calcium in the leaching solution were subtracted from the values of calcium obtained for treated and untreated samples. Later the difference between treated sample and untreated sample was calculated to get excess of calcium that was adsorbed. From the exchangeable calcium value and lime requirement in tons of CaCO_3 per hectare was calculated (Puri, 1964).

3.7 ANALYSIS OF PLANT SAMPLES

Plant samples collected at harvest stage were washed with water, air dried and were later dried in the oven at 60°C, powdered and used for chemical analysis.

3.7.1 Nitrogen

500 mg of the powdered sample was digested in sulfuric acid along with the digestion mixture consisting K_2SO_4 , $CuSO_4$ and Selenium powder in a Kjeldahl flask. The digested material was distilled in an alkaline medium. Liberated ammonia was trapped in boric acid mixed indicator medium and titrated against standard sulfuric acid (Jackson, 1973).

3.7.2 Wet ashing for mineral analysis

One gram powdered sample was digested carefully with nitric acid on a hot plate. After cooling it was digested on a hot plate with di-acid mixture containing nitric acid and perchloric acid (10:4) until gelatinous white residue was left over. It was cooled and the volume was made to 100 ml with 6N hydrochloric acid. Suitable aliquots were taken for the analysis of phosphorus, potassium, calcium, magnesium and sulfur.

3.7.2.1 Phosphorus

It was determined by vanado-molybdo-phosphoric acid yellow colour method in nitric acid medium and the intensity of the colour was read at 430 nm wavelength as described by Jackson (1973).

3.7.2.2 Calcium and magnesium

These two elements were determined by versenate titration employing suitable indicators as described by Jackson (1973).

3.7.2.3 Potassium

Potassium was determined by flame photometer as explained by Jackson (1973).

3.7.2.4 Sulfur

Sulfur was estimated by turbidometric method as outlined by Jackson (1973).

3.8 ANALYSIS OF LIMING MATERIALS

For pot culture experiment, burnt lime was used as a liming material. One gram of the representative lime sample was acid digested to get calcium in the form of calcium chloride. The

calcium and magnesium content in the digested samples were determined by versenate titration technique and the percentage of CaCO_3 in the lime powder was calculated.

3.9 STATISTICAL ANALYSIS

The data obtained by the analysis of soil and plant was analysed statistically for test of significance as explained in Fisher's method of analysis of variance.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

In this chapter data pertaining to the physico chemical characteristics, acid soil characterisation, effect of lime on the seedling growth of coffee and relationship between soil properties and lime are reported.

4.1 LABORATORY STUDIES

4.1.1 Physico chemical properties of coffee growing soils.

The data pertaining to physico-chemical properties of the coffee growing soils are presented in the Table - 2.

4.1.1.1 Soil pH

The pH of the soils of Kodagu district ranged from 3.9 - 6.3 in soil : water suspension, 3.1-5.6 in soil : potassium chloride suspension and 3.64-6.44 in soil : calcium chloride suspension. The pH of the soils of Chikmagalur ranged from 5.2-6.4, 4.3-5.8 and 4.41-5.70 in soil : water, soil : potassium chloride and soil : calcium chloride respectively. Similarly in Hassan district, the pH of soil ranged from 4.8-6.4, 4.2-6.1 and 4.5-6.1 in respective soil suspension.

4.1.1.2 Electrical conductivity

The electrical conductivity ranged from 0.02-0.56, 0.02-0.40 and 0.02-0.11 dsm^{-1} at 25°C. in Kodagu, Chikmagalur and Hassan district respectively.

4.1.1.3 Mechanical analysis

Perusal of mechanical analysis data reveal that most of the soils from Kodagu district belongs to sandy loam category. The clay content ranged from 15.0-42.5 percent. In Chikmagalur the majority of soils are sandy loam, very few were sandy clay loam and sandy clay. The clay content ranges from 16.3-48.5. In Hassan district, there is equal number of sandy loam and sandy clay loam texture soils. The clay content ranged from 16.3-45.0.

4.1.1.4 Organic carbon

Organic carbon and C:N ratio in Kodagu district ranged from 0.5-3.8 and 1:2.6-1:20 respectively. Similarly in Chikmagalur and Hassan district, it is ranged from 0.2-3.4, 1:2.9-1:50 and 0.3-2.1, 1:4.8-1:33.5 respectively. Highest amount of organic carbon noticed in Kodagu followed by Chikmagalur district and lowest in Hassan district.

Table-2: Physico-Chemical properties of the surface soil from coffee growing areas

Sl. No.	CHARACTERS	KODAGU (107)	CHIKMAGALUR (59)	HASSAN (16)
1.	Clay (Percent)	15.0-42.5	16.3-48.5	16.3-42.5
2.	Texture	SL-SCL	SL-SCL	SL-SCL
3.	pH (1:2.5 soil water suspension)	3.9-6.3	5.2-6.4	4.8-6.4
4.	pH (1:2.5 soil KCl suspension)	3.1-5.6	4.3-5.8	4.2-6.1
5.	pH (1:2.5 soil CaCl ₂ suspension)	3.64-6.44	4.41-5.70	4.55-6.14
6.	EC (1:2.5 soil water extract at 25° C) $d S m^{-1}$	0.02-0.56	0.02-0.40	0.02-0.11
7.	Organic Carbon (percent)	0.5-3.8	0.2-3.4	0.3-2.1
8.	C:N ratio	1:2.6-1:20	1:2.9-1:50	1:4.8-1:33.5
9.	Bray's P (ppm)	0.89-27.2	2.0-18.2	7.32-11.7
10.	Sodium acetate extractable Sulfur (ppm)	0.89-35.3	6.3-36.3	11.4-24.0

* Numerical values in Parnatheses indicate number of samples analysed.

Bray's No. 1 P ranged from 0.89-27.2, 2.0-18.2 and 7.32-11.7 ppm in Kodagu, Chikmagalur and Hassan districts respectively.

4.1.1.6 Sulfur

Sodium acetate extractable sulfur ranged from 0.89-35.3, 6.3-36.3 and 11.4-24.0 ppm in the districts of Kodagu, Chikmagalur and Hassan as mentioned in the Table-2.

4.1.1.7 Exchangeable cations

The exchangeable cations viz., calcium, magnesium and potassium ranged from 0.74-10.82, 0.16-3.03 and 0.06-0.54 in Kodagu, 1.64-7.71, 0.49-3.53, and 0.08-0.94 in Chikmagalur and 2.87-9.43, 0.67-3.12 and 0.12-0.28 c.mol (P⁺)kg⁻¹ in Hassan district. Exchangeable sodium was in traces or absent in the soils analysed.

4.1.1.8 Cation exchange capacity

Cation exchange capacity determined by barium replacement method ranged from 7.31-42.27, 20.22-33.08 and 17.35-38.48 c.mol(P⁺)kg⁻¹ in Chikmagalur and Hassan district respectively. Base saturation in these soils ranged from 4.8-45.5, 15.2-42.3 and 14.9-33.5 percent in the respective three districts.

4.1.1.9 Calcium saturation

Calcium saturation as a function of cation exchange capacity ranged from 5.09-66.5, 8.70-24.51 and 5.26-27.75 in Kodagu, Chikmagalur and Hassan district as mentioned in the Table-3.

4.1.1.10 Effective cation exchange capacity

Effective cation exchange capacity is a summation of calcium, magnesium, potassium and exchangeable acidity. It ranged from 4.02-21.53, 8.10-22.4 and 7.62-14.82 c.mol (p⁺)kg⁻¹ in Kodagu, Chikmagalur and Hassan district.

4.1.1.11 Extractable aluminium

As per Hesse (1973) in acid soils, NH₄.OAC (p^H 4.8) extractable aluminium as denoted as exchangeable acidity and it ranged from 1.28-18.02, 3.62-12.95 and 1.17-3.82 c.mol(p⁺)kg⁻¹ in Kodagu, Chikmagalur and Hassan district respectively.

Table-3 : Exchangeable cations and percent base saturation in the surface soil of the coffee growing areas.

Sl. No.	CHARACTERS	KODAGU	CHIKMAGALUR	HASSAN
RANGE				
1.	Calcium {c. mol (p ⁺) kg ⁻¹ }	0.74-10.82	1.64-7.71	2.87-9.43
2.	Magnesium {c. mol (p ⁺) kg ⁻¹ }	0.16-3.03	0.49-3.53	0.67-3.12
3.	Potassium {c. mol (p ⁺) kg ⁻¹ }	0.06-0.54	0.08-0.94	0.12-0.28
4.	Cation exchange capacity {c. mol (p ⁺) kg ⁻¹ }	7.31-42.27	20.22-33.08	17.35-38.48
5.	Calcium saturation (percent)	5.09-66.5	8.70-24.51	5.26-27.75
6.	Base saturation (percent)	4.8-45.5	15.2-42.3	14.9-33.5

Aluminium saturation as a function of effective cation exchange capacity was calculated using extractable aluminium values. Aluminium saturation in Kodagu, Chikmagalur and Hassan ranged from 10.5-85.0, 26.4-80.7 and 14.6-49.3 percent respectively as mentioned in the Table-4.

4.1.2 Different forms of soil acidity in coffee growing soils.

Results obtained on different forms of soil acidity in the surface soils of coffee have been presented in Table-5.

4.1.2.1 Exchangeable acidity

Exchangeable acidity determined by 1N. NH₄ OAC (pH 4.8) ranged from 1.28-18.02, 3.62-12.95 and 1.17-3.82 c.mol (p⁺) kg⁻¹ in Kodagu, Chikmagalur and Hassan district respectively.

4.1.2.2 Potential acidity

Potential acidity determined by barium chloride triethanol amine buffer (pH 8.2) ranged from 11.12-36.88, 9.6-36.48 and 17.28-34.56 c.mol (p⁺) kg⁻¹ respectively.

4.1.2.3 pH dependent acidity

pH dependent acidity is the difference of total potential acidity and exchange acidity. In the samples studied, pH dependent acidity ranged from 8.38-34.63, 5.25-28.43 and 14.81-31.25 c.mol (p⁺) kg⁻¹ and percentage contribution of pH dependent acidity to total acidity ranged from 29.4-27.5 in Kodagu, 20.66-93.4 in Chikmagalur and 56.9-87.5 in Hassan district.

4.1.3 Lime requirement and lime potential of the coffee growing soils.

Lime requirement of a soil is the amount of liming material required to neutralise the acidity of that soil and there by to rise its pH value to a level that is ideal for crop growth. Lime requirement and lime potential value are given in Table-6.

4.1.3.1 Lime requirement

From the data on the lime requirement, it was observed that lime requirement as estimated by exchangeable calcium method gave higher values as compared to that of Adams and Evans method. Maximum lime requirement as estimated by exchangeable

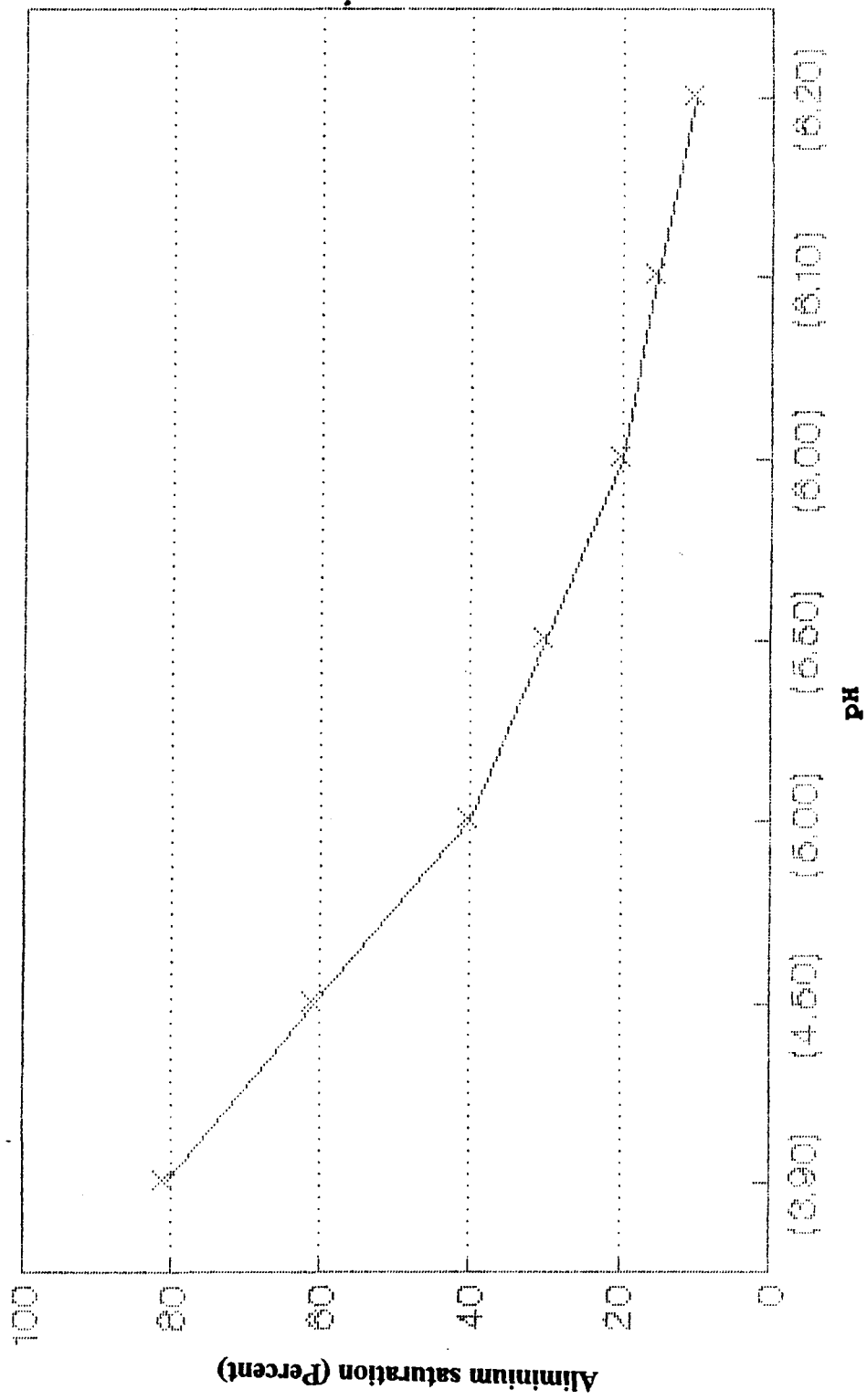


Figure - 6 : pH and Aluminium Saturation

Table-4 : Cation exchange capacity and Aluminium status of the surface soil from coffee growing areas

Sl No.	CHARACTERS	KODAGU	CHIKMAGALUR	HASSAN
RANGE				
1.	Effective cation exchange capacity {c. mol (p ⁺) kg ⁻¹ }	4.02-21.53	8.10-22.4	7.62-14.82
2.	NH ₄ . OAC pH 4.8 Extractable Aluminium {c. mol (p ⁺) kg ⁻¹ }	1.28-18.02	3.62-12.95	1.17-3.82
3.	Aluminium saturation of effective cation exchange capacity (percent)	10.5-85.0	26.4-80.7	14.6-49.3

Table-5 : Forms of acidity in the surface soil of the coffee growing areas.

Sl No.	CHARACTERS	KODAGU	CHIKMAGALUR	HASSAN
		RANGE		
1.	Potential acidity {c. mol (p ⁺) kg ⁻¹ }	11.12-36.88	9.6-36.48	17.28-34.56
2.	Exchange acidity {c. mol (p ⁺) kg ⁻¹ }	1.28-18.02	3.62-12.95	1.17-3.82
3.	pH dependent acidity {c. mol (p ⁺) kg ⁻¹ }	8.38-34.63	5.25-28.43	14.81-31.85
4.	CEC {c. mol (p ⁺) kg ⁻¹ }	7.31-42.27	20.22-33.48	17.35-38.48
5.	Percent contribution of pH dependent acidity to total acidity	29.50-97.50	20.66-93.40	56.90-87.50

Table-6 : Lime requirement and lime potential of the surface soil from coffee growing areas.

Sl. No.	CHARACTERS	KODAGU	CHIKMAGALUR	HASSAN
		RANGE		
1.	Buffer method (tons / ha)	1.23-9.98	0.66-8.38	1.95-6.77
2.	Exchangeable Calcium method (tons/ha)	1.97-13.99	1.45-12.59	3.87-8.02
3.	Lime potential	2.45-5.00	3.27-4.56	3.41-5.00

calcium method was 13.99 tons per hectare for the soils of Kodagu followed by Chikmagalur with 12.59 and 8.02 tons per hectare in Hassan.

As per Adams and Evans method of lime requirement method, the amount of lime required, ranged from 1.23-9.98, 0.66-8.38 and 1.95-6.77 tons per hectare in Kodagu, Chikmagalur and Hassan district respectively.

4.1.3.2 Lime potential

The lime potential ranged from 2.45-5.00 in Kodagu, 3.27-4.56 in Chikmagalur and 3.41-5.00 in Hassan district.

4.2 PROFILE STUDIES

4.2.1 Physico-chemical properties of profile sample

Results of the physico-chemical analysis of the soil profile have been presented in the Table-7 and 8.

4.2.1.1 Soil pH

In general soil pH is acidic in all the profile samples, except in profile No.4. pH increased with depth in all the profiles except in profile No.5, where, decrease in pH is recorded at lower depth.

The pH in soil water suspension ranged from 4.9-6.1 in the surface profile samples of all the location. Profile No.1, 2 and 5 are more acidic with pH less than 5.5 as compared to the 3 and 4 profiles. Beyond 50 cms the pH recorded was more than 4.8 in all the profiles. The soil pH in 0.1 N KCl is less in all the profile samples. The reduction in pH of the soils in neutral salt solution (0.1 N KCl) varies from 0.3-1.6 units. pH in surface samples ranged from 4.4-5.5.

Soil pH in 0.01 M CaCl_2 is comparatively less in all the profile as compared to soil-water and soil-KCl suspension.

4.2.1.2 Electrical conductivity

Electrical conductivity of soil samples of all depth in all the profile are in acceptable limits.

Table - 7 : Physical properties of the soil profile from coffee growing areas.

Sl. No.	Location	Depth (cm)	Clay (%)	Textural class
1. Village : Theralu, Taluk : Virajpet, District : Kodagu				
1.		0-15	11.6	LS
2.		15-30	11.6	LS
3.		30-45	15.6	SL
4.		45-60	15.6	SL
5.		60-90	19.6	SL
6.		90+	17.0	SL
2. Village : Bettageri, Taluk : Madikeri, District : Kodagu				
7.		0-18	17.0	SL
8.		18.44	23.0	SCL
9.		44.82	25.0	SCL
10.		82+	21.0	SCL
3. Village : Daswal, Taluk : Madikeri, District : Kodagu				
11.		0-60	18.3	SL
12.		60-85	20.0	SL
13.		85-105	15.0	SL
14.		105+	17.5	SL
4. Village : Chettalli (CRS), Taluk : North Kodagu, District : Kodagu				
15.		0-45	32.5	SCL
16.		45-90	35.0	SCL
17.		90-135	31.5	SCL
18.		135-180	46.8	SC
5. Village : Balehonur (CCRI), Taluk : Chikmagalur, District : Chikmagalur				
19.		0-60	25.0	SL
20.		60-83	25.0	SL
21.		83-101	41.2	SC
22.		101-130	45.0	SC

LS = Loamy Sand SCL = Sandy Clay Loam CRS : Central Coffee Research Sub-Station
 SL = Sandy Loam SC = Sandy Clay CCRI : Central Coffee Research Institute.

Table - 8 : Chemical properties of the soil profile from coffee growing areas.

