

DYNAMICS OF POTASSIUM IN THE SOIL OF KOLE LANDS

BY
K. N. JYOTHIKUMARI

THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture

KERALA AGRICULTURAL UNIVERSITY

Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR

KERALA, INDIA

1996

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I hereby declare that the thesis entitled "**Dynamics of potassium in the soil of *kole* lands**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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K. N. JYOTHIKUMARI

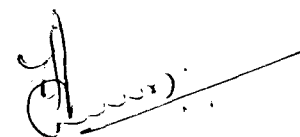
Dr.K.A. MARIAM
Associate Professor
Department of Soil Sciences and
Agricultural Chemistry
College of Horticulture

Vellanikkara

CERTIFICATE

Certified that the thesis entitled **Dynamics of potassium in the soil of *kole* lands** is a record of the research work done independently by **Mrs.K.N. Jyothikumari** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship or other similar titles to her.

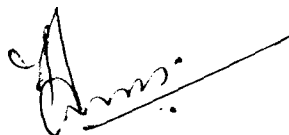
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Dr.K.A. MARIAM
Chairperson
Advisory Committee

CERTIFICATE


We, the undersigned members of the Advisory Committee of Mrs.K.N.Jyothikumari, a candidate for the degree of **Master of Science in Agriculture** with major in **Soil Science and Agricultural