Sl. No.	Location	Depth (cm)	pH		EC (dsm ⁻¹)	Organic carbon (%)	C:N ratio	Bray's P (ppm)	Sodium acetate extractable Sulphur (ppm)
			H ₂ O	KCl					
1. Village : Theralu , Taluk : Virajpet, District : Kodagu.									
1.		0-15	5.5	4.9	0.65	3.43	1:2.9	5.2	11.3
2.		15-30	5.6	5.0	0.41	3.33	1:3.0	5.2	11.3
3.		30-45	5.7	5.1	0.30	3.10	1:3.2	5.2	9.30
4.		45-60	5.6	5.0	0.25	2.36	1:4.2	4.2	11.3
5.		60-90	5.8	5.1	0.21	1.65	1:6.1	4.2	9.30
6.		90+	5.8	5.3	0.31	1.56	1:6.4	3.8	9.30
2. Village : Bettageri, Taluk : Madikeri, District : Kodagu.									
7.		0-18	4.9	4.8	0.49	2.17	1:8.6	6.6	11.3
8.		18-44	4.6	4.4	0.34	2.29	1:4.4	6.6	9.30
9.		44-82	4.8	4.8	4.55	1.35	1:7.4	4.3	9.30
10.		82+	5.2	5.2	0.49	1.20	1:8.3	4.3	9.30
3. Village : Daswal, Taluk : Madikeri, District : Kodagu.									
11.		0-60	5.9	4.9	0.11	0.30	1:33	18.7	32.9
12.		60-85	5.0	4.0	0.05	2.51	1:4.0	16.1	8.60
13.		85-105	5.2	4.1	0.02	1.11	1:9.0	3.90	17.2
14.		105+	5.3	4.3	0.03	1.20	1:8.3	1.10	36.0
4. Village : Chettalli (CRS), Taluk : North Coorg, District : Kodagu.									
15.		0-45	6.1	5.5	0.12	0.30	1:33	2.9	20.4
16.		45-90	6.3	5.4	0.09	0.10	1:100	1.6	17.2
17.		90-135	6.4	5.6	0.09	0.20	1:50	1.1	12.5
18.		135-180	6.6	5.6	0.09	0.10	1:100	3.0	31.3
5. Village : Balehonur (CCRI), Taluk : Chikmagalur, District : Chikmagalur.									
19.		0-60	5.3	4.4	0.04	1.31	1:7.6	3.0	5.9
20.		60-83	5.3	4.3	0.05	0.30	1:33	1.4	12.5
21.		83-101	5.6	4.7	0.05	0.10	1:100	2.1	10.9
22.		101-130	5.5	4.9	0.04	0.03	1:33	1.4	8.0

* CRS : Central Coffee Research Sub-Station.

* CCRI : Central Coffee Research Institute.

4.2.1.3 Mechanical analysis

Mechanical analysis of data reveals that the clay content increase with depth and it ranged from 11.6-46.8 percent. Maximum clay content is recorded in profile No. 4 and 5.

4.2.1.4 Organic carbon

The analytical results on organic carbon content of profile samples indicate that, there was decreases in organic carbon as the depth of the profile increased. Upto 45 cms depth, more organic carbon content was recorded as compared to deeper layer. Among all the profile tested, profile 1 and 2 recorded substantial amount of organic carbon.

The organic carbon content in profile No. 1, 2, 3, 4 and 5 ranged from 1.56-3.43, 1.20-2.29, 0.30-2.51, 0.10-0.30, 0.03-1.31. C:N ratio for these profiles ranged from 1:2.9-1:6.4, 1:4.4-1:1:8.6, 1:4.0-1:33, 1:33-1:100, 1:7.6-1:100 respectively.

4.2.1.5 Available phosphorus

Available phosphorus (Bray's I) generally decreased with increase in depth with a sole exception in profile No.4. Profile No.3 recorded lowest quantity of available phosphorus. In majority of the profiles maximum available phosphorus was recorded upto 45 cms depth.

4.2.1.6 Available sulfur

Available sulfur (Sodium acetate) generally decreased as depth of the profile increases. However there is no consistency in the trend.

4.2.1.7 Exchangeable cations

The data have been furnished in the Table-9. Exchangeable cations viz., Ca^{++} , Mg^{++} , K^+ and Na^+ are analysed in all the profiles. The data indicate that exchangeable Ca^{++} contribute to the major portion of the exchange complex. Exchangeable Na^+ contributed the lowest to the exchange complex. In general there is no definite trend in exchangeable cation in the profiles.

4.2.1.8 Cation exchange capacity (CEC)

Cation exchange capacity decreased with increase in the soil depth, except in profile No. 5, where increasing trend is observed after 83 cm depth. Maximum CEC is recorded upto 45 cm depth.

Table - 9 : Exchangeable cations in the soil profile from coffee growing areas.

Sl. No.	Location	Depth (cm)	Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	CEC	Calcium saturation (%)	Base saturation (%)
			----- c. mol p ⁺ kg ⁻¹ -----						
1. Village : Theralu, Taluk : Virajpet, District : Kodagu.									
1.		0-15	3.5	1.4	0.38	0.10	34.1	10.3	15.9
2.		15-30	2.5	0.5	0.39	0.11	30.8	8.1	11.4
3.		30-45	2.0	0.3	0.51	0.11	30.8	6.5	9.5
4.		45-60	2.0	0.3	0.51	0.11	24.9	8.0	11.7
5.		60-90	1.8	0.3	0.44	0.14	21.6	8.3	12.4
6.		90+	1.9	0.5	0.59	0.13	19.9	9.6	15.7
2. Village : Bettageri, Taluk : Madikeri, District : Kodagu.									
7.		0-18	3.6	0.9	0.58	0.14	18.8	19.1	27.7
8.		18-44	2.6	0.4	0.52	0.11	18.8	13.8	19.3
9.		44--82	3.5	0.6	0.70	0.10	16.4	21.3	28.4
10.		82+	4.5	0.7	0.45	0.11	16.0	28.1	31.0
3. Village : Daswal, Taluk : Madikeri, District : Kodagu.									
11.		0-60	2.05	0.49	0.71	-	35.4	5.8	9.2
12.		60-85	1.39	1.07	0.43	-	29.5	4.7	9.6
13.		85-105	1.72	0.91	0.23	-	30.2	4.7	9.5
14.		105+	1.48	0.94	0.25	-	25.8	5.7	0.3
4. Village : Chettali (CRS), Taluk : North Coorg, District : Kodagu.									
15.		0-45	5.4	3.2	0.46	-	28.4	18.9	31.6
16.		45-90	5.2	1.9	0.77	-	30.9	16.7	25.3
17.		90-135	3.6	2.2	0.05	-	31.9	11.3	18.4
18.		135-180	4.26	2.79	0.08	-	26.2	11.8	27.2
5 Village : Balehonur (CCRI), Taluk : Chikmagalur, District : Chikmagalur.									
19.		0-60	3.2	2.13	0.38	-	31.7	10.1	18.0
20.		60-83	1.72	0.90	0.15	-	27.6	6.2	10.1
21.		83-101	1.39	0.75	0.13	-	30.8	4.5	5.8
22.		101-130	1.64	0.41	0.11	-	32.5	5.1	6.6

* CRS : Central Coffee Research Sub-Station.

* CCRI : Central Coffee Research Institute.

4.2.1.9 Calcium saturation

It varied from 4.7-26.1 percent in all the profiles studied.

4.2.1.10 Base saturation

No definite trend was noticed in base saturation with depth of the profiles. However maximum base saturation was noticed in profile No. 2 and 4 as compared to rest of the profiles.

4.2.1.11 Effective cation exchange capacity (ECEC)

The data pertaining to effective CEC, Exchangeable aluminium and aluminium saturation have been presented in a Table-10. Effective CEC, computed by adding the exchangeable cations plus extractable aluminium did not show any definite trend in the profiles. It ranged from 2.6-16.1 c. mol (p⁺) kg⁻¹.

4.2.1.12 Exchangeable aluminium

Exchangeable aluminium in the soil profiles ranged from 0.86-13.2 c mol (p⁺) kg⁻¹. Exchangeable aluminium values recorded by the profile No. 4 varied from 1.3-2.4 c.mol (p⁺) kg⁻¹. Maximum exchangeable aluminium was recorded upto 83 cms in sub surface profiles.

4.2.1.13 Aluminium saturation

Aluminium saturation of the effective CEC did not show any consistent trend with the depth of the profile. It ranged from 12.4-82.1 percent. Higher aluminium saturation was recorded in the profiles of 3 and 5 as compared to the rest of profiles.

4.2.2 Forms of acidity in the coffee growing profile samples

Results obtained on forms of soil acidity have been presented in the Table-11.

4.2.2.1 Potential acidity

Total potential acidity decreased with increase in the depth of the profile No. 1 and 3. In the rest of the profiles no definite trend was observed. It ranged from 5.36-30.72 c. mol (p⁺)kg⁻¹. In general total potential acidity was higher in first two or three soil depth.

4.2.2.2 Exchangeable acidity

Values of exchangeable acidity is generally lower (0.86-13.24 c.mol (p⁺) kg⁻¹ in the profiles as compared to potential acidity.

Table - 10 : Cation exchange capacity and Aluminium status of the soil profile from coffee growing areas.

Sl. No.	Location	Depth (cm)	Effective Cation Exchange Capacity ----- c.mol. (p ⁺) kg ⁻¹ -----	NH ₄ OAC pH 4.8 Extractable Aluminium	Aluminium saturation of ECEC (%)
1. Village : Theralu, Taluk : Virajpet, District : Kodagu.					
1.		0-15	6.42	1.02	15.89
2.		15-30	4.39	0.89	20.27
3.		30-45	3.8	0.96	24.47
4.		45-60	4.08	1.17	28.68
5.		60-90	3.92	1.24	31.63
6.		90+	4.29	1.17	27.27
2. Village : Bettageri, Taluk : Madikeri, District : Kodagu.					
7.		0-18	6.28	1.06	16.88
8.		18-44	4.52	0.89	19.70
9.		4-82	5.53	0.86	15.56
10.		82+	6.81	1.05	15.42
3. Village : Daswal, Taluk : Madikeri, District : Kodagu.					
11.		0-60	12.40	9.18	73.30
12.		60-85	16.10	13.20	82.10
13.		85-105	13.80	10.90	79.30
14.		105+	12.00	6.70	55.70
4. Village : Chettalli (CRS), Taluk : North Kodagu, District : Kodagu.					
15.		0-45	10.40	1.30	12.40
16.		45-90	8.40	1.30	15.00
17.		90-135	7.40	1.50	20.30
18.		135-180	9.50	2.40	25.10
5. Village : Balehonur (CCRI), Taluk : Chikmagalur, District : Chikmagalur.					
19.		0-60	8.30	2.60	31.00
20.		60-83	5.30	2.50	47.80
21.		83-101	2.70	1.00	35.40
22.		101-130	2.60	1.50	40.60

* CRS : Centra Coffee Research Sub-Station.

* CCRI : Central Coffee Research Institute.

Table - 11 : Forms of acidity in the soil profile from coffee growing areas.

Sl. No.	Location	Depth (cm)	Forms of Acidity			Percent contribution of pH dependent acidity to total acidity
			Potential acidity ----- c. mol (p ⁺) kg ⁻¹ -----	Exchange acidity	pH dependent acidity	
1. Village : Theralu, Taluk : Virajpet, District : Kodagu.						
1.		0-15	21.38	1.02	20.36	59.70
2.		15-30	17.37	0.89	16.48	53.50
3.		30-45	17.37	0.96	16.40	53.30
4.		45-60	14.70	1.17	13.53	54.40
5.		60-90	12.03	1.24	10.79	49.95
6.		90+	10.69	1.17	9.52	47.80
2. Village : Bettageri, Taluk : Madikeri, District : Kodagu.						
7.		0-18	6.68	1.06	5.62	29.89
8.		18-44	8.02	0.89	7.13	37.90
9.		44-82	5.36	0.86	4.50	24.73
10.		82+	6.68	1.05	5.63	35.20
3. Village : Daswal, Taluk : Madikeri, District : Kodagu.						
11.		0-60	28.80	9.18	19.62	55.40
12.		60-85	24.16	13.24	20.92	70.96
13.		85-105	23.64	10.90	12.74	42.17
14.		105+	22.64	6.69	15.95	61.70
4. Village : Chettalli (CRS), Taluk : North Kodagu, District : Kodagu.						
15.		0-45	26.64	1.28	25.36	88.30
16.		45-90	23.14	1.26	21.78	70.50
17.		90-135	26.64	1.49	25.15	72.60
18.		135-180	23.64	2.39	21.25	81.00
5. Village : Balehonur, Taluk : Chikmagalur, District : Chikmagalur.						
19.		0-60	30.72	2.56	28.16	88.80
20.		60-83	26.64	2.54	24.08	87.20
21.		83-101	26.88	0.97	25.91	84.12
22.		101-130	30.48	1.48	29.00	89.20

* CRS : Central Coffee Research Sub-Station.

* CCRI : Central Coffee Research Institute.

4.2.2.3 pH dependent acidity

pH dependent acidity ranged from 4.5-29.0 c.mol.(p⁺) kg⁻¹. Higher values of pH dependent acidity were noticed in profile No. 4 and 5. In these profiles the pH dependent acidity ranged from 21.25-29.0 c.mol.p⁺kg⁻¹. The percent contribution of pH dependent acidity to total acidity ranged from 24.73-88.3 percent .Higher values of pH dependent acidity recorded in profile No. 3,4 and 5. In these profile percent contribution of pH dependent acidity ranged from 42.17-88.3 percent.

4.2.3 Lime requirement and lime potential of the coffee profile soil samples.

Lime requirement and lime potential values are given in the Table - 12.

4.2.3.1 Lime requirement

Maximum lime requirement as per exchangeable calcium method was 10.17 tons per hectare in profile No.3 and the minimum lime requirement was 2.91 tons per hectare in profile No.4. In general lime requirement ranged form 2.91 to 10.17 tons per hectare.

4.2.3.2 Lime potential

The values of lime potential is generally lower as compared to pH in water and pH in KCl. It ranged from 3.76-4.56, 3.66-4.06, 3.25-3.81, 4.47-4.77 and 3.76-4.24 in profile No.1, 2, 3, 4 and 5. Maximum lime potential was recorded in profile No. 1 and 3 and minimum in rest of the profiles.

4.3 CORRELATION STUDIES

4.3.1 Correlation co-efficient (r) among the different properties of the surface soils from coffee growing districts.

Correlation co-efficients (r) were worked out for the soils of Kodagu, Chikmagalur and Hassan district and values have been presented in Table 13, 14 and 15.

- Clay is positively correlated with CEC, ECEC and Exchangeable acidity in all the coffee growing soils of Karnataka.
- Clay is positively correlated with organic carbon, potential acidity and pH dependent acidity in soils of Kodagu and Hassan but it is negatively correlated with soils of Chikmagalur.

Table-12 : Lime requirement and lime potential of the soil profile from coffee growing areas.

Sl. No.	Location	Depth (cm)	Methods		Lime potential
			Buffer method	Exchangeable Calcium method	
----- (tons/ha) -----					
1. Village : Theralu, Taluk : Virajpet, District : Kodagu					
1.		0-15	3.50	4.95	3.76
2.		15-30	3.78	5.34	3.86
3.		30-45	3.46	4.89	4.56
4.		45-60	3.76	5.31	3.76
5.		60-90	4.75	6.71	4.56
6.		90+	4.73	6.69	4.16
2. Village : Battageri, Taluk : Madikeri, District : Kodagu					
7.		0-18	3.86	5.46	3.66
8.		18-44	4.12	5.83	3.26
9.		44-82	3.96	5.60	3.66
10.		82+	5.14	7.26	4.06
3. Village : Daswal, Taluk : Madikeri, District : Kodagu					
11.		0-60	6.77	7.26	3.81
12.		60-85	5.36	6.29	3.20
13.		85-105	9.98	10.17	3.11
14.		105+	7.06	7.26	3.25
4. Village : Chettalli (CRS), Taluk : North Kodagu, District : Kodagu					
15.		0-45	3.55	3.87	4.47
16.		45-90	1.23	2.91	4.55
17.		90-135	2.18	3.35	4.64
18.		135-180	1.03	3.87	4.77
5. Village : Balehonur, Taluk : Chikmagalur, District : Chikmagalur					
19.		0-60	4.24	5.81	3.76
20.		60-83	5.50	7.26	3.96
21.		83-101	3.55	5.33	4.15
22.		101-130	3.58	4.91	4.24

CRS : Central Coffee Research Sub-Station.

CCRI : Central Coffee Research Institute.

- Clay is positively correlated with calcium saturation in soils of Kodagu but it is negatively correlated in soils of Chikmagalur and Hassan district.
- Clay is positively correlated with aluminium saturation in soils of Kodagu and Chikmagalur but it is negatively correlated with soils of Hassan district.
- Organic carbon is positively correlated with ECEC but it is negatively correlated with CEC in all the coffee growing soils
- Potential acidity, exchangeable acidity are positively correlated with organic carbon in soils of Kodagu, Chikmagalur but it is negatively correlated with organic carbon in soils of Hassan.
- Organic carbon is positively correlated with calcium saturation in soils of Hassan and Kodagu but it is negatively correlated in soils of Chikmagalur.
- Aluminium saturation is negatively correlated with organic carbon in soils of Kodagu and Chikmagalur but it is positively correlated in soil of Hassan.
- pH dependent acidity is negatively correlated with organic carbon in soils of Chikmagalur and Hassan but it is positively correlated in soils of Kodagu.
- pH dependent acidity is positively correlated with CEC in all the coffee growing soils.
- CEC is positively correlated with ECEC, potential and exchangeable acidity in soils of Kodagu and Hassan but it is negatively related in soils of Chikmagalur.
- CEC is negatively correlated with calcium saturation and aluminium saturation in soils of Kodagu and Hassan but it is positively correlated in soils of Chikmagalur district.
- Effective CEC is positively correlated with calcium saturation and exchangeable acidity in all the coffee growing district.
- Effective CEC is positively correlated with aluminium saturation in soils of Chikmagalur and Hassan but it is negatively correlated in soils of Kodagu.
- Potential acidity is positively correlated with ECEC in soils of Kodagu and Chikmagalur but it is negatively correlated in soils of Hassan.
- pH dependent acidity is positively correlated with Kodagu soils but it is negatively correlated in soils of Chikmagalur and Hassan.

- Calcium saturation is negatively correlated with aluminium saturation and exchangeable acidity in all the coffee growing soils.
- Potential acidity is positively correlated with calcium saturation in Kodagu soils but it is negatively correlated in soils of Hassan and Chikmagalur.
- pH dependent acidity is positively correlated with calcium saturation in soils of Kodagu and Chikmagalur and negatively correlated in Hassan district soils.
- Potential acidity is positively correlated with aluminium saturation in soils of Kodagu and Hassan but it is negatively correlated in soils of Chikmagalur.
- Exchangeable acidity is positively correlated with aluminium saturation in soils of Kodagu and Chikmagalur but it is negatively correlated on soils of Hassan.
- pH dependent acidity is negatively correlated with aluminium saturation in soils of Kodagu and Chikmagalur but it is positively correlated in soils of Hassan district.
- Potential acidity is positively correlated with exchangeable acidity in soils of Kodagu and Chikmagalur but it is negatively correlated in soils of Hassan.
- pH dependent acidity is positively correlated with potential acidity but it is negatively correlated with exchangeable acidity in all the coffee growing soils of Karnataka.

4.3.2 Correlation co-efficient (r) among the different soil properties of the coffee growing soils with lime requirement methods and lime potential.

Results obtained on correlation co-efficient (r) between different physico-chemical properties and lime requirement by various methods have been recorded in Table 13, 14 and 15.

- Clay, Aluminium saturation, Exchange acidity and pH dependent acidity are positively correlated with buffer and exchangeable calcium method in all the soils of district.
- Buffer method is positively correlated with effective cation exchange capacity and potential acidity in all the soils of district.

Table-13 : Correlation co-efficient(r) among the different properties of the surface soils from coffee growing area of Kodagu district.

Sl. No.	Soil properties	pH in H ₂ O	pH in KCl	pH in CaCl ₂	Buffer method	Exch. Ca. method	Clay	Organic carbon	CEC	ECEC	Ca. Saturation	Al. Saturation	Pot. Acidity	Exch. Acidity	pH dep. Acidity	
1.	pH in Kcl	0.8082**														
2.	pH in CaCl ₂	0.5845*	0.6097*													
3.	Buffer method	-0.5716*	-0.5151*	-0.3970												
4.	Exch. Ca. method	-0.4794	-0.4112	-0.3289	0.8329**											
5.	Clay	-0.1553	-0.1803	-0.1407	0.1738	0.1689										
6.	Organic carbon	0.0636	0.0675	0.2971	0.0763	0.0981	0.1169									
7.	CEC	0.1403	0.0626	0.1992	-0.0026	-0.0925	0.0249	-0.0222								
8.	ECEC	-0.0488	-0.1768	0.1232	0.2582	0.2136	0.2758	0.3474	0.4202							
9.	Ca. Saturation	0.2360	0.1040	0.3668	-0.6087	-0.0183	0.1784	0.3527	-0.0175	0.3358						
10.	Al. Saturation	-0.4272	-0.4028	-0.5299*	0.2844	0.2473	0.0585	-0.1698	-0.1343	-0.0312	-0.5858*					
11.	Pot. Acidity	-0.0614	-0.0838	0.0092	0.2786	0.2474	0.1110	0.0842	-0.4085	0.4570	0.1134	0.0019				
12.	Exch. Acidity	-0.3378	-0.3707	-0.2625	0.4379	0.4326	0.0992	0.1669	0.0753	0.6100	-0.2299	0.5533*	0.3233			
13.	pH dep. Acidity	0.0220	-0.0340	0.1258	0.0614	0.0079	0.0255	0.1542	0.5570*	0.5983	0.2165	-0.1832	0.7088**	-0.0340		
14.	Lime potential	0.6813**	0.7023**	0.8113**	-0.5425*	-0.4233	-0.1406	0.1564	0.0662	-0.0945	0.2509	-0.5062	-0.1090	-0.3615	-0.0374	

* Significant at 5 percent.

** Significant at 1 percent

Table 14 : Correlation co-efficient(r) among the different properties of the surface soils from coffee growing area of Chikmagalur district.

Sl. No.	Soil properties	pH in H ₂ O	pH in KCl	pH in CaCl ₂	Buffer method	Exch. Ca method	Clay	Organic carbon	CEC	ECEC	Ca Saturation	Al Saturation	Pot. Acidity	Exch. Acidity	pH dep. Acidity	
1.	pH in KCl	0.6180*														
2.	pH in CaCl ₂	0.8513**	0.6543**													
3.	Buffer method	-0.4467	-0.3145	-0.4145												
4.	Exch. Ca method	-0.2757	-0.2681	-0.3143	0.7503**											
5.	Clay	-0.2232	-0.0508	-0.3050	0.2761	0.2429										
6.	Organic carbon	-0.1027	-0.1241	-0.2106	-0.1473	-0.0839	-0.1654									
7.	CEC	0.3073	0.2255	0.4236	0.0098	-0.0107	0.0139	-0.6574**								
8.	ECEC	0.1639	0.1922	0.2495	0.0174	-0.0961	0.0455	0.3205	-0.1304							
9.	Ca Saturation	0.3938	0.4081	0.5053	-0.2759	-0.4794	-0.2498	-0.1710	0.2024	0.1011						
10.	Al Saturation	-0.3375	-0.1199	-0.2884	0.3863	0.2506	0.4370	-0.2959	0.0624	0.3063	-0.4468					
11.	Pot. Acidity	-0.1711	-0.1091	-0.2837	0.0110	0.0305	-0.0282	0.7603**	-0.4809	0.3344	-0.1330	-0.2266				
12.	Exch. Acidity	-0.1202	-0.0853	-0.0710	0.2053	0.1741	0.0548	0.2883	-0.2082	0.7106	-0.2299	-0.3834	0.5582*	0.2936		
13.	pH dep. Acidity	-0.1213	-0.0261	-0.0959	0.0750	0.0149	-0.0125	-0.2709	0.1718	-0.3461	0.2761	-0.2411	0.2224	-0.4166		
14.	Lime potential	0.3653	0.2541	0.3154	-0.3558	-0.2277	-0.3189	0.8373**	-0.4620	0.4474	0.0595	-0.4266	0.5625*	0.2552	-0.3821	

* Significant at 5 percent.

** Significant at 1 percent

Table-15 : Correlation co-efficient(r) among the different properties of the surface soils from coffee growing area of Hassan district.

Sl. No.	Soil properties	pH in H ₂ O	pH in KCl	pH in CaCl ₂	Buffer method	Exch. Ca.meth od	Clay	Organic carbon	CEC	ECEC	Ca Saturation	Al. Saturation	Pot. Acidity	Exch. Acidity	pH dep. Acidity	
1.	pH in KCl	0.6954***														
2.	pH in CaCl ₂	0.4622	0.6238*													
3.	Buffer method	0.0880	-0.1266	-0.2393												
4.	Exch. Ca.method	-0.4133	-0.3324	-0.1884	0.2364											
5.	Clay	0.2467	0.1298	0.3348	0.1170	0.2751										
6.	Organic Carbon	0.4384	0.4538	0.2558	-0.2335	-0.1960	0.2198									
7.	CEC	0.3073	0.1799	0.4427	0.0420	-0.2632	0.3738	-0.1627								
8.	ECEC	0.1019	0.0248	0.2919	0.2610	-0.0173	0.3466	0.1757	0.5819*							
9.	Ca Saturation	0.0695	0.1750	0.2214	0.1752	0.0981	-0.0997	0.1170	-0.2554	0.2120						
10.	Al. Saturation	-0.3641	-0.6579***	-0.6482***	0.1033	0.1657	-0.0542	0.0319	-0.1943	0.0230	-0.3285					
11.	Pot. Acidity	0.0657	-0.1206	0.0499	0.3589	-0.0157	0.1072	-0.2356	0.2245	-0.1304	-0.1980	0.3342				
12.	Exch. Acidity	-0.1812	-0.1919	-0.1674	0.2486	0.3420	0.6164*	-0.2062	0.0134	0.0513	-0.0344	-0.1490	-0.2317			
13.	pH dep. Acidity	0.1038	-0.133	0.1291	0.2872	-0.0343	0.0514	-0.2803	0.2110	-0.2171	-0.1256	0.1963	0.9786**	-0.2505		
14.	Lime potential	-0.3097	0.0436	-0.0039	-0.0498	-0.3412	-0.4532	-0.0890	-0.3223	-0.0105	0.3269	-0.2049	-0.3536	-0.1219	-0.3335	

* Significant at 5 percent.

** Significant at 1 percent.

- Buffer method is negatively correlated with effective pH and calcium saturation in soils of Kodagu and Chikmagalur. But it is positively correlated with soils of Hassan district.
- Organic carbon is negatively correlated with Buffer method in soils of Chikmagalur and Hassan but it is positively correlated with soils of Kodagu soils.
- Cation exchange capacity is positively correlated with soils of Chikmagalur and Hassan but it is negatively correlated with Kodagu soil.
- Exchangeable calcium method is negatively correlated with pH and effective cation exchange capacity.
- Calcium saturation is negatively correlated with exchangeable calcium method in soils of Kodagu and Chikmagalur but it is positively correlated with Hassan soils.
- Organic carbon content is negatively correlated with both the methods of lime requirement soils of Chikmagalur and Hassan but it is positively correlated with Kodagu soils.
- Lime potential is positively correlated with calcium saturation but it is negatively correlated with clay content, pH dependent acidity aluminium saturation in coffee growing soils.
- Lime potential is positively correlated with pH, organic carbon in soils of Kodagu and Chikmagalur but it is negatively correlated with soils of Hassan.
- Effective CEC, potential acidity and exchangeable acidity are negatively correlated with soils of Kodagu and Hassan but it is positively correlated with soils of Chikmagalur.
- Cation exchange capacity is negatively correlated with lime potential in soils of Chikmagalur and Hassan but it is positively correlated with soils of Kodagu.

4.3.3 Correlation co-efficient (r) among the different soil properties of profile sample with lime requirement method and lime potential.

Results obtained on correlated co-efficient (r) among the different soil properties of profile samples with lime requirement method and lime potential have been presented in the Table 16, 17, 18, 19 and 20.

Table-16 : Correlation co-efficient(r) among the different properties of the profile sample from Teralu

Sl. No.	Soil properties	pH in H ₂ O	pH in KCl	pH in CaCl ₂	Line potential	Buffer method	Exch. Ca method	Clay	Organic carbon	CEC	EC/EC	Ca Saturation	Al Saturation	Pot Acidity	Exch. Acidity
1.	pH in KCl	0.7248**													
2.	pH in CaCl ₂	0.8863**	0.6424**												
3.	Line potential	0.7920**	0.2844	0.5400**											
4.	Buffer method	0.8206**	0.8623**	0.7224**	0.3948										
5.	Exch. Ca method	0.8205**	0.8610**	0.7227**	0.3941	1.0000									
6.	Clay	0.8738**	0.7961**	0.6527**	0.7636**	0.7472**	0.7460**								
7.	Organic carbon	-0.8276**	-0.9532**	-0.7492**	-0.4390	-0.9140**	-0.9136**	-0.8839**							
8.	CEC	-0.8200**	-0.9800**	-0.7704**	-0.3860	-0.8991**	-0.8985**	-0.8410**	0.9855**						
9.	EC/EC	-0.7042**	-0.5947*	-0.5680*	-0.6259*	-0.3828	-0.3803	-0.6552**	0.5138*	0.5149*					
10.	Ca Saturation	-0.2313	0.0432	-0.0623	-0.5545*	0.2642	0.2669	-0.2374	-0.1142	-0.0529	0.7526**				
11.	Al Saturation	0.7885**	0.8744**	0.5900*	0.6131*	0.6727**	0.6705**	0.9316**	-0.8558**	-0.8676**	-0.8129**	-0.3784			
12.	Pot. Acidity	-0.8791**	-0.9541**	-0.8291**	-0.4636	-0.8856**	-0.8848**	-0.8361**	0.9523**	0.9836**	0.7013**	0.0731	-0.8764**		
13.	Exch. Acidity	0.5490*	0.8427*	0.4126	0.2759	0.7358**	0.7352**	0.8107**	-0.8912**	-0.8335**	-0.2543	0.2482	0.7658**	-0.7313**	
14.	pH dep. Acidity	-0.8769**	-0.9590**	-0.8200**	-0.4641	-0.8902**	-0.8895**	-0.8440**	0.9585**	0.9868**	0.6936**	0.6645**	-0.8814**	0.9997**	-0.7466**

* Significant at 5 percent.

** Significant at 1 percent.

Table 17: Correlation co-efficient (r) among the different properties of the profile sample from Bettigeri.

Sl. No.	Soil properties	pH in H ₂ O	pH in KCl	pH in CaCl ₂	Lime potential	Buffer method	Exch. Ca. method	Clay	Organic carbon	CEC	ECEC	Ca. Saturation	Al. Saturation	Pot. Acidity	Exch. Acidity
1.	pH in KCl	0.1983													
2.	pH in CaCl ₂	0.9798**	0.0000												
3.	Lime potential	0.9798**	0.0000	1.0000**											
4.	Buffer method	0.7618**	0.2691	0.7160**	0.7060**										
5.	Exch. Ca. method	0.7602**	0.2702	0.7041**	0.7041**	1.0000**									
6.	Clay	-0.3708	-0.7656**	-0.2390	-0.2390	0.0165	0.0171								
7.	Organic carbon	-0.6863**	0.3238*	-0.7990**	-0.7990**	-0.6167*	-0.6150*	-0.3864							
8.	CEC	-0.6446**	0.5374*	-0.7570**	-0.7571**	-0.6333*	-0.6318*	-0.4524	0.9961**						
9.	ECEC	0.9563**	0.2069	0.9411**	0.9410**	0.5448*	0.5428*	-0.5432*	-0.5645*	-0.5017					
10.	Ca. Saturation	0.9495**	-0.0997	0.9857**	0.9857**	0.7580**	0.7562**	-0.0783	-0.8399**	-0.8502*	0.8707**				
11.	Al. Saturation	-0.7805**	0.4141	-0.8859**	-0.8859**	-0.3771	-0.3745	0.0197	0.8630**	0.8155**	-0.8040**	0.0-0.8862**			
12.	Pot. Acidity	-0.3309	0.7697**	-0.5038	-0.5038	0.1083	0.1109	-0.2346	0.6898**	0.8493**	-0.4197	-0.5201*	0.8470**		
13.	Exch. Acidity	0.7448**	0.7147**	0.6237*	0.6237*	0.4253	0.4244	-0.8853**	-0.0306	0.02985	0.8196**	0.5006	-0.3229	0.1117	
14.	pH dep. Acidity	-0.4052	0.7051**	-0.5674*	-0.5674*	0.0678	0.0704	-0.1501	0.6970**	0.6504**	-0.5019	0.5719*	0.0036**	0.9953**	0.0153

* Significant at 5 percent.

** Significant at 1 percent.

Table 18 : Correlation co-efficient (r) among the different properties of the profile sample from Madikeri

Sl. No.	Soil properties	pH in H ₂ O	pH in KCl	pH in CaCl ₂	Lime potential	Buffer method	Exch. Ca. method	Clay	Organic carbon	CEC	ECEC	Ca Saturation	Al Saturation	Pot Acidity	Exch. Acidity	
1.	pH in KCl	0.9940**														
2.	pH in CaCl ₂	0.9840**	0.9825**													
3.	Lime potential	0.9740**	0.9645**	0.9933**												
4.	Buffer method	-0.2188	-0.1157	-0.1986	-0.3102											
5.	Exch. Ca. method	-0.2722	-0.1671	-0.2287	-0.3369	0.9918**										
6.	Clay	0.1813	0.0835	0.1904	0.3028	-0.9889	-0.9622									
7.	Organic carbon	-0.7787**	-0.8351**	-0.7528**	-0.6757**	-0.4335	-0.3674	0.4758								
8.	CEC	0.6612**	0.6955**	0.7959**	0.7808**	-0.0137	-0.0329	0.0958	-0.5212*							
9.	ECEC	-0.6491**	-0.6732**	-0.5240*	-0.4632	-0.3058	-0.1923	0.4162	0.8525**	-0.0430						
10.	Ca Saturation	0.8534**	0.8268**	0.7333**	0.7299**	-0.2284	-0.3326	-0.1213	-0.6921**	0.1752	-0.8495**					
11.	Al Saturation	-0.2787	-0.2512	-0.0849	-0.0711	0.0077	0.1336	0.1409	0.3504	0.5161*	0.7876**	-0.7336**				
12.	Pot Acidity	0.8450**	0.8539**	0.9330**	0.9344**	-0.2181	-0.2013	0.2633	-0.5814*	0.9481**	-0.2091	-0.4453	0.2781			
13.	Exch. Acidity	-0.4932	-0.4919	-0.3251	-0.2851	-0.1617	-0.0352	0.2983	0.6477**	0.2457	0.9473**	-0.8376	0.9435**	0.0330		
14.	pH dep. Acidity	0.9607**	0.9662**	0.9021**	0.8754**	-0.0382	-0.1177	-0.0282	-0.8794**	0.5003	-0.8347**	0.9239**	-0.4872	0.6911**	-0.06996**	

* Significant at 5 percent.

** Significant at 1 percent.

Table 19 : Correlation co-efficient (r) among the different properties of the profile sample from Chottail

Sl. No.	Soil properties	pH in H ₂ O	pH in KCl	pH in CaCl ₂	Lime potential	Buffer method	Exch. Ca.method	Clay	Organic carbon	CEC	ECEC	Ca. Saturation	Al. Saturation	Pot. Acidity	Exch. Acidity	
1.	pH in KCl	0.5853*														
2.	pH in CaCl ₂	0.0835	0.0907													
3.	Lime potential	0.7269**	0.1801	-0.5689*												
4.	Buffer method	-0.8110**	-0.0053	-0.1219	-0.7127**											
5.	Exch. Ca.method	0.0760	0.6083*	-0.6688**	0.2853	0.4014										
6.	Clay	0.7643**	0.3284	-0.5688*	0.9872**	-0.6518**	0.4046									
7.	Organic carbon	-0.7527**	0.0909	-0.0909	-0.7071**	0.9951**	0.4432	-0.6323*								
8.	CEC	-0.3638	-0.3060	0.8877**	-0.7996**	0.1504	-0.7679**	-0.8416**	0.1410							
9.	ECEC	-0.3376	-0.1134	-0.9541**	0.3001	0.4127	0.7149**	0.3144	0.3802	-0.7541**						
10.	Ca. Saturation	-0.8794**	-0.7736**	-0.4418	-0.3247	0.5580*	-0.0365	-0.4033	0.4744	0.0298	0.5942*					
11.	Al. Saturation	0.9743**	0.7512**	0.0616	0.6602**	-0.6582**	0.2519	0.7317**	-0.5850*	-0.4092	-0.2761	-0.9168**				
12.	Pot. Acidity	-0.6253**	0.1903	0.3534	-0.8914**	0.8729**	0.1640	-0.8121**	0.8971**	0.4925	-0.0658	0.1992	-0.4677			
13.	Exch. Acidity	0.8674**	0.6623**	-0.3753	0.8563**	-0.5542*	0.5270*	0.9236**	-0.4992	-0.7624**	0.1573	-0.6610**	0.9021**	-0.5823*		
14.	pH dep. Acidity	-0.5828*	0.2780	0.2676	-0.8262**	0.8912**	0.2881	-0.7321**	0.9218**	0.3814	0.0157	0.1703	-0.4062	0.9917**	-0.4877	

* Significant at 5 percent.

** Significant at 1 percent.

Table 20 : Correlation co-efficient (r) among the different properties of the profile sample from Babbar

Sl. No.	Soil properties	pH in H ₂ O	pH in KCl	pH in CaCl ₂	Lime potential	Buffer method	Exch. Ca method	Clay	Organic carbon	CEC	ECEC	Ca Saturation	Al. Saturation	Pot. Acidity	Exch. Acidity
1.	pH in KCl	0.8271**													
2.	pH in CaCl ₂	0.8268**	0.8598**												
3.	Lime potential	0.8263**	0.8505**	0.9998**											
4.	Buffer method	-0.7984**	-0.8587**	-0.5425*	-0.5311*										
5.	Exch. Ca method	-0.7226**	-0.8887**	-0.5454*	-0.5318*	0.9831*									
6.	Clay	0.9119**	0.9768**	0.9285**	0.9230**	-0.8149**	-0.8143**								
7.	Organic carbon	-0.6785**	-0.5895*	-0.9193**	-0.9262**	0.2018	0.1806	-0.7180**							
8.	CEC	0.4292	0.7183**	0.2623	0.2449	-0.8787**	-0.9338**	0.5990*	0.1386						
9.	ECEC	-0.8633**	-0.6888**	-0.9346**	-0.9405**	0.4279	0.3701	-0.8238**	0.9519**	-0.0242					
10.	Ca Saturation	0.2583	0.7465**	0.5967*	0.5836*	-0.4508	-0.5928*	0.6310*	-0.3584	0.6072**	-0.2732				
11.	Al. Saturation	-0.1876	-0.1592	0.3017	0.3128	0.6315*	0.5892*	-0.0675	-0.5922*	-0.7047**	-0.3322	0.1264			
12.	Pot. Acidity	-0.1801	0.3073	-0.1543	-0.1732	-0.4139	-0.5446*	0.0972	0.4883	0.7978**	0.4712	0.6207*	-0.5174*		
13.	Exch. Acidity	-1.0000**	-0.8309**	-0.8347*	-0.8343**	0.7945**	0.7203**	-0.9158**	0.6880**	-0.4257	0.8691**	-0.2670	0.1753	0.1815	
14.	pH dep. Acidity	0.6598**	0.9531**	0.8651**	0.8555**	-0.6859**	-0.7612**	0.9101**	-0.6294**	0.6267**	-0.6367*	0.8943**	0.0658	0.3596	0.6672**

* Significant at 5 percent.

** Significant at 1 percent.

4.3.3.1 Teralu

Both the methods of lime requirement are significantly and positively correlated with pH (0.8206**, 0.7472**), clay (0.6726*, 0.7358**), aluminium saturation (0.6727**, 0.6705**) and exchangeable acidity (0.7358**, 0.7352**) and exchangeable acidity (0.7358**, 0.7352**).

These methods had significant negative correlations with organic carbon (-0.9140**, -0.9136**), CEC (-0.8991**, -0.8985**) and potential acidity (-0.8856**, -0.8848).

Lime potential was significantly and positively correlated with pH (0.7920**), clay (0.7636**) and aluminium saturation (0.6134**), and negatively correlated with organic carbon, CEC, ECEC, calcium saturation potential acidity but the values were not significant.

4.3.3.2 Bettageri

Lime requirement methods are positively correlated with pH (0.7616**, 0.7602**), ECEC (0.5448**, 0.5428**) and calcium saturation (0.7580**, 0.7564**) and negatively correlated with organic carbon (-0.6167*, -0.6150*) and CEC (-0.6333*, -0.6318*)

Lime requirement is also found to be positively correlated with all forms of acidity but the value was not significant.

Lime potential had a significant positive correlation with pH (0.9798**), ECEC (0.9410**), calcium saturation (0.985**), and extractable acidity (0.623*) but negatively correlated with organic carbon, CEC, aluminium saturation and pH dependent acidity (-0.7990**, -0.7571**, -0.959** and -0.574*). It is also negatively correlated with potential acidity but the value was not significant.

4.3.3.3 Madikeri

Both the method of lime requirement are negatively correlated with pH, organic carbon, CEC, ECEC, calcium saturation of all forms of acidity but the values were not significant.

Al saturation is positively correlated with both the methods of lime requirement but the values were not significant.

Lime potential had a significant positively correlation with pH, CEC, Calcium saturation, potential acidity and pH dependent acidity (0.974**, 0.7806**, 0.7299**, 0.9349** and 0.9021**).

It is also correlated negatively with clay, ECEC, aluminium saturation and exchangeable acidity but the values were not significant.

4.3.3.4 Chettalli

Buffer method is negatively correlated with pH (-0.811**), clay (-0.6518**), aluminium saturation (-0.6582**) and exchangeable acidity (-0.5542*) and positively with organic carbon (0.9951*), calcium saturation (0.5580*), potential acidity (0.8729**) and pH dependent acidity (0.8912**).

Lime potential had positive significant correlated with pH (0.7268**), clay (0.9872**), aluminium saturation (0.6602**) and exchangeable acidity (0.8563**) and negative significant correlated with organic carbon (-0.7071**), CEC (-0.7996**), potential acidity (-0.8914**) and pH dependent acidity (-0.8262**).

4.3.3.5 Balehonur

Both the method of lime requirement had a significant positively correlated with aluminium saturation (0.6315*), 0.5892*) and exchangeable acidity (0.7985**, 0.7203**) and negatively correlated with pH (-0.7984**, -0.7226**), clay (-0.814**, -0.8143**), CEC (-0.8787**, -0.9338**) and pH dependent acidity (-0.6859**, -0.7612**).

Lime potential had significant positively correlated with pH (0.8263**) clay (0.9230**), calcium saturation (0.5836*) and pH dependent acidity (0.8555**), and negatively correlated with organic carbon (-0.9262**), effective cation exchange capacity (-0.9805**) and exchangeable acidity (-0.8343**).

4.4 POT CULTURE STUDIES

4.4.1 Influence of varying levels of lime requirement and calcium saturation on the neutralisation of soil acidity (Table - 21).

4.4.1.1 Soil pH

There was a significant increase in soil pH with lime levels over control and fertilizer treatments. The maximum change in pH per unit of lime addition was within 30 days, after the addition of lime to acid soils (2.83 units at 2.00 lime requirement and 2.7 units in 100 percent calcium saturation).

Table-21 : Effect of different levels of lime on the neutralization of soil acidity.

Sl. No.	Treatments	30 days						60 days						90 days						120 days						150 days						Potential Acidity																																																																		
		H ₂ O		KCl		pH		H ₂ O		KCl		pH		H ₂ O		KCl		pH		H ₂ O		KCl		pH		H ₂ O		KCl		pH		90		120		150 days																																																														
1	Absolute control	5.00	4.73	5.01	5.71	5.01	5.08	5.14	5.13	5.81	5.17	27.20	25.00	23.80	23.60	23.22	5.30	4.89	4.97	5.65	4.99	5.69	5.03	29.20	24.60	24.70	23.90	24.80	5.60	5.59	5.87	6.79	5.93	6.83	6.02	22.77	19.23	18.63	18.36	18.10	6.87	5.93	7.18	6.21	7.21	6.29	6.49	7.31	6.55	18.36	16.83	15.72	14.89	14.88	7.06	6.21	7.68	6.49	7.68	6.55	7.67	6.68	6.69	15.23	14.65	14.35	13.87	13.80	7.67	6.69	8.03	7.00	8.17	7.06	8.21	7.12	8.26	7.15	10.68	7.68	6.89	6.03	5.87	7.83	6.72	8.18	7.36	8.29	7.44	8.39	7.59	8.44	7.64	5.95	4.59	3.93	2.51	2.27
2.	NPK alone	5.30	4.89	4.97	5.65	4.99	5.69	5.03	29.20	24.60	24.70	23.90	24.80	5.60	5.59	5.87	6.79	5.93	6.83	6.02	22.77	19.23	18.63	18.36	18.10	6.87	5.93	7.18	6.21	7.21	6.29	6.49	7.31	6.55	18.36	16.83	15.72	14.89	14.88	7.06	6.21	7.68	6.49	7.68	6.55	7.67	6.68	6.69	15.23	14.65	14.35	13.87	13.80	7.67	6.69	8.03	7.00	8.17	7.06	8.21	7.12	8.26	7.15	10.68	7.68	6.89	6.03	5.87	7.83	6.72	8.18	7.36	8.29	7.44	8.39	7.59	8.44	7.64	5.95	4.59	3.93	2.51	2.27															
3.	NPK + 0.25 LR	5.60	5.59	5.87	6.79	5.93	6.83	6.02	22.77	19.23	18.63	18.36	18.10	6.87	5.93	7.18	6.21	7.21	6.29	6.49	7.31	6.55	18.36	16.83	15.72	14.89	14.88	7.06	6.21	7.68	6.49	7.68	6.55	7.67	6.68	6.69	15.23	14.65	14.35	13.87	13.80	7.67	6.69	8.03	7.00	8.17	7.06	8.21	7.12	8.26	7.15	10.68	7.68	6.89	6.03	5.87	7.83	6.72	8.18	7.36	8.29	7.44	8.39	7.59	8.44	7.64	5.95	4.59	3.93	2.51	2.27																											
4.	NPK + 0.5 LR	6.87	5.93	7.18	6.21	7.21	6.29	6.49	7.31	6.55	18.36	16.83	15.72	14.89	14.88	7.06	6.21	7.68	6.49	7.68	6.55	7.67	6.68	6.69	15.23	14.65	14.35	13.87	13.80	7.67	6.69	8.03	7.00	8.17	7.06	8.21	7.12	8.26	7.15	10.68	7.68	6.89	6.03	5.87	7.83	6.72	8.18	7.36	8.29	7.44	8.39	7.59	8.44	7.64	5.95	4.59	3.93	2.51	2.27																																							
5.	NPK + 1 LR	7.06	6.21	7.68	6.49	7.68	6.55	7.67	6.68	6.69	15.23	14.65	14.35	13.87	13.80	7.67	6.69	8.03	7.00	8.17	7.06	8.21	7.12	8.26	7.15	10.68	7.68	6.89	6.03	5.87	7.83	6.72	8.18	7.36	8.29	7.44	8.39	7.59	8.44	7.64	5.95	4.59	3.93	2.51	2.27																																																					
6.	NPK + 1.5 LR	7.67	6.69	8.03	7.00	8.17	7.06	8.21	7.12	8.26	7.15	10.68	7.68	6.89	6.03	5.87	7.83	6.72	8.18	7.36	8.29	7.44	8.39	7.59	8.44	7.64	5.95	4.59	3.93	2.51	2.27	6.60	5.57	6.70	5.53	6.80	5.57	6.87	5.64	6.92	5.69	22.7	22.30	21.50	20.70	19.80																																																				
7.	NPK + 2.0 LR	7.83	6.72	8.18	7.36	8.29	7.44	8.39	7.59	8.44	7.64	5.95	4.59	3.93	2.51	2.27	6.60	5.57	6.70	5.53	6.80	5.57	6.87	5.64	6.92	5.69	22.7	22.30	21.50	20.70	19.80	Saturation																																																																		
8.	NPK +25% Ca. Saturation	6.60	5.57	6.70	5.53	6.80	5.57	6.87	5.64	6.92	5.69	22.7	22.30	21.50	20.70	19.80	6.80	5.83	7.00	6.00	6.97	5.95	6.84	6.00	6.94	6.10	19.4	17.0	15.50	14.90	13.90	Saturation																																																																		
9.	NPK + 50 % Ca. Saturation	6.80	5.83	7.00	6.00	6.97	5.95	6.84	6.00	6.94	6.10	19.4	17.0	15.50	14.90	13.90	7.0	6.00	7.26	6.40	7.50	6.50	7.60	6.54	7.63	6.65	16.0	15.0	14.70	13.80	13.60	Saturation																																																																		
10.	NPK + 75 % Ca. Saturation	7.0	6.00	7.26	6.40	7.50	6.50	7.60	6.54	7.63	6.65	16.0	15.0	14.70	13.80	13.60	7.70	6.70	7.90	6.80	7.93	6.90	8.00	7.20	8.10	7.30	11.0	10.0	8.60	7.00	5.90	Saturation																																																																		
11.	NPK + 100 % Ca. Saturation	7.70	6.70	7.90	6.80	7.93	6.90	8.00	7.20	8.10	7.30	11.0	10.0	8.60	7.00	5.90	Saturation																																																																																	

* LR : Lime Requirement.

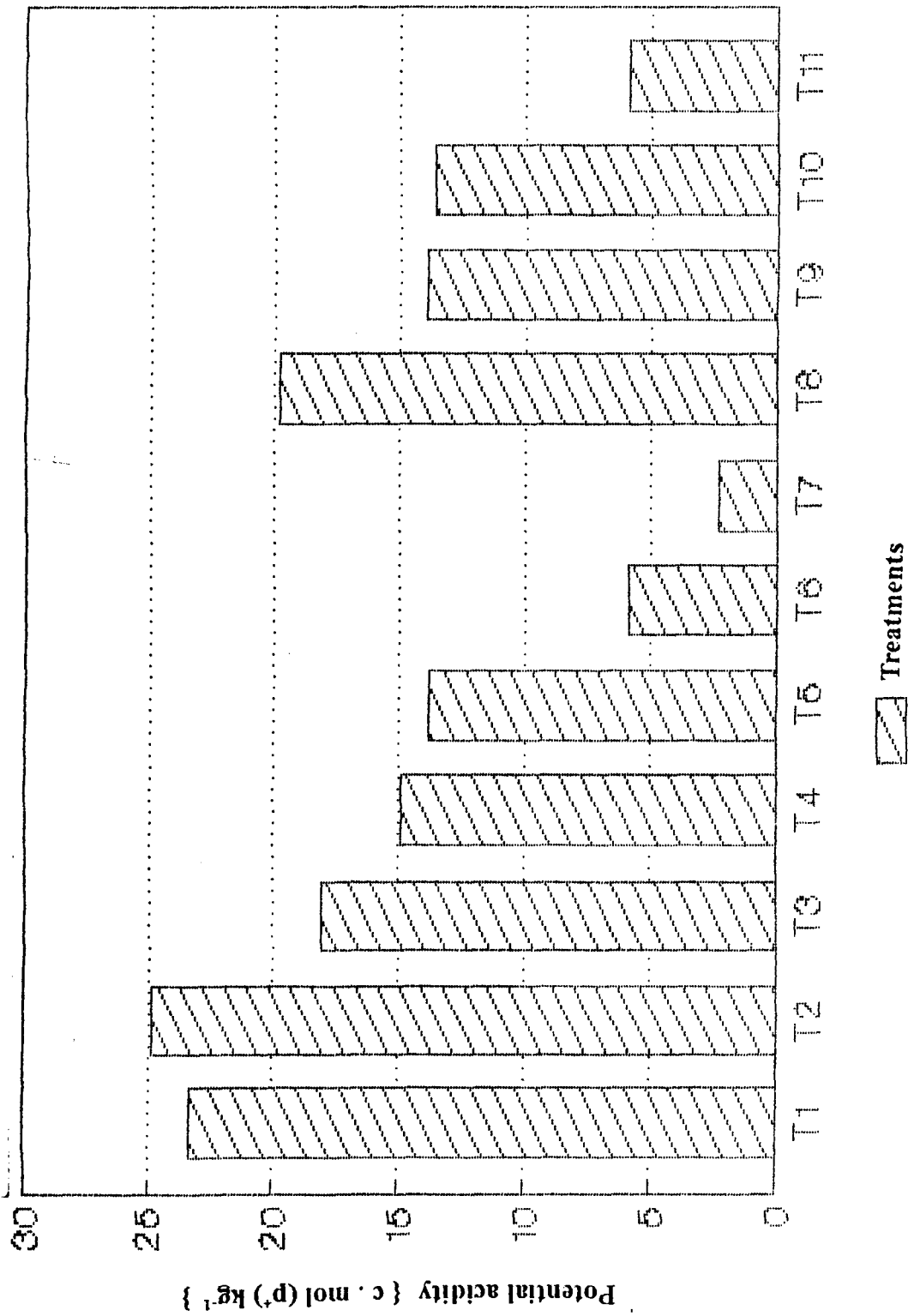


Figure - 8 : Lime and Potential acidity relationship.

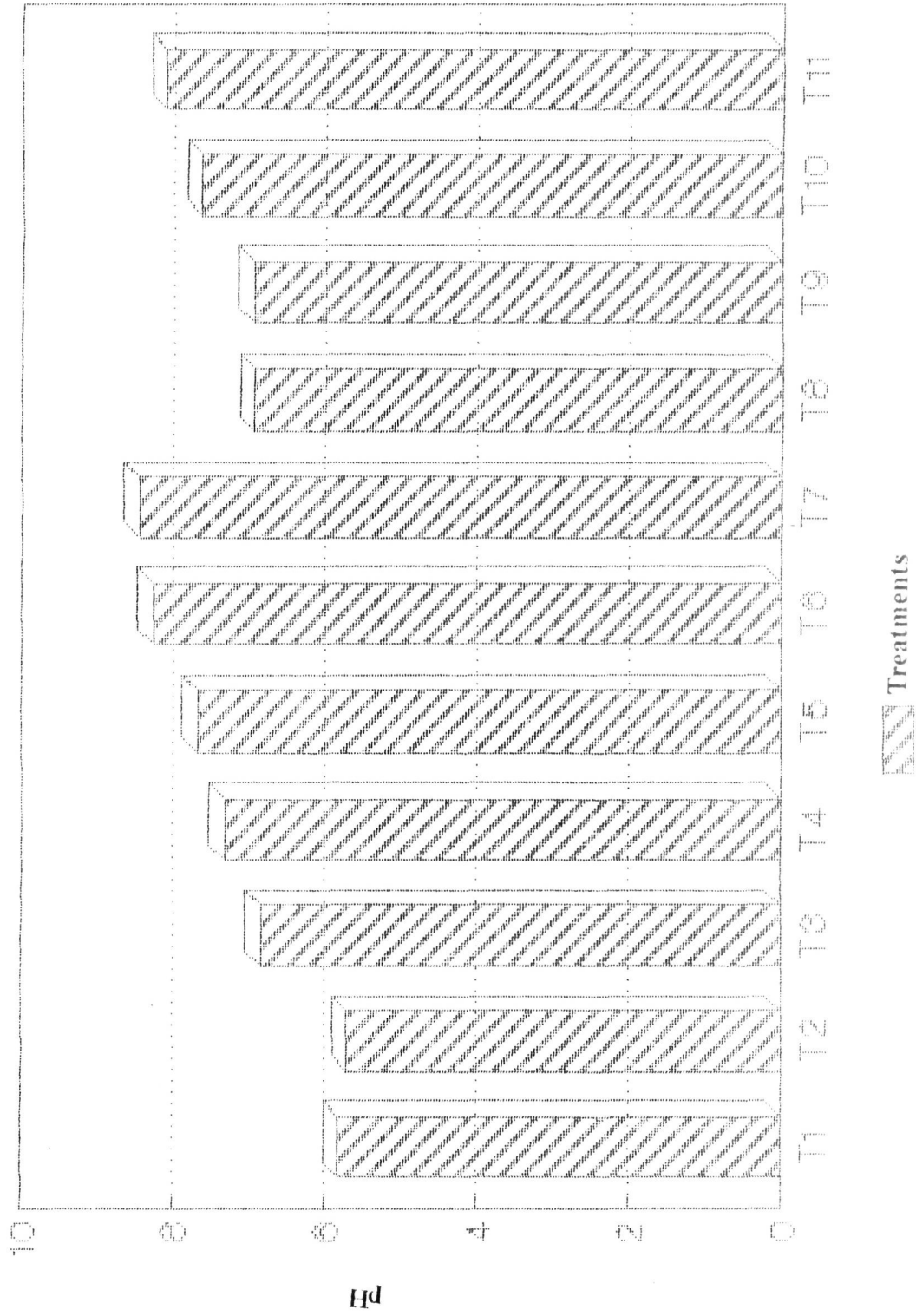


Figure - 7 : pH and Lime Requirement relationship.

Potential acidity decreased considerably due to the lime addition. In control plots potential acidity was 27.2 c. mol (p⁺) kg⁻¹. This was reduced to 2.27 and 5.90 c. mol (p⁺) kg⁻¹ in 2.00 lime requirement and 100 percent calcium saturation level after 5 months.

4.4.2 Nutrient content in plant as influenced by the addition of different levels of lime (Table - 22).**4.4.2.1 Plant height**

Although significant difference in the plant height were noticed among the treatment, no definite trend could be established in one an half year old seedlings.

4.4.2.2 Number of leaves

Lime addition at lower levels has increase the number of leaves increased from 14 in control to 17 in 1.00 lime requirement and 15 in 25 percent calcium saturation to 17 in 75 percent calcium saturation.

4.4.2.3 Phosphorus

Lime addition caused significant changes in 'P' content of the plants. Successive increment of lime addition has resulted in significant increase in P content. The 'P' content in control treatment was 0.16 percent. It raised to 0.32 and 0.28 percent in 2.00 lime requirements and 100% calcium saturation.

4.4.2.4 Potassium

Addition of lime significantly decreased the potassium content in coffee seedlings. As compared to control treatment the decrease in 'K' content was 2.6 percent in 2.00 lime requirement and 2.1 percent in 100% calcium saturation level.

4.4.2.5 Calcium

Calcium content in plants increased with lime addition in both lime requirement and calcium saturation treatments.

4.4.2.6 Magnesium

Magnesium content in plants significantly increased due to the addition of lime. Very low content of 'Mg' noticed in 2.00 lime requirement treatment (0.03) and in 100% calcium saturation level (0.03).

Table-22 : Effect of lime addition on the plant characters and nutrient content at 5 months after transplanting.

Sl. No.	CHARACTERS	TREATMENTS														F-test	SEM	CD at 5%	CV %
		1	2	3	4	5	6	7	8	9	10	11	12	13	14				
1.	Plant height	18.0	21.0	22.0	22.0	25.0	19.0	19.0	18.1	15.1	17.0	19.0	19.0	17.0	19.0	*	0.7267	2.2897	3.9187
2.	No. of Leaves	14	16	15	16	17	14	14	15	16	17	14	14	17	14	NS	0.7986	2.5163	4.9148
3.	Nutrient content in plants																		
	% N	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.02	NS	0.1682	0.5300	33.6852
	% P	0.16	0.20	0.22	0.29	0.27	0.32	0.30	0.22	0.25	0.28	0.29	0.28	0.28	0.29	*	0.0580	0.1828	2.8504
	% K	3.50	5.60	3.40	2.10	2.70	2.20	2.60	2.60	2.10	2.40	2.10	2.40	2.10	2.10	*	0.2373	0.7478	3.4279
	% Ca.	0.14	0.13	0.14	0.13	0.11	0.13	0.15	0.10	0.11	0.11	0.13	0.11	0.11	0.13	*	0.7740	0.2438	5.7224
	% Mg.	0.02	0.03	0.04	0.04	0.04	0.05	0.03	0.08	0.03	0.04	0.03	0.04	0.04	0.03	NS	0.1558	0.4909	19.9718
	% S	0.07	0.11	0.11	0.12	0.12	0.13	0.16	0.01	0.01	0.01	0.02	0.01	0.01	0.02	*	0.1895	0.5972	18.8766

* Significant at 5 percent.

NS : Non Significant

4.4.2.7 Sulfur

Liming significantly increased sulfur content of plants. Maximum content of 0.16 percent and 0.02 percent were registered where 2.00 lime requirement and 100 percent calcium saturation treatments were improved. Low content of 0.01 percent was noticed in case of control plot.

DISCUSSION

V. DISCUSSION

5.1 Characterisation of soil acidity.

One hundred and seventy surface and five profile soil samples were collected from coffee growing tracts of Kodagu, Chikmagalur and Hassan district. In this chapter, physico chemical properties, lime requirement methods and their interrelationship besides the effect of lime on coffee seedlings are discussed.

Soils under coffee cultivation are fairly deep 17.5 to 35 cms depth. Soils are covered with thick vegetation and with intense biological activity (Krishnamurthy Rao and Ramaiah, 1993). The soils fall under the textural class of sandy loam and sandy clay loam. This is due to the parent material derived from granite, gneiss and dibase rocks, either they are red loam or non gravelly red loams. Taxonomically these soils belong to Alfisol, Ultisol and Inceptisol. They generally contain low acid insolubles ranging between 15 to 20 percent. Silica sesquioxide ratio is lower than two (Krishnappa Naik et.al. 1988).

The pH of soils are distinctly acidic and it ranged from 3.1 to 5.6, 5.2 to 6.4 and 4.8 to 6.4 in Kodagu, Chikmagalur and Hassan district respectively. Organic carbon varies from medium to high and it ranged from 0.5 to 3.8, 0.2 to 3.4 and 0.3 to 2.1 in Kodagu, Chikmagalur and Hassan district respectively. The clay content varies from 15 to 42.5, 16.3 to 48.5 and 16.3 to 42.5 percent in these respective districts. The clay belongs to Kaolinitic type. Cation exchange capacity of surface soils ranged from 7.3 to 42.3, 20.2 to 33.1 and 17.4 to 38.5 c.mol (p⁺) kg⁻¹. It is interesting to know that cationic exchange capacity is rather high in majority of profile tested. It is a fact that CEC is highly dependent on the valency of the extracting cation. Hesse (1973) reported that when divalents like barium were used in extractant, CEC values were rather high. This is because barium ion extracts soluble cations in addition to exchangeable cations. He further states if an accurate assessment of CEC wanted, it is necessary to eliminate salt, by leaching. The lower value of CEC in the surface soil indicate the permanent charge contribution to the total net negative charge is less. The percent base saturation varies from 4.8 to 45.5, 15.2 to 42.3 and 14.9 to 33.5 percent. Aluminium saturation varies from 10.5 to 85.0, 26.4 to 80.7 and 14.6 to 49.3 and calcium saturation varies from 5.09 to 66.5, 8.70 to 24.1 and 5.26 to 27.95 in Kodagu, Chikmagalur and Hassan district. C:N ratio of these coffee soils range from 1:26 to 1:20, 1:29 to 50.0 and 1:48 to 1:33.5 in respective districts.

In majority of profile and surface samples, available phosphorus and sulfur content was low to marginal with few exception. This may be due to adsorption of phosphorus to iron and aluminium surfaces of low solubility. Sulfate will be leached due to high

rainfall, when OH^- of water displace $\text{SO}_4^{=}$ from the anion exchange sites. The results corroborate with those of Sreedhar Adiga and Ananthanarayana, 1996 and Dolui and Nayak, 1981.

Exchangeable calcium, magnesium, and potassium values recorded in all the profile and surface soils are low. However there is no definite trend in this regard.

The pH of soil in neutral salt solution (0.1 N KCl or 0.01 M CaCl_2) decreased when compared to pH in soil water suspension. It is due to the displacement of adsorbed hydrogen and aluminium ion from the surface of clay into solution by cation of the salts. For soils carrying positive charge the anion of the salt can exchange with such anions as OH^- adsorbed by the clay resulting in raise of pH in salt solution, when compared to pH in water suspension. In the present investigation on all the soils gave lower pH in salt solution indicating that clay particles are carrying net negative charge (Mongia and Bondyopadyay, 1991)

The cause for low base saturation in these soils is due to acidic parent material (granite, gneiss schist and laterite) and high rainfall leading to leaching of bases. The high aluminium saturation is mainly due to aluminium rich silicate clay and trivalent aluminium adsorbed on the pH dependent charge.

5.2 Nature of soil acidity

The pH value of soil indicate that they are acidic in nature 3.9 to 5.9. Soil acidity is essentially due to the exchangeable H^+ ion Aluminium also contributes to acidity through the stepwise hydrolysis , resulting H^+ ion.

The basic chemistry of aluminium in soil acidity involved in that, the clay particle interact with H^+ ion. The Hydrogen saturated clay undergo spontaneous decomposition. The Hydrogen ion penetrate the octahedral layer and replaces the Al atoms. The Al released is than adsorbed by the clay complex and a H-Al-clay complex is formed rapidly. The Al^{3+} ions may hydrolyze and produce H^+ ions.

Clay Al + 3 H_2O \longrightarrow $\text{Al}(\text{OH})_3$ + H Clay \rightleftharpoons H^+ . The reaction contributes to increase in H^+ ion concentration in clay (Kim. H.Tan, 1993).

In the district of Kodagu, Chikmagalur and Hassan, rainfall is more than 1000 mm, which causes leaching of bases and the deciduous forest contributes to the organic matter accumulation. The organic matter decomposition results in the formation of weak acids

and results in soil acidity (Govindarajan and Venkata Rao, 1976): According to Ganeshmurthy and Mongia (1989), non recycling of basic cation like calcium and magnesium would also be reason to low calcium saturation and increase in acidity in soil.

5.3 Forms of acidity

Soil acidity comprises of active acidity and potential acidity (Brady, 1991). Several forms of acidity contribute to the total acidity. As compared to the total acidity, the values of exchangeable acidity are low in all the soils. According to Coleman and Thomas (1967), the exchange acidity as a part of total acidity varies with nature of soil and base saturation.

The barium chloride triethanol amine exchangeable acidity value for the soils suggest that nature of soil acidity is pH dependent acidity. Misra et.al., (1989), reported that pH dependent acidity contributed more than 83 percent of the total acidity. pH dependent acidity ranging from 8.38-34.63, 5.25-28.43 and 14.81-31.25 c.mol (p⁺) kg⁻¹ and percentage contribution of pH dependent acidity in the three district is 24.4 to 97.5, 20.66-93.4, 56.9 to 87.5. The contribution made by the exchange acidity towards total acidity was very low. According to Pal et. al. (1994), the magnitude of contribution of exchange acidity to total acidity is more than 60 per cent if the pH of the soil was less than 3.6. Das et. al. (1991) reported that a major contribution of 2.9 to 7.1 percent of exchange acidity towards total acidity in lateritic soils. Relatively low contribution of exchange acidity towards total acidity has been reported by Sharma et.al., (1990). Higher contribution made by pH dependent acidity may be due to higher value of pH dependent charges associated with increased iron and aluminium oxides and organic matter in the soils (Kamprath, 1970 and Mishra et.al. 1987).

The higher total potential acidity may be due to higher percentage of organic matter in the soil which contributed to total acidity through their functional groups like carboxylic and phenolic -OH (Das et. al. 1991). Sharma et. al. (1990) attributed higher potential acidity to the higher content of aluminium on the exchange complex and organic matter contents of the soil.

Peech (1965) used barium chloride - triethanol amine to extract acidity and reported that extractable acidity results from the replacement of H⁺ and Al³⁺ ions and from the dissociation of acidic groups neutralized by free triethanolamine, a weak base which is well buffered at pH 8.2. The barium ion besides replacing exchangeable ions also increase the degree of disassociation of the acidic groups on the clay surface.

The factors that influence soil acidity were studied by correlating various properties of soil with different forms of soil acidity. Correlation studies reveal that the soil factor contribute very strongly to soil acidity in hilly areas.

Soil properties like organic matter content, cation exchange capacity, effective cation exchange capacity, aluminium saturation, calcium saturation, exchange acidity, pH dependent acidity and potential acidity correlated positively with the clay content in soils of Kodagu. This is attributed to the nature of clay. Clay contains aluminum (Al^{3+}) and silica (SiO_2) which exhibit permanent and pH dependent charges. That must be a reason for positive correlation between cation exchange capacity, effective cation exchange capacity and calcium saturation (Thomas, 1988).

Significant correlation of pH dependent acidity with clay is mainly due to the inorganic components of soil. Although the dominant clay mineral in these soils is kaolinite. Soil organic matter possesses number of functional groups contains H^+ ion that can contribute to the different form of acidities depending upon their magnitude.

The association of extractable aluminium with exchangeable and potential acidity is understandable because of hydroxy aluminium polymers will not be neutralised and disassociation of Al^{3+} and H^+ ion from exchange sites will not be possible as they would be strongly adsorbed (Sharma et.al., 1990).

For these soils lime requirement was determined by equilibrating the soil with the buffer solution and it was related to the various fractions of acidity. Lime requirement by exchangeable calcium method (Puri, 1964) ranged from 1.97-1.399, 1.45-12.59 and 3.87-8.02 tons per hectare in Kodagu, Chikmagalur and Hassan district respectively, where as that determined by Adam and Evans (1968) method ranged from 1.23-9.98, 0.66-8.38 and 1.95 to 6.77 tons per hectare. Among the two methods tried exchangeable calcium method was found to be better, as evidenced in the correlation studies, and also in the pot culture studies which was carried out by following this method. Besides, the superiority of this method can be attributed to the strong electrolyte (KCl) used as an extractant in determining the lime requirement (Patil and Ananthnarayana, 1989).

Adam and Evans (1962) method designed to be rapid procedure with relatively high degree of accuracy for determination of lime requirement of soil of low CEC and soils having small amount of 2:1 clay minerals.

The lime needs of the soils were high. This is due to the high content of clay and organic matter.

Sims and Dennis (1989) indicated that organic matter is the primary soil component responsible for pH buffering in Delaware soils and Adam and Evans method was the best predictor of actual lime requirement.

Lime requirement correlated negatively with pH of the soils. This is in accordance with that of the results obtained by Ananthnarayana and Perur (1973b). This is attributed to the fact that pH measures only the intensity factor of soil acidity but the chemistry of liming involved replacement of exchangeable hydrogen from the exchange complex as well as free hydrogen ions in soil solution. Hence, without measuring the potential acidity properly the recommendation of lime based on pH would be misleading.

Organic matter content correlated positively with lime requirement method in Kodagu soils. Sims and Dennis (1989) attributed the relationship between lime requirement and organic matter to greater accumulation of acidic cations on the exchange sites. They also reported that the cations are chelated by organic matter in a form not readily displaced by ordinary exchange sites, but they reacted with lime when added to soil.

The contribution of titrable acidity or pH dependent charges, may contribute for the positive relationship between lime requirement and organic matter.

In coffee growing soils, both the lime requirement method gave positive correlation value with clay, aluminium saturation, exchangeable acidity and pH dependent acidity. Lime content increased with the reserve acidity.

Lime potential is negatively correlated with both the methods of lime requirement. In these studies lime potential is not affected by the various factors like suspension effect, soil water ratios and electrolyte levels. This is in accordance with the findings of Ananthnarayana and Manjunatha Prabhu (1992). Lime potential for obtaining stable reading in pH measurement Panda (1987) suggested the use of activity ratio for determination of soil acidity and base saturation. It characterise the composition of the exchange complex with respect to its saturation by H^+ and Ca^{2+} ions. Many of the methods for determination of lime requirement take into consideration the lime potential.

5.4 Pot culture studies

5.4.1 Changes in chemical properties of the soil due to liming.

5.4.1.1 Soil reaction

The data in the Table-21 indicated that liming has significantly increased the pH from very acidic to around neutral conditions. The extent of raise of pH was proportional

to the amount of lime added. Addition of lime results in the dissociation of calcium ions into solution which will be leached out and/or neutralized by OH⁻ ion in solution. So there will be a increase in the percent base saturation and concomitant increase in soil pH. Perusal of the data indicated that the equilibrium is established in the lime acid soil neutralization is very fast in the initial 30 days and there after it decreased. This is because when Ca²⁺ displaces hydrogen from the exchange sites, H gets leached out or neutralised and the equilibrium is established between lime and soil particles. Hence further change in the pH will be slow (Ananathanarayana and Perur, 1973). The results obtained are concomitant with the result of Bishnoi, et.al., 1988, Gupta et.al., 1989, Mathur et.al., 1991.

5.4.1.2 Total potential acidity

Data in the Table-21 show that potential acidity considerably decreased due to liming. The potential acidity is due to the exchangeable H and Al in the soil and organic matter. (Sharma et.al., 1990, Das et.al., 1991). Addition of lime restrict the proton formation activities in soil. Thus potential acidity which has a function of different H⁺, Al³⁺ and organic matter reduced due to lime addition. Similar observation were made by Bishnoi, et.al., 1988, Gupta et.al., 1989.

Consequent to the neutralising of soil acidity by the lime addition, there was a favorable root growth and plant height and number of leaves. At higher solution concentration of Ca⁺⁺ in soil plant height and number of leaves decreased, possibly due to the antagonistic effect of calcium on potassium which is evident in these study (5.4.2.3). This is in accordance with the finding of Ananathnarayana and Manjunatha Prabu (1992).

5.4.2 Nutrient content in plants as influenced by the addition of different levels of lime (Table - 22.).

5.4.2.1 Nitrogen

Treatmental difference with respect to nitrogen content is not evident due to the lower age of seedlings.

5.4.2.2 Phosphorus

Successive increment of lime addition resulted in the significant increase in the phosphorus in plants. This is attributed to the increased availability of phosphorus due to increase in soil pH and higher solution concentration of phosphorus. Gupta *et. al.*,

1989 and Patiram *et. al.* 1989, opines that the increased phosphorus content may be due to reduced aluminium toxicity.

5.4.2.3 Potassium

Addition of lime significantly decrease the potassium content in plants resulting in the lower uptake of potassium. Thus the lime potash antagonistic interaction is evident. (Ananthanarayana and Manjunatha Prabhu, 1992).

5.4.2.4 Calcium

Addition of lime to soil has increased calcium concentration in soil solution. Calcium being divalent ion is adsorbed strongly on the permanent charge of soil colloid. Due to lime addition the pH of soil increased and then became favorable for better development of root and growth of plants. (Ravi Kumar and Ananathanarayana, 1995). Hence calcium content in coffee has increased.

5.4.2.5 Magnesium

Magnesium content in plants increased significantly due to the addition of lime. This is due to the concomitant release of magnesium to the soil due to the addition of lime and create favorable Ca : Mg ratio in the soil and plant system.

5.4.2.6 Sulfur

There is a significant increase in sulfur content in coffee seedling due to the addition of liming. Sulfur will be found adsorbed as sulphate ions. Due to lime addition the acidity got neutralised and hence the pH dependent charge decreased. As a result sulphate ion got desorbed into the soil solution. Thus sulfur became available in large amounts. Hence the sulfur content in plant is also increased (Sreedara Adiga and Ananthanarayana, 1996).

SUMMARY

VI. SUMMARY

In Karnataka Coffee is grown under heavy rainfall areas under tropical humid conditions. Soil pH under coffee is mostly acidic. Hitherto lime needs of coffee soils were determined solely based on chemical lime requirement methods. But for the effective liming programme the nature of soil acidity is a must. Hence an attempt was made to characterise the nature of soil acidity as an effective means to determine Lime needs of coffee soils and to relate the effect of lime levels on the growth of coffee seedlings.

One hundred and seventy surface soil samples and five profile soil samples representative of coffee areas from Kodagu, Chikmagalur and Hassan districts were used for acid soil characterisation. Result reveal

- Soils studied are acidic in nature. Majority of soil under study are sandy loam to sandy clay with medium to high organic matter content. Kaolinite is the dominant mineral. Taxonomically these soils belongs to Alfisols, Ultisols and Inceptisols.
- The total potential acidity is high ranging from 17.12 to 36.88(Kodagu), 9.6 to 36.48(Chikmagalur) And 17.28 to 34.56 (Hassan) c. mol (p⁺) kg⁻¹ .
- Exchange acidity contribute only 1.17 to 18.02 c. mol (p⁺)kg⁻¹ in these soils. Variation is in the quantum of acidity in this soil is due to the slope and physico chemical properties.
- High amount of ammonium acetate pH 4.8 extractable aluminium indicate the presence of appreciable amount of AlSiO₃ and hydroxy aluminium polymers in soils.
- Permanent charge contribution to total potential acidity is rather low. But the contribution of pH dependent charge or variable charge is maximum. The percentage contribution of pH dependent acidity towards total acidity ranged from 20.66 to 97.5 in coffee soils. It is influenced by the organic matter, aluminium saturation and clay .
- The exchangeable aluminium and percent aluminium saturation increased with decrease in soil pH. The percent base saturation ranged from 4.8 to 45.5., 15.2 to 42.3 and 14.9 to 33.5 percent in Kodagu, Chikmagalur, and Hassan district. The management of such soils includes liming to neutralise exchangeable aluminium to tolerance levels of crop.
- C:N ratio of soils ranged from 1: 2.6 to 1 : 50, signifying the influence of organic matter. The available phosphorus is low , medium and medium to high in case of potassium. Sodium acetate extractable sulfur is adequate in these soils.

Lime requirement of soils were determined by exchangeable calcium method and Adams and Evans method. Lime requirement by exchangeable calcium method recorded higher values (1.97 to 13.99, 14.5 to 12.59 and 3.87 to 8.02 tons of calcium carbonate per hectare. Where as the same in Adams and Evans method was lower (1.23-9.98, 0.66 to 8.38 and 1.95 to 6.77 tons of calcium carbonate per hectare) in the districts of Kodagu, Chikmagalur and Hassan. Correlation studies reveal that exchangeable calcium method is superior to Adams and Evans method in the soils of coffee grown in Karnataka.

Lime potential is negatively correlated with both the method of lime requirement. In these studies lime potential is taken into consideration while determining lime requirement.

Pot culture studies reveal that

1. The effect of lime on the height and the number of leaves in one and half years old seedling is not substantial.
2. Neutralisation of soil acidity with lime is maximum within the first four week after lime addition. The potential acidity decreased due to the addition of lime by 78.1 percent in lime requirement method and 59.6 percent in calcium saturation method, at the end of four weeks.
3. Synergistic effect of lime on P, Ca & Mg content were observed.
4. Antagonistic effect of lime on potassium content in plant is observed.

Future line of work.

1. The role of varying silica-sesquioxide ratios in coffee growing soils should be related to the nature of acidity and lime requirement
2. Effect of Phosphate and Potassium potential consequent to liming should be assessed for working out the P and K nutrition of coffee.
3. Kinetics of aluminium desorption from the clay humus complex should be assessed for working out the lime needs of the soil.
4. Detoxification of aluminium by organic matter should be investigated.
5. Effect of liming on the acid soil on the quality parameters of coffee seeds should be investigated.

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* Originals not seen

APPENDICES

APPENDIX

Appendix-I : Physical properties of the surface soil from coffee growing areas.

1	2	3	4
Sl. No.	Location	Clay (%)	Textural class
	Kodagu District		
	Biligiri estate, Madikeri.		
1.		40.0	SCL
2.		25.0	SL
3.		22.5	SL
4.		25.0	SL
5.		30.0	SCL
6.		20.0	SL
7.		37.5	SCL
8.		33.8	SCL
9.		31.3	SCL
10.		31.3	SCL
11.		32.5	SCL
12.		35.0	SCL
	Lakshmi estate, Madikeri.		
13.		30.0	SCL
14.		35.0	SCL
15.		30.0	SCL
16.		41.3	SCL
	Ashoka estate, Madikeri.		
17.		35.0	SCL
18.		40.0	SCL
	Ram's farm estate, Madikeri.		
19.		22.5	SL
20.		38.3	SCL
21.		29.3	SCL
	Sampige Kolly estate, Madikeri.		
22.		37.5	SCL
23.		30.0	SCL
24.		25.0	SL
25.		30.0	SCL
26.		32.5	SCL
	Sharma estate, Madikeri.		
27.		22.5	SL
28.		12.5	SL
29.		28.5	SL
30.		20.0	SL
	Kudakageril estate, Madikeri.		
31.		32.5	SL
32.		27.5	SL
	Apsora estate, Madikeri.		
33.		37.5	SCL
	Chettalli farm estate, North Coorg.		
34.		31.3	SCL
35.		30.4	SCL

1	2	3	4
36.		33.8	SCL
37.		31.3	SCL
38.		29.8	SCL
39.		29.5	SCL
40.		22.5	SCL
CCL, Sonticoppa, Bhuthankadu division, Somvarpet taluk, North Kodagu.			
41.		31.5	SCL
42.		30.0	SCL
43.		27.5	SCL
44.		32.5	SCL
45.		30.0	SCL
46.		27.5	SCL
47.		22.5	SL
48.		37.5	SCL
49.		32.5	SCL
50.		27.5	SL
51.		32.8	SCL
52.		32.5	SCL
53.		25.0	SCL
54.		25.0	SCL
55.		40.0	SCL
56.		26.8	SCL
57.		27.5	SCL
58.		27.5	SCL
59.		27.5	SCL
60.		28.8	SCL
61.		25.0	SCL
62.		22.5	SCL
63.		42.5	SCL
CCL, Nullugottey division, Virajpet taluk, South Kodagu.			
64.		22.5	SL
65.		35.0	SCL
66.		23.8	SL
67.		25.0	SCL
68.		21.3	SL
69.		32.5	SCL
70.		25.0	SCL
71.		27.3	SCL
72.		32.5	SCL
73.		31.3	SCL
74.		17.5	SL
CCL, Washmullagottey division, Polibetta, South Kodagu.			
75.		41.3	SCL
76.		32.2	SCL
77.		25.0	SCL
78.		20.0	SL
79.		25.0	SCL
80.		28.5	SL
81.		18.8	SL
82.		17.5	SL
83.		18.8	SL
84.		37.5	SL

1	2	3	4
85.	CCL, Kottabetta division, Polibetta, Virajpet, South Kodagu.	16.3	SL
86.		22.5	SCL
87.		20.0	SL
88.		23.8	SCL
89.		22.5	SCL
90.		22.5	SCL
91.		31.3	SCL
92.		21.3	SL
93.	CCL, Muncha division, Polibetta, Virajpet, South Kodagu.	21.3	SL
94.		22.5	SL
95.		23.3	SL
96.		22.5	SL
97.		15.0	SL
98.		21.3	SL
99.		26.3	SL
100.		25.0	SCL
101.		26.3	SL
102.		23.8	SL
103.		30.0	SCL
104.		22.5	SL
105.		32.0	SCL
106.		31.3	SCL
107.		23.8	SCL
Hassan District			
CCL, Cognur division, Karadibetta estate, Royar koppal, Sakaleshpur.			
108.		27.5	SL
109.		16.3	SL
110.		45.0	SCL
111.		35.0	SCL
112.		25.0	SL
113.		25.0	SL
114.		35.0	SCL
115.		32.5	SCL
116.		27.5	SL
117.		30.0	SCL
118.		25.0	SL
119.		25.0	SL
120.		32.5	SCL
121.		25.0	SL
122.		38.8	SCL
123.		31.3	SCL
Chikmagalur District			
Malandur village.			
124.		22.5	SL
125.		26.3	SL
126.		22.5	SL
127.		22.5	SL
128.		22.5	SL
129.		25.0	SL
130.		25.0	SL

1	2	3	4
131.		22.5	SL
132.		18.8	SL
133.		22.5	SL
134.		22.5	SL
135.		28.5	SL
136.		27.5	SL
137.		23.8	SL
138.		23.8	SL
139.		16.3	SL
140.		26.5	SL
141.		27.5	SL
142.		22.5	SL
	CCRI, Balehonur, Chikmagalur.		
143.		22.5	SL
144.		26.3	SL
145.		21.3	SCL
146.		21.5	SL
147.		27.5	SL
148.		20.0	SL
149.		21.5	SL
150.		32.5	SCL
151.		37.5	SCL
152.		32.5	SCL
153.		27.5	SL
154.		40.0	SC
155.		27.5	SL
156.		37.5	SCL
157.		36.3	SCL
	Tathkole village, Mudigere.		
158.		35.0	SL
159.		28.8	SL
160.		20.0	SL
161.		25.0	SL
162.		36.0	SL
163.		32.5	SCL
164.		31.8	SCL
165.		30.0	SCL
166.		23.8	SL
	Narasimharajapura		
167.		35.0	SCL
168.		22.5	SL
169.		32.5	SCL
170.		31.3	SCL
171.		32.5	SCL
172.		45.0	SC

SL : Sandy Loam

SCL : Sandy Clay Loam

SC : Sandy Clay

CCL : Consolidated Coffee Limited

CCRI : Central Coffee Research Institute

Appendix -II : Chemical properties of the surface soil from coffee growing areas.

1	2	3	4	5	6	7	8	9
Sl. No.	Location	pH		EC	organic carbon	C:N ratio	Bray's P	Sodium acetate Extr. S.
		H ₂ O	KCl	dsm ⁻¹	(%)		(ppm)	(ppm)
Kodagu District								
Biligiri estate, Madikeri.								
1.		5.3	4.8	0.26	2.6	1:3.8	2.1	6.9
2.		5.8	5.4	0.09	1.7	1:5.9	2.8	10.3
3.		4.9	4.3	0.09	0.9	1:11.1	5.2	13.8
4.		5.3	3.9	0.05	1.3	1:7.7	4.4	14.8
5.		5.0	4.0	0.06	1.0	1:10	3.8	7.9
6.		5.3	4.1	0.05	0.8	1:12.5	5.0	12.8
7.		3.9	3.1	0.03	2.3	1:4.4	2.9	4.9
8.		5.3	4.5	0.25	3.4	1:3	5.9	10.8
9.		5.1	4.1	0.05	2.3	1:4.4	5.4	7.8
10.		4.4	3.2	0.05	1.1	1:9.1	3.8	17.7
11.		5.5	4.7	0.09	0.5	1:20	3.8	10.0
12.		5.0	4.7	0.07	0.8	1:12.5	3.9	14.0
Lakshmi estate, Madikeri.								
13.		5.3	4.5	0.05	0.7	1:14.3	1.4	11.8
14.		5.2	4.0	0.09	1.3	1:7.7	3.6	12.8
15.		4.9	4.3	0.23	2.4	1:4.4	2.5	13.8
16.		5.1	4.5	0.34	1.6	1:6.3	2.3	14.8
Ashoka estate, Madikeri.								
17.		5.1	4.2	0.06	0.6	1:16.6	1.12	7.9
18.		4.7	3.9	0.04	2.6	1:3.9	0.89	13.3
Ram's farm estate, Madikeri.								
19.		4.9	4.0	0.11	2.0	1:5	21.4	18.7
20.		5.3	4.1	0.08	2.4	1:4.2	3.8	16.8
21.		5.7	4.6	0.05	1.8	1:5.6	2.9	14.8
Sampige Kolly estate, Madikeri.								
22.		5.3	4.4	0.04	0.2	1:5.0	3.8	6.9
23.		4.9	4.2	0.11	1.6	1:6.3	5.7	17.7
24.		5.5	4.2	0.06	1.0	1:10	5.2	11.8
25.		6.3	5.3	0.13	2.8	1:3.6	5.2	10.4
26.		5.4	4.2	0.02	0.8	1:12.5	4.91	8.9
Sharma estate, Madikeri.								
27.		4.6	4.0	0.26	0.4	1:25	1.1	9.0
28.		6.0	5.2	0.08	2.6	1:3.9	4.6	27.5
29.		6.0	5.3	0.12	3.6	1:2.8	6.6	25.1
30.		4.9	4.3	0.05	2.9	1:3.5	4.91	22.6
Kudakageril estate, Madikeri.								
31.		5.5	5.0	0.09	3.8	1:2.6	15.2	20.7
32.		5.0	4.0	0.11	1.3	1:7.7	10.7	26.6
Apsora estate, Madikeri.								
33.		6.3	5.9	0.09	1.7	1:5.9	3.6	6.9
Chettalli farm estate, North Coorg.								
34.		4.8	4.3	0.02	1.6	1:6.3	17.8	31.5
35.		4.8	2.8	0.05	2.0	1:5	16.5	32.5
36.		5.3	4.4	0.06	1.6	1:6.3	6.9	28.5
37.		5.1	4.2	0.05	1.2	1:8.3	10.1	20.0
38.		4.6	3.6	0.09	1.3	1:7	13.2	16.7

1	2	3	4	5	6	7	8	9
39.		5.6	4.7	0.28	1.4	1:7.1	17.6	18.7
40.		5.5	4.5	0.02	1.3	1:7	20.1	20.7
CCL, Sonticoppa, Bhuthanakadu division, Somvarpet taluk, North Kodagu.								
41.		5.8	5.0	0.05	1.9	1:5.3	12.9	22.0
42.		6.1	5.1	0.08	1.3	1:7.7	13.3	24.2
43.		5.1	4.3	0.05	1.6	1:6.3	12.9	26.5
44.		6.1	5.1	0.08	1.6	1:6.3	12.9	22.0
45.		5.2	4.4	0.04	1.4	1:7.1	14.6	26.0
46.		5.0	4.1	0.04	2.1	1:4.8	16.3	29.6
47.		5.0	3.8	0.04	1.5	1:6.7	11.5	20.5
48.		5.6	4.8	0.08	2.0	1:5	12.3	25.0
49.		5.9	4.6	0.07	1.3	1:7.7	10.7	23.5
50.		5.8	4.7	0.05	2.6	1:3.9	8.2	24.4
51.		5.7	4.8	0.04	1.3	1:7.7	14.9	26.5
52.		5.1	4.1	0.41	1.5	1:6.7	11.5	22.7
53.		5.8	4.8	0.12	2.4	1:4.2	16.3	28.8
54.		5.2	4.7	0.31	0.8	1:12	17.3	32.6
55.		6.0	5.1	0.04	2.6	1:3.9	7.8	22.0
56.		5.9	4.2	0.09	1.5	1:6.67	21.0	29.5
57.		6.0	5.2	0.05	1.6	1:3	20.5	28.8
58.		5.9	4.0	0.05	2.0	1:5	11.5	25.8
59.		5.1	3.9	0.04	0.4	1:25	4.2	23.5
60.		5.2	4.3	0.06	1.1	1:9.1	27.2	25.0
61.		5.3	4.3	0.04	1.7	1:5.1	12.7	25.8
62.		4.8	4.1	0.08	1.1	1:9.1	26.7	28.0
63.		4.9	3.8	0.04	1.7	1:5.9	7.9	25.8
CCL, Nullugotey division, Virajpet taluk, South Kodagu.								
64.		6.2	5.4	0.05	0.9	1:11.1	8.0	7.1
65.		5.3	5.1	0.04	0.5	1:20	11.1	9.4
66.		6.2	4.9	0.06	1.2	1:8.3	5.9	9.0
67.		5.4	4.5	0.16	1.9	1:5.3	15.4	15.7
68.		5.0	4.9	0.11	1.3	1:7.7	12.5	14.9
69.		5.5	4.5	0.08	1.6	1:6.3	5.4	5.5
70.		5.2	4.5	0.12	1.5	1:6.7	9.9	3.2
71.		5.1	4.6	0.14	1.5	1:6.7	12.5	5.5
72.		5.4	5.0	0.48	0.6	1:16.7	9.8	3.9
73.		6.3	5.4	0.08	2.3	1:4.4	6.8	10.2
74.		5.9	5.6	0.05	1.3	1:7.7	6.0	7.8
CCL, Washmullagotey division, Polibetta, South Kodagu.								
75.		6.0	5.5	0.13	1.4	1:7.1	22.3	32.9
76.		4.7	3.9	0.17	0.7	1:14.3	11.7	35.3
77.		5.7	5.1	0.14	2.9	1:3.5	6.6	29.0
78.		6.1	5.5	0.12	0.5	1:20	17.5	25.9
79.		5.9	5.2	0.09	1.4	1:7.1	24.8	25.1
80.		5.4	4.8	0.05	0.8	1:12.5	6.8	23.5
81.		5.5	5.0	0.12	1.6	1:6.3	17.9	26.6
82.		4.9	4.2	0.09	0.8	1:12.5	12.5	27.4
83.		5.5	4.7	0.06	1.8	1:5.6	16.8	28.2
84.		4.9	4.6	0.06	0.6	1:16.7	15.4	31.0
85.		5.2	4.4	0.09	0.4	1:25	16.3	34.5
CCL, Kottabetta division, Polibetta, Virajpet, South Kodagu.								
86.		3.7	3.4	0.14	1.5	1:6.7	15.9	11.0
87.		5.7	5.3	0.33	2.3	1:4.4	26.3	1.2
88.		5.6	5.0	0.25	1.3	1:7.7	29.0	14.9
89.		5.6	5.0	0.08	1.1	1:9.1	17.1	15.7
90.		6.0	5.0	0.50	1.7	1:5.9	23.5	29.0
91.		5.5	5.2	0.70	1.7	1:5.9	24.4	22.7

1	2	3	4	5	6	7	8	9
92.		5.7	5.5	0.44	2.3	1:4.4	19.9	27.4
93.		4.7	4.6	0.57	1.3	1:7.7	15.4	19.6
CCL, Muncha division, Polibetta, Virajpet, South Kodagu.								
94.		5.4	4.6	0.03	1.1	1:9.1	2.9	15.7
95.		6.0	5.2	0.04	1.9	1:5.3	6.4	14.1
96.		6.0	5.2	0.05	0.8	1:12.5	6.51	22.7
97.		6.0	5.2	0.03	0.9	1:11.1	6.6	18.0
98.		5.9	5.2	0.04	0.6	1:16.7	8.9	21.2
99.		5.7	5.3	0.03	1.4	1:7.1	6.9	17.2
100.		6.1	5.3	0.07	0.4	1:25	9.1	18.8
101.		6.0	5.2	0.07	2.0	1:5.0	9.8	22.7
102.		6.0	5.4	0.08	0.9	1:11.1	10.7	21.2
103.		6.0	5.4	0.11	1.3	1:7.7	9.2	27.4
104.		5.3	4.5	0.42	1.7	1:5.9	3.8	20.4
105.		5.9	5.0	0.46	0.7	1:4.3	8.9	23.5
106.		5.7	4.8	0.11	1.7	1:5.9	9.2	12.8
107.		5.1	4.1	0.13	2.0	1:5.0	9.8	30.5
Hassan District								
CCL, Cognur division, Karadibetta estate, Royar koppal, Sakaleshpur.								
108.		6.4	6.1	0.08	1.6	1:6.3	11.7	11.4
109.		5.0	4.7	0.09	0.8	1:12.5	10.3	11.4
110.		5.5	4.8	0.11	0.7	1:14.3	9.0	22.0
111.		5.6	4.6	0.04	1.3	1:7.7	8.3	18.2
112.		5.7	5.0	0.07	0.6	1:16.7	9.6	18.5
113.		4.8	4.6	0.04	0.8	1:12.5	9.5	24.0
114.		5.9	5.2	0.04	1.0	1:10	8.3	21.2
115.		5.5	4.6	0.05	2.0	1:50	9.2	12.1
116.		5.9	5.0	0.04	0.6	1:16.7	10.4	18.2
117.		6.1	5.3	0.05	2.1	1:4.8	8.4	20.5
118.		5.1	4.2	0.03	0.3	1:33.3	8.5	16.7
119.		5.8	5.1	0.05	1.4	1:7.14	7.9	20.5
120.		5.9	5.2	0.02	1.0	1:10	5.8	18.2
121.		6.0	4.4	0.08	0.8	1:12.5	7.3	21.5
122.		5.7	5.1	0.07	1.4	1:7.1	5.6	20.0
123.		6.0	4.9	0.02	1.2	1:50	8.6	18.9
Chikmagalur District								
Malandur village.								
124.		6.3	5.6	0.28	1.3	1:7.7	6.0	8.9
125.		6.3	5.2	0.08	1.2	1:8.3	7.1	27.4
126.		6.0	5.1	0.10	0.9	1:11	4.5	15.7
127.		5.9	4.8	0.10	1.9	1:5.3	5.0	19.6
128.		6.3	5.2	0.08	3.4	1:2.9	4.5	16.2
129.		6.2	5.3	0.12	1.3	1:7.7	7.1	23.5
130.		5.5	4.3	0.12	2.7	1:3.7	5.8	12.5
131.		6.0	5.2	0.05	3.0	1:3.3	4.2	26.6
132.		6.3	5.4	0.09	1.0	1:10	5.9	22.7
133.		6.4	5.6	0.12	2.3	1:4.4	6.9	26.6
134.		6.3	5.5	0.15	2.0	1:5	8.6	24.3
135.		6.1	5.1	0.07	2.4	1:4.2	5.9	11.8
136.		6.3	5.4	0.06	0.6	1:16.7	5.7	11.8
137.		6.4	5.7	0.12	2.2	1:4.5	3.9	12.5
138.		6.2	5.2	0.15	1.4	1:7.1	3.0	19.6
139.		6.2	5.2	0.05	0.7	1:14.3	3.0	31.3
140.		6.3	5.3	0.05	1.3	1:7.7	5.4	25.0
141.		6.1	5.4	0.08	0.9	1:11	3.6	25.7
142.		5.2	4.3	0.05	1.0	1:10	4.9	23.5

1	2	3	4	5	6	7	8	9
	CCRI, Balehonur, Chikmagalur.							
143.	5.8	4.6	0.07	0.3	1:33	5.2	21.2	
144.	6.2	5.0	0.04	0.3	1:33	5.0	21.9	
145.	6.0	5.1	0.04	1.1	1:9.2	3.0	23.8	
146.	5.8	5.1	0.08	1.1	1:9.2	8.5	23.5	
147.	6.2	5.2	0.08	0.3	1:33	5.4	21.9	
148.	5.6	4.6	0.07	1.5	1:6.7	8.9	36.0	
149.	5.9	5.1	0.12	0.7	1:14	6.8	28.0	
150.	5.8	4.6	0.04	0.2	1:50	7.9	7.9	
151.	6.3	5.0	0.06	1.9	1:5.3	9.6	37.3	
152.	5.7	4.8	0.07	0.5	1:20	10.8	22.0	
153.	6.0	5.0	0.07	1.9	1:5.3	6.5	36.3	
154.	6.0	5.0	0.05	1.2	1:8.4	11.7	12.5	
155.	5.8	4.6	0.04	1.1	1:9.2	5.4	9.4	
156.	5.7	4.6	0.05	1.4	1:7.2	5.4	11.0	
157.	6.0	4.9	0.05	1.4	1:7.2	3.9	12.5	
	Tathkole, Mudigere							
158.	5.9	5.0	0.07	1.7	1:5.9	7.9	19.6	
159.	5.9	4.9	0.07	1.9	1:5.3	7.5	19.6	
160.	6.1	5.0	0.05	1.4	1:7.2	6.3	14.1	
161.	6.2	5.3	0.08	1.3	1:7.8	4.5	12.5	
162.	6.3	5.8	0.02	1.1	1:9.2	4.9	18.0	
163.	5.5	4.9	0.33	0.9	1:11.2	5.4	13.5	
164.	6.4	5.6	0.08	1.1	1:9.2	5.5	20.0	
165.	4.8	4.3	0.40	2.9	1:3.5	5.2	17.4	
166.	6.3	5.7	0.27	1.0	1:10	8.3	14.9	
	Narasimharajapura							
167.	5.6	5.4	0.08	3.12	1:3.3	9.1	12.5	
168.	5.8	5.0	0.13	2.61	1:3.8	18.2	17.0	
169.	6.0	5.3	0.16	2.11	1:4.8	16.3	21.9	
170.	5.5	4.6	0.12	1.01	1:10	15.2	13.3	
171.	5.4	4.6	0.08	2.51	1:4	21.2	19.6	
172.	5.6	4.8	0.09	1.01	1:10	13.5	6.3	

CCL : Consolidated coffee limited.

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Appendix - III : Exchangeable cations, Calcium saturation and base saturation in the surface soil of the coffee growing areas.

1	2	3	4	5	6	7	8
Sl. No.	Location	Ca ⁺⁺	Mg ⁺⁺	K ⁺	CEC	Calcium saturation (%)	Base saturation (%)
		----- c. mol. (p ⁺) kg ⁻¹ -----					
Kodagu District							
Biligiri estate, Madikeri.							
1.		3.94	2.71	0.20	18.37	21.37	37.8
2.		2.05	1.72	0.39	19.87	10.32	20.9
3.		0.90	0.38	0.11	14.7	6.14	9.5
4.		2.46	1.67	0.12	18.95	12.98	9.5
5.		2.21	1.72	0.07	24.12	9.18	16.6
6.		1.56	0.74	0.09	17.75	8.86	13.6
7.		4.26	1.07	0.40	20.22	5.27	28.5
8.		7.63	1.97	0.54	29.52	28.82	34.3
9.		1.23	1.15	0.10	24.12	5.09	10.28
10.		1.64	0.41	0.41	23.08	7.01	10.7
11.		2.86	0.57	0.27	22.63	1.87	16.5
12.		3.77	2.54	0.60	32.62	11.56	36.88
Lakshmi estate, Madikeri.							
13.		2.71	0.16	0.09	26.42	10.24	13.1
14.		2.21	1.07	0.13	22.72	9.74	15.0
15.		2.21	1.40	0.12	19.53	11.34	19.1
16.		3.77	1.48	0.14	21.48	17.56	25.1
17.		1.48	1.40	0.10	19.29	7.65	15.5
18.		1.64	1.82	0.08	0.82	40.79	18.1
Ram's farm estate, Madikeri							
19.		1.56	1.31	0.14	22.97	6.78	13.1
20.		1.70	1.07	0.38	26.07	6.60	12.1
21.		2.30	1.48	0.19	24.23	9.48	16.3
Sampige Kolly estate, Madikeri.							
22.		2.71	1.39	0.38	25.57	11.58	17.5
23.		2.05	0.66	0.21	20.22	10.14	14.5
24.		1.89	1.31	0.27	24.00	7.85	14.5
25.		5.08	2.62	0.23	17.46	29.12	44.4
26.		3.2	2.13	0.20	19.64	16.28	23.6
Sharma estate, Madikeri.							
27.		1.8	0.16	0.10	22.86	7.89	9.0
28.		4.51	1.89	0.23	27.45	14.94	24.1
29.		3.73	1.89	0.23	25.73	28.36	22.7
30.		5.82	0.74	0.25	18.26	31.88	27.3
31.		6.32	2.38	0.27	22.28	27.97	40.3
32.		2.05	1.40	0.31	17.57	11.66	21.4
Apsora estate, Madikeri.							
33.		4.67	2.46	0.26	22.97	20.35	32.2
Chettalli farm estate, North Kodagu.							
34.		2.46	0.49	0.21	24.47	10.05	12.0
35.		3.03	1.89	0.32	25.04	12.12	20.9
36.		2.21	1.15	0.18	20.90	11.02	16.9
37.		3.12	0.66	0.10	19.29	16.16	20.2

1	2	3	4	5	6	7	8
38.		2.3	0.50	0.12	20.56	11.17	14.2
39.		2.54	1.97	0.60	22.74	11.18	2.5
40.		4.02	1.0	0.47	12.40	32.40	44.3
CCL, Sonticoppa, Bhuthanakadu division, Somvarpet taluk, North Kodagu.							
41.		7.22	2.32	0.21	32.05	22.51	30.42
42.		6.15	1.64	0.12	22.28	27.60	35.5
43.		5.58	1.15	0.16	36.18	15.41	19.0
44.		10.82	2.38	0.51	39.05	27.72	35.1
45.		5.33	1.15	0.31	31.93	16.69	21.3
46.		5.08	1.39	0.32	32.62	15.58	20.8
47.		4.02	1.38	0.08	31.82	12.63	17.2
48.		6.97	1.15	0.33	36.98	18.85	22.9
49.		8.69	1.89	0.29	35.84	24.25	30.3
50.		10.0	2.38	0.43	39.05	25.62	32.8
51.		7.71	2.25	0.31	32.05	24.05	32.0
52.		8.86	2.23	0.31	33.65	26.32	33.9
53.		7.46	2.21	0.29	34.57	21.58	28.8
54.		5.58	1.07	0.37	32.62	17.09	21.5
55.		7.13	2.39	0.24	35.26	20.22	26.0
56.		4.23	1.80	0.25	36.64	30.66	17.1
57.		8.12	1.72	0.24	42.27	19.20	23.8
58.		6.64	1.56	0.26	33.61	18.65	23.8
59.		9.43	3.03	0.19	29.64	31.82	42.7
60.		3.2	1.97	0.26	31.63	10.02	17.0
61.		4.51	1.42	0.19	39.74	11.35	15.4
62.		4.1	1.30	0.19	37.90	10.82	15.0
CCL, Nullugottey division, Virajpet taluk, South Kodagu.							
63.		4.46	1.47	0.20	37.33	12.52	13.9
64.		3.28	1.00	0.18	32.05	10.23	13.9
65.		3.16	0.82	0.20	32.28	9.70	12.3
66.		2.67	0.40	0.14	28.26	9.43	11.4
67.		3.16	0.74	0.23	28.48	11.08	14.5
68.		2.09	0.53	0.18	29.41	7.10	9.5
69.		2.01	0.57	0.15	26.06	6.90	9.4
70.		2.67	0.53	0.13	26.19	10.17	12.7
71.		3.9	0.82	0.17	33.19	11.7	14.7
72.		2.26	0.57	0.15	32.05	7.03	9.3
73.		2.79	0.74	0.12	28.60	9.70	12.8
74.		1.72	0.45	0.07	27.66	6.20	8.1
CCL, Washmullagottey division, Polibetta, South Kodagu.							
75.		3.61	1.05	0.13	23.66	6.20	14.3
76.		2.29	0.74	0.14	35.61	6.20	18.7
77.		3.73	1.15	0.28	38.59	9.60	13.4
78.		4.31	1.40	0.17	34.23	12.57	17.2
79.		6.4	1.8	0.17	39.28	16.28	21.3
80.		4.39	0.62	0.17	35.26	12.44	17.6
81.		2.46	0.41	0.12	29.41	8.30	10.2
82.		2.17	0.46	0.06	28.83	7.50	9.4
83.		2.26	0.70	0.11	23.66	9.50	13.0
84.		2.42	0.82	0.25	37.33	6.50	9.5
85.		2.58	0.78	0.13	32.35	7.03	11.5

1	2	3	4	5	6	7	8
CCL, Kottabetta division, Polibetta, Virajpet, South Kodagu.							
86.		1.85	0.49	0.20	18.95	9.70	13.4
88.		2.54	0.53	0.23	23.77	10.69	14.0
89.		2.54	0.70	0.36	20.33	12.50	17.7
90.		4.26	1.03	0.44	18.00	12.50	23.9
91.		2.83	0.74	0.49	22.97	12.59	17.7
92.		3.73	0.62	0.49	22.05	12.39	22.0
93.		2.34	0.57	0.32	23.66	9.87	13.7
CCL, Muncha division, Polibetta, Virajpet, South Kodagu.							
94.		2.91	0.82	0.28	16.31	17.84	24.6
95.		2.71	0.50	0.26	22.85	1.84	95.6
96.		2.32	0.82	0.25	21.36	15.55	20.3
97.		3.12	0.80	0.19	22.74	13.70	18.1
98.		3.16	0.62	0.17	23.66	13.34	16.7
99.		4.1	1.24	0.41	20.22	20.27	28.4
100.		3.81	0.58	0.20	24.58	15.51	18.7
101.		3.32	0.45	0.24	26.76	12.41	15.0
102.		3.03	0.78	0.13	19.29	15.72	20.7
103.		3.24	0.72	0.19	20.56	15.25	20.2
104.		3.03	0.73	0.24	17.57	17.09	28.2
105.		3.54	1.64	0.29	21.59	16.33	25.3
106.		0.74	0.25	0.25	30.55	9.01	4.8
107.		3.36	0.34	0.34	37.33	19.82	12.1
Hassan District							
CCL, Cognur division, Karadibetta estate, Royar koppal, Sakaleshpur.							
108.		5.25	1.88	0.26	28.48	18.42	25.9
109.		4.51	1.62	0.20	22.28	20.02	28.4
110.		5.29	1.64	0.20	31.82	16.61	22.4
112.		4.76	1.35	0.15	27.34	17.39	22.9
113.		2.87	1.89	0.13	32.85	8.70	14.9
114.		4.31	1.15	0.16	32.39	9.50	17.35
115.		3.28	0.67	0.15	17.35	19.82	23.6
116.		5.58	1.23	0.23	34.5	16.23	20.5
117.		5.49	1.8	0.17	32.16	17.08	23.4
118.		5.74	1.39	0.25	29.90	19.19	24.7
119.		5.58	2.30	0.21	32.62	17.08	24.8
120.		9.43	3.12	0.12	38.48	24.51	33.2
121.		3.77	1.07	0.13	31.13	12.12	16.0
122.		5.99	2.62	0.28	37.67	15.89	23.6
123.		4.84	2.30	0.17	37.67	12.85	18.5
Chikmagalur District							
Malandur village.							
124.		5.9	1.72	0.51	25.16	23.47	32.3
125.		4.26	1.56	0.36	24.93	17.10	24.8
126.		6.23	2.09	0.51	25.57	16.67	21.5
127.		3.77	1.23	0.30	24.58	15.35	21.6
128.		4.1	2.38	0.36	29.64	13.83	23.1
129.		7.71	1.89	0.83	28.83	26.74	3.62
130.		3.12	0.49	0.39	26.30	11.85	15.2
131.		6.07	0.49	0.35	29.29	20.72	23.6
132.		3.61	1.31	0.33	30.78	27.95	18.8
133.		6.81	1.39	0.49	32.28	17.10	30.0

1	2	3	4	5	6	7	8
134.		7.54	1.56	0.64	38.60	26.38	34.1
135.		5.25	0.66	0.45	29.63	17.71	34.5
136.		3.77	1.64	0.51	21.83	17.28	27.1
137.		7.46	1.89	0.48	32.50	22.96	30.3
138.		7.95	1.31	0.46	32.08	24.05	29.4
139.		5.41	1.80	0.51	30.67	17.65	25.2
140.		5.74	1.89	0.49	30.56	8.78	26.6
141.		4.92	1.15	0.37	31.01	15.86	20.8
142.		2.05	1.07	0.44	24.12	8.49	14.8
	CCRI, Balehonur, Chikmagalur.						
143.		3.69	1.72	0.51	29.86	12.36	19.8
144.		6.15	3.53	0.08	21.94	16.07	44.5
145.		4.43	1.39	0.71	26.53	16.69	24.6
146.		2.30	1.23	0.28	27.45	8.36	13.9
147.		7.3	2.46	0.48	30.56	23.88	33.5
148.		2.46	1.39	0.21	23.32	10.55	17.4
149.		4.02	1.48	0.49	29.06	13.83	20.6
150.		2.87	1.39	0.09	23.66	12.13	18.4
151.		3.19	0.57	0.64	27.79	11.51	15.8
152.		3.2	0.74	0.21	23.55	13.58	17.2
153.		6.56	1.23	0.64	32.96	20.18	25.6
154.		3.61	1.07	0.43	25.50	14.15	20.0
155.		2.3	0.98	0.13	21.24	10.69	15.9
156.		1.64	1.15	0.32	31.13	5.26	10.0
157.		3.2	1.15	0.28	27.79	11.51	16.7
	Tathkole village, Mudigere						
158.		4.43	1.80	0.34	26.99	16.41	24.3
159.		3.67	0.82	0.39	26.53	17.62	18.4
160.		4.67	1.52	0.27	25.04	18.67	25.8
161.		4.31	1.64	0.44	31.13	13.94	20.5
162.		5.99	2.05	0.41	32.05	18.68	26.4
163.		2.95	1.97	0.48	28.72	10.28	18.8
164.		4.1	1.31	0.33	29.41	13.94	21.4
165.		5.17	2.33	0.33	25.96	19.89	30.2
166.		5.82	2.03	0.94	26.42	22.04	37.1
	Narasimharajapura						
167.		7.05	3.2	0.32	26.31	19.89	42.3
168.		5.01	1.89	0.56	24.92	20.07	29.9
169.		6.40	0.98	0.43	27.91	22.92	28.0
170.		3.12	0.98	0.49	22.97	13.57	20.0
171.		3.20	1.56	0.51	20.22	15.82	26.1
172.		2.87	1.31	0.49	22.28	12.88	20.1

CCL : Consolidated Coffee Limited.

CCRI : Central Coffee Research Institute.

Appendix IV : Effective cation exchange capacity and Aluminium status of the surface soil from coffee growing areas.

1	2	3	4	5
Sl. No.	Location	ECEC	NH ₄ OAC Extractable Aluminium ----- c. mol (p ⁺) kg ⁻¹ -----	Aluminium saturation of ECEC (%)
Kodagu District				
Biligiri estate, Madikeri.				
1.		8.63	1.79	20.6
2.		7.05	2.89	40.7
3.		4.02	2.63	65.5
4.		4.95	1.30	26.2
5.		6.98	2.98	42.7
6.		6.14	3.75	61.1
7.		10.5	4.77	45.4
8.		16.0	5.87	36.7
9.		9.54	7.06	44.1
10.		6.79	4.33	63.8
11.		10.88	7.57	69.6
12.		15.29	8.38	54.8
Lakshmi estate, Madikeri.				
13.		8.19	5.23	63.8
14.		9.38	5.19	65.4
15.		9.38	5.65	16.3
16.		11.4	6.05	52.8
Ashoka estate, Madikeri				
17.		7.96	5.08	63.8
18.		4.79	2.25	47.0
Ram's farm estate, Madikeri.				
19.		18.23	15.27	83.5
20.		21.20	18.05	85.0
21.		7.96	5.08	63.8
Sampige Kolly estate, Madikeri.				
22.		10.00	5.5	55.2
23.		7.77	4.85	62.5
24.		8.24	4.77	57.9
25.		10.56	2.63	24.9
26.		10.49	4.96	47.3
Sharma estate,				
27.		6.17	4.1	66.5
28.		21.53	14.91	69.3
29.		13.48	4.06	30.1
30.		12.92	6.05	46.8
Kudakageri estate, Madikeri				
31.		14.51	5.63	38.8
32.		8.59	4.63	53.9
Apsora estate, Madikeri.				
33.		8.93	1.54	17.2
Chettalli farm estate, North Kodagu.				
34.		10.02	6.86	68.5

1	2	3	4	5
35.		12.89	7.65	59.4
36.		5.79	2.25	38.9
37.		6.45	2.58	40.0
38.		7.00	4.09	58.5
39.		9.57	4.45	46.5
40.		7.52	2.05	27.3
CCL, Sonticoppa, Bhuthanakadu division, Somvarpet taluk, North Kodagu.				
41.		9.63	2.09	21.7
42.		10.5	2.60	10.5
43.		12.11	5.23	43.2
44.		15.56	1.85	11.9
45.		12.65	5.87	46.4
46.		12.61	5.82	46.1
47.		9.40	4.61	48.9
48.		12.40	2.90	31.6
49.		12.18	1.32	10.8
50.		14.68	1.87	12.7
51.		11.42	2.84	24.8
52.		13.79	3.38	24.6
53.		13.13	4.15	31.6
54.		11.25	4.24	37.7
55.		12.80	4.04	31.6
56.		16.10	2.76	17.2
57.		11.93	1.85	15.5
58.		11.59	3.13	27.0
59.		16.86	4.21	25.0
60.		13.19	7.76	58.8
61.		11.67	6.2	53.1
62.		12.59	7.65	60.7
63.		18.8	8.82	47.0
CCL, Nullugotney division, Virajpet taluk, South Kodagu				
64.		6.48	2.78	42.9
65.		6.39	2.21	34.7
66.		7.03	4.59	65.3
67.		9.15	4.94	54.0
68.		5.77	2.96	51.4
69.		8.20	5.47	66.9
70.		6.22	2.89	46.5
71.		6.90	3.66	53.0
72.		7.15	4.17	58.3
73.		6.67	3.02	45.3
74.		4.24	2.00	47.0
CCL, Washmullagotney division, Polibetta, South Kodagu..				
75.		7.56	3.33	44.0
76.		5.67	2.95	52.0
77.		9.86	4.70	47.7
78.		8.16	2.95	36.1
79.		10.73	2.36	22.0
80.		9.51	4.34	45.6
81.		5.63	2.63	46.7
82.		6.03	3.64	66.3

1	2	3	4	5
83.		5.02	1.96	39.0
84.		7.75	4.26	55.0
85.		5.61	2.12	37.8
	CCL, Kottabetta division, Polibetta, Virajpet, South Kodagu.			
86.		8.43	4.04	28.4
87.		6.62	2.40	36.2
88.		7.24	3.93	54.3
89.		6.00	2.34	39.8
90.		7.65	1.92	25.1
91.		5.78	1.72	29.8
92.		6.35	1.52	23.9
93.		7.31	4.08	55.8
	CCL, Muncha division, Polibetta, Virajpet, South Kodagu			
94.		7.11	3.84	54.02
95.		5.57	2.36	42.4
96.		5.38	1.72	32.0
97.		5.85	2.18	37.2
98.		6.00	2.05	34.0
99.		7.00	1.83	26.3
100.		5.90	2.21	37.3
101.		5.73	1.72	29.3
102.		6.23	2.29	36.7
103.		5.31	2.25	42.4
104.		6.77	3.13	46.2
105.		5.18	1.38	24.8
106.		7.87	6.40	81.4
107.		7.31	2.8	38.2
	Hassan District			
	CCL, Cognur division, Karadibetta estate, Royar koppal, Sakaleshpur.			
108.		7.62	1.17	15.4
109.		8.13	2.80	34.4
110.		9.7	2.58	26.6
111.		10.0	4.45	44.5
112.		9.0	2.71	30.2
113.		8.40	3.55	42.1
114.		8.00	2.38	41.5
115.		7.47	3.82	49.3
116.		9.81	2.78	35.9
117.		10.00	2.47	31.9
118.		9.58	2.20	22.9
119.		10.29	2.21	23.1
120.		14.82	2.16	14.6
121.		8.50	3.53	41.5
122.		11.96	3.07	25.7
123.		10.82	3.51	35.4
	Chikmagalur District			
	Malandur village.			
124.		12.48	4.35	34.8
125.		14.14	7.95	56.2
126.		17.41	11.05	63.5
127.		15.71	10.41	66.3
128.		11.22	4.38	39.0

1	2	3	4	5
129.		20.51	10.08	49.2
130.		10.82	6.83	33.3
131.		12.00	5.03	42.3
132.		14.58	4.33	29.7
133.		10.82	6.8	33.3
134.		14.55	4.0	33.0
135.		22.40	12.95	89.0
136.		16.10	10.13	83.1
137.		13.22	3.39	25.6
138.		14.16	4.43	31.3
139.		12.06	4.33	35.9
140.		18.28	10.20	55.6
141.		19.27	12.84	66.6
142.		11.92	8.34	70.0
	CCRI, Balehonur, Chikmagalur.			
143.		9.77	3.84	39.3
144.		13.89	4.13	29.7
145.		14.23	7.71	54.2
146.		14.80	11.00	74.3
147.		15.00	4.76	31.7
148.		9.44	5.38	57.0
149.		9.46	3.48	36.9
150.		8.10	3.75	46.3
151.		10.41	6.00	57.6
152.		13.76	9.62	70.0
153.		14.68	6.25	42.6
154.		12.80	7.72	60.2
155.		8.86	5.45	61.5
156.		16.13	13.02	80.7
157.		16.43	11.81	71.9
	Tathkole village, Mudigere			
158.		16.94	10.37	61.2
159.		15.27	9.40	61.5
160.		13.73	3.62	26.4
161.		10.91	4.49	41.1
162.		12.68	4.23	33.4
163.		15.75	10.35	65.7
164.		12.22	6.58	53.8
165.		12.0	6.15	51.3
166.		14.69	4.9	33.4
	Narasimharajapura			
167.		17.14	6.57	38.3
168.		11.34	3.88	34.2
169.		12.47	4.66	37.4
170.		9.84	5.26	53.4
171.		1.17	4.90	48.2
172.		14.14	9.47	70.5

CCL : Consolidated Coffee Limited.

CCRI : Central Coffee Research Institute.

Appendix - V : Forms of Acidity in the surface soil of the coffee growing areas.

1	2	3	4	5	6
Sl. No.	Location	Pot. Acidity	Forms of Acidity Exch. Acidity	pH dep. Acidity	Percent contribution of pH dep. Acidity to total acidity.
		----- c. mol (p ⁺) kg ⁻¹ -----			
Kodagu District					
Biligiri estate, Madikeri.					
1.		19.2	1.79	17.91	97.5
2.		19.2	2.89	16.31	82.1
3.		21.12	2.63	18.49	84.3
4.		19.2	1.30	17.7	
5.		11.52	2.98	8.54	93.4
6.		23.04	3.75	19.3	85.5
7.		24.96	4.77	20.19	90.86
8.		32.64	5.87	26.77	90.68
9.		17.28	7.06	10.22	42.37
10.		26.88	6.33	20.50	88.80
11.		18.8	7.57	11.23	49.60
12.		36.88	8.38	28.5	87.40
Lakshmi estate, Madikeri.					
13.		23.04	5.23	17.81	67.4
14.		23.04	5.19	17.85	78.5
15.		21.88	5.65	16.23	83.1
16.		21.12	6.05	15.07	70.2
Ashoka estate, Madikeri					
17.		23.04	5.08	17.92	92.9
18.		26.88	2.25	24.63	87.9
Ram's farm estate, Madikeri.					
19.		26.88	15.27	11.61	80.5
20.		19.2	9.02	10.18	38.2
21.		21.12	7.02	14.05	58.0
Sampige Kolly estate, Madikeri					
22.		21.12	5.52	15.6	61.0
23.		21.88	4.85	17.03	84.2
24.		21.12	4.77	16.35	68.1
25.		13.34	2.63	10.71	61.3
26.		13.34	4.96	8.38	42.7
Sharma estate, Madikeri.					
27.		20.72	4.10	16.62	50.8
28.		30.72	14.91	15.81	57.6
29.		21.12	4.06	17.06	66.3
30.		30.72	6.05	24.67	87.29
Kudakagenil estate, Madikeri.					
31.		21.12	5.63	15.49	69.6
32.		13.34	4.63	8.71	49.6
Apsora estate, Madikeri.					
33.		19.2	1.54	15.66	76.9
Chetalli Farm Estate, North Kodagu					
34.		20.72	6.86	13.86	57.1

1	2	3	4	5	6
35.		22.64	7.65	14.99	59.9
36.		17.78	2.25	15.03	71.9
37.		17.28	2.58	14.70	76.2
38.		13.34	4.09	9.25	50.0
39.		15.36	4.45	10.91	48.0
40.		12.12	2.05	10.07	81.2
CCL, Sonticoppa, Bhuthanakadu division, Somvarpet taluk, North Kodagu.					
41.		11.52	2.09	9.43	29.4
42.		32.64	2.60	30.04	93.1
43.		32.64	5.23	27.41	75.8
44.		36.48	1.85	34.63	88.7
45.		30.32	5.87	24.45	76.6
46.		28.40	5.82	28.2	86.5
47.		28.8	4.61	24.19	76.5
48.		28.64	3.90	24.79	77.7
49.		30.72	1.32	29.4	82.0
50.		34.56	1.87	32.69	83.7
51.		19.2	2.84	16.36	51.0
52.		32.48	3.38	29.1	86.5
53.		34.40	4.15	30.3	87.6
54.		32.48	4.24	28.24	86.6
55.		30.72	4.04	26.68	75.7
56.		32.64	2.76	29.88	81.5
57.		32.64	1.85	30.79	72.8
58.		30.72	3.13	27.59	77.5
59.		24.56	4.21	20.35	68.7
60.		32.24	7.76	24.48	76.7
61.		36.48	6.20	30.28	76.2
62.		38.4	7.65	30.75	81.2
63.		40.32	8.82	31.5	84.4
CCL, Nullugotthey division, Virajpet taluk, South Kodagu.					
64.		20.32	2.78	17.54	54.7
65.		28.8	2.21	26.59	82.4
66.		30.64	4.60	26.04	92.2
67.		30.48	4.94	25.54	89.7
68.		32.64	4.96	27.68	94.1
69.		32.64	5.47	27.17	93.5
70.		21.12	2.89	18.23	69.6
71.		20.32	2.95	17.37	52.3
72.		24.91	4.17	20.79	64.9
73.		19.2	3.02	16.16	56.6
74.		15.36	2.00	13.36	48.3
CCL, Washmullagotthey division, Polibetta, South Kodagu.					
75.		20.0	3.33	16.67	70.5
76.		24.16	2.95	21.12	59.6
77.		34.56	4.70	29.9	77.5
78.		19.4	2.95	16.45	48.1
79.		19.4	2.36	17.04	43.4
80.		22.24	4.34	17.9	50.8
81.		23.04	2.63	20.41	69.4
82.		15.64	3.64	12.00	41.6
83.		15.36	1.96	13.40	56.6

1	2	3	4	5	6
84.		13.44	4.26	9.18	24.6
85.		15.36	2.12	13.24	40.9
	CCL, Kottabetta division, Polibetta, Virajpet, South Kodagu.				
86.		20.32	4.64	16.28	85.9
87.		16.48	2.40	14.08	61.6
88.		20.8	4.30	16.87	71.0
89.		20.32	2.38	17.94	88.2
90.		19.40	1.92	17.48	92.0
91.		22.96	1.72	21.24	92.5
92.		22.64	1.52	21.12	95.8
93.		20.72	4.08	16.64	70.3
	CCL, Muncha division, Polibetta, Virajpet, South Kodagu.				
94.		18.8	3.84	14.96	91.7
95.		22.8	2.36	20.44	91.5
96.		21.12	1.72	19.4	89.2
97.		22.8	2.18	20.6	90.1
98.		21.96	2.05	19.91	84.2
99.		16.88	1.83	15.1	74.7
100.		21.12	2.21	18.91	76.9
101.		20.32	1.72	18.6	70.3
102.		18.8	2.29	16.51	83.4
103.		21.8	2.25	19.55	95.1
104.		20.32	3.13	17.19	97.8
105.		21.12	1.28	19.84	92.0
106.		24.96	6.40	18.56	60.8
107.		23.04	2.79	20.25	55.1
	Hassan District				
	CCL, Cognur division, Karadibetta estate, Royar koppal, Sakaleshpur.				
108.		23.04	1.17	21.87	76.8
109.		21.12	2.80	18.32	82.2
110.		2.64	2.58	20.06	63.0
111.		32.24	4.45	27.79	81.4
112.		34.56	2.71	31.85	85.3
113.		28.80	3.55	25.25	76.9
114.		30.72	2.38	28.34	87.5
115.		28.80	3.82	24.98	68.9
116.		32.64	2.78	29.86	86.9
117.		17.28	2.47	14.81	46.0
118.		23.64	2.20	21.44	71.7
119.		30.72	2.21	28.51	87.4
120.		30.72	2.16	28.56	74.2
121.		30.72	3.53	27.19	87.3
122.		32.64	3.07	29.57	78.5
123.		24.96	3.51	21.45	56.9
	Chikmagalur District				
	Malandur village				
124.		9.60	4.35	5.25	20.86
125.		24.56	7.95	16.61	66.6
126.		26.48	11.05	15.43	52.1
127.		22.64	10.41	12.23	49.8
128.		24.56	4.38	20.18	68.1
129.		24.96	10.08	14.88	51.6

1	2	3	4	5	6
130.		26.88	6.83	20.65	78.5
131.		26.48	5.03	21.45	73.2
132.		23.04	4.33	19.31	62.7
133.		25.00	4.50	20.50	63.5
134.		24.96	4.0	20.96	73.2
135.		26.88	12.95	13.93	54.5
136.		19.20	10.13	9.07	41.5
137.		28.40	3.39	25.01	77.0
138.		26.88	4.43	22.45	67.8
139.		30.32	4.33	15.99	52.1
140.		26.88	10.71	16.17	52.9
141.		26.88	12.84	14.04	45.3
142.		30.72	8.34	22.38	92.8
	CCRI, Balehonur, Chikmagalur				
143.		24.56	3.84	20.72	69.4
144.		23.04	4.13	18.91	86.2
145.		24.56	7.71	16.85	83.5
146.		20.32	11.00	19.32	7.4
147.		30.72	4.76	25.96	84.9
148.		23.04	5.38	17.66	75.7
149.		24.56	3.48	21.08	72.5
150.		13.44	3.75	9.69	41.0
151.		19.60	6.00	13.6	48.9
152.		24.50	9.62	14.49	63.4
153.		20.32	6.25	14.09	42.7
154.		28.80	7.72	21.08	82.7
155.		13.44	5.45	7.99	37.2
156.		26.88	11.02	13.88	44.6
157.		28.40	11.81	16.59	59.7
	Tathkole village, Mudigere				
158.		26.88	10.37	16.51	61.2
159.		26.88	9.40	17.48	65.9
160.		22.64	3.62	19.02	75.9
161.		23.04	4.49	18.55	59.6
162.		23.04	4.23	18.81	58.7
163.		21.12	10.35	10.77	37.5
164.		28.8	6.58	22.22	75.5
165.		26.48	6.15	20.33	78.3
166.		24.56	4.90	19.66	74.4
	Narasimharajapura				
167.		35.00	6.57	28.43	78.3
168.		36.48	3.88	32.6	93.4
169.		22.24	4.66	17.58	63.0
170.		26.78	2.26	19.22	84.0
171.		26.48	4.9	21.58	82.0
172.		22.64	2.47	20.17	90.5

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Appendix - VI : Lime requirement and lime potential of the surface soil from coffee growing areas.

1	2	3	4	5
Sl. No.	Location	Methods		Lime potential
		Buffer method ----- tons/ha -----	Exch. Ca. m method	
Kodagu District				
Biligiri estate, Madikeri.				
1.		5.23	5.33	3.94
2.		5.20	5.36	3.66
3.		3.63	3.89	3.41
4.		3.27	5.94	3.20
5.		5.27	5.52	3.29
6.		4.91	6.33	3.32
7.		11.49	10.67	2.45
8.		8.19	11.66	3.67
9.		8.07	11.48	3.30
10.		8.68	12.35	2.61
11.		5.40	7.69	3.02
12.		90.2	12.83	3.01
Lakshmi estate, Madikeri.				
13.		4.24	5.99	3.64
14.		2.38	3.39	3.55
15.		6.80	9.68	3.50
16.		6.15	9.65	3.72
Ashoka estate, Madikeri.				
17.		5.94	7.62	3.41
18.		8.17	9.20	2.92
Ram's farm estate, Madikeri.				
19.		5.45	7.26	3.31
20.		4.59	6.53	3.41
21.		3.18	4.53	3.72
Sampige Kolly estate, Madikeri.				
22.		5.50	8.71	3.47
23.		6.35	7.26	3.27
24.		4.72	7.23	3.41
25.		3.65	4.00	3.13
26.		6.02	7.94	3.55
Sharma estate, Madikeri.				
27.		8.99	11.61	3.18
28.		5.71	6.29	4.19
29.		3.63	8.71	4.34
30.		6.10	11.13	4.06
Kudakageril estate, Madikeri.				
31.		6.02	9.20	4.12
32.		5.27	9.1	3.46
Apsora estate, Madikeri.				
33.		2.54	6.1	4.22
Chettalli farm estate, North Coorg.				
34.		5.38	9.03	2.87

1	2	3	4	5
35.		8.35	11.14	3.24
36.		4.42	6.29	3.40
37.		5.73	5.83	3.50
38.		6.12	8.71	2.96
39.		6.18	8.79	3.80
40.		3.76	6.78	3.87
	CCL, Sonticoppa, Bhuthanakadu division, Somvarpet taluk, North Kodagu.			
41.		4.73	4.86	5.00
42.		3.78	4.84	4.96
43.		4.79	5.81	3.26
44.		4.86	4.76	4.99
45.		4.49	4.82	3.26
46.		8.79	11.14	3.05
47.		7.49	5.80	2.78
48.		4.75	5.81	3.39
49.		1.23	1.97	4.61
50.		4.44	5.58	3.91
51.		5.72	8.87	3.68
52.		6.79	8.23	3.69
53.		8.70	10.84	3.33
54.		4.37	4.79	3.57
55.		4.73	4.04	3.96
56.		4.86	5.00	3.33
57.		3.78	4.84	4.19
58.		3.24	5.00	3.39
59.		7.26	10.83	2.5
60.		8.49	13.99	3.22
61.		4.19	4.88	3.26
62.		8.79	13.94	3.14
63.		9.67	14.04	2.88
	CCL, Nullugotthey division, Virajpet taluk, South Kodagu.			
64.		1.70	3.39	3.18
65.		3.81	6.39	3.88
66.		4.44	6.78	3.74
67.		6.35	7.75	3.35
68.		4.29	6.87	3.70
69.		3.91	6.29	3.37
70.		2.96	5.92	3.97
71.		2.07	3.39	3.55
72.		3.49	5.93	3.82
73.		2.00	3.87	4.14
74.		4.12	5.81	4.19
	CCL, Washmullagotthey division, Polibetta, South Kodagu.			
75.		7.23	10.99	4.31
76.		9.98	10.65	2.84
77.		4.75	5.69	3.97
78.		3.78	5.81	4.34
79.		4.86	7.54	4.12
80.		4.49	5.33	3.56
81.		4.52	5.39	3.12
82.		5.62	6.78	3.14

1	2	3	4	5
83.		5.09	6.58	3.34
84.		4.49	5.33	3.42
85.		3.24	3.87	3.52
	CCL, Kottabetta division, Polibetta, Virajpet, South Kodagu.			
86.		8.91	12.59	2.72
87.		5.73	8.34	4.09
88.		6.29	11.14	3.83
89.		6.44	8.23	3.80
90.		2.93	6.78	4.62
91.		6.29	7.45	3.96
92.		2.93	3.97	4.36
93.		6.99	8.85	3.36
	CCL, Muncha division, Polibetta, Virajpet, South Kodagu.			
94.		8.19	9.75	3.43
95.		3.78	3.87	4.10
96.		3.24	3.79	4.09
97.		3.78	4.91	4.10
98.		3.78	4.81	4.11
99.		4.29	6.68	3.80
100.		3.55	7.26	4.18
101.		2.70	7.65	4.46
102.		2.93	3.87	4.26
103.		2.70	7.62	4.21
104.		3.34	7.82	4.03
105.		3.55	7.92	4.13
106.		8.67	9.67	3.28
107.		6.44	7.91	4.67
	Hassan District			
	CCL, Cognur division, Karadibetta estate, Royar koppal, Sakaleshpur.			
108.		3.89	5.23	4.37
109.		4.02	4.36	3.24
110.		5.01	7.26	3.76
111.		5.02	5.91	3.41
112.		2.71	5.00	3.90
113.		2.86	6.24	3.48
114.		2.96	5.81	3.99
115.		4.29	7.62	3.49
116.		6.77	7.00	3.82
117.		1.95	4.84	4.15
118.		3.17	8.22	3.89
119.		4.44	5.20	3.98
120.		4.44	4.91	4.19
121.		3.87	4.91	3.52
122.		3.55	5.10	5.00
123.		2.96	4.26	3.81
	Chikmagalur District			
	Malandur village			
124.		4.78	6.78	4.56
125.		3.07	4.35	4.10
126.		3.75	5.33	4.18
127.		5.46	7.77	3.93
128.		7.85	11.14	4.19

1	2	3	4	5
129.		4.78	6.78	4.39
130.		8.88	12.59	3.54
131.		6.83	9.68	5.21
132.		8.14	8.71	4.36
133.		2.73	3.87	4.37
134.		4.10	5.81	4.53
135.		0.66	1.45	4.12
136.		2.54	4.6	4.53
137.		2.05	2.91	4.53
138.		4.44	6.29	4.30
139.		2.27	4.35	4.53
140.		3.83	7.74	4.39
141.		6.07	8.61	4.26
142.		5.73	7.13	3.47
	CCRI, Balehonur, Chikmagalur.			
143.		6.85	9.13	3.79
144.		5.93	8.41	4.03
145.		6.69	9.49	4.20
146.		7.84	11.12	4.03
147.		5.00	9.20	4.19
148.		3.14	5.81	3.63
149.		5.47	7.76	3.99
150.		3.55	4.36	3.72
151.		3.78	7.75	4.01
152.		8.19	10.17	3.56
153.		5.91	10.17	4.06
154.		5.43	9.14	3.93
155.		3.39	6.29	3.59
156.		6.78	8.94	3.69
157.		4.44	7.67	3.87
	Tathkole, Mudigere			
158.		5.06	6.19	4.00
159.		5.08	5.32	3.94
160.		5.08	8.91	3.89
161.		6.15	9.91	4.19
162.		5.39	7.64	4.16
163.		6.78	10.04	4.07
164.		4.68	11.14	4.37
165.		4.98	6.29	3.27
166.		2.56	3.87	4.39
	Narasimharajapura			
167.		6.02	8.07	4.1
168.		5.71	6.29	3.79
169.		4.73	6.29	3.91
170.		6.78	7.75	3.52
171.		7.07	8.71	3.44
172.		7.16	8.49	3.73

CCL : Consolidated Coffee Limited.

CCRI : Central Coffee Research Institute.

Appendix V: Correlation Co-efficient (r) among the different properties of the one hundred and seventy surface soil from coffee growing soils.

Sl. No.	Soil properties	pH in H ₂ O	pH in KCl	pH in CaCl ₂	Buffer method	Exch. Ca. method	Clay	Organic carbon	CEC	ECEC	Ca Saturation	Al Saturation	Pot. Acidity	Exch. Acidity	pH dep. Acidity
1.	pH in KCl	0.7545**													
2.	pH in CaCl ₂	0.6160*	0.6058												
3.	Buffer method	-0.4919	-0.4315	-0.3769											
4.	Exch. Ca. method	-0.3788	-0.3522	-0.3040	0.8002										
5.	Clay	-0.1403	-0.1194	-0.1371	0.1747	0.1688									
6.	Organic carbon	0.0306	-0.0254	0.0294	-0.0438	-0.0024	-0.0646								
7.	CEC	0.1661	0.1223	0.2355	-0.0405	-0.1167	0.0672	-0.2929							
8.	ECEC	0.2262	0.0824	0.2188	0.1753	0.1385	0.1490	0.2587	0.2357						
9.	Ca Saturation	0.2829	0.2129	0.3912	-0.0724	-0.1156	0.0595	0.0245	0.0220	0.2954					
10.	Al Saturation	-0.2969	-0.2743	-0.4254	0.3273	0.2681	0.1438	-0.1747	-0.1146	0.1323	-0.5108				
11.	Pot. Acidity	-0.0166	-0.0492	-0.1032	0.1836	0.1651	0.1796	0.3451	0.2372	0.3745	0.0707	-0.0604			
12.	Exch. Acidity	-0.0163	-0.1014	-0.0954	0.2926	0.3044	0.1189	0.2092	-0.0245	0.6300	-0.1595	0.4696	0.2427		
13.	pH dep. Acidity	-0.0311	-0.0290	0.0688	0.0126	-0.0490	0.0496	-0.1189	0.4857	0.0128	0.2002	-0.2307	0.6034	-0.2034	
14.	Lime potential	0.4661	0.4696	0.5277	-0.3941	-0.3188	-0.2245	0.4153	-0.0701	0.1686	0.2186	-0.3629	0.0792	0.0047	0.1185

* Significant at 5 percent.

** Significant at 1 percent.

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ವಿಶ್ವವಿದ್ಯಾನಿಲಯ ಸಂಘಾಲಯ
ಗಾ.ಕೃ.ವಿ.ಕೆ, ಬೆಂಗಳೂರು-65

29 FEB 1996

ಅನುಷ್ಠಾನ ಸಂ **Th. 4048**

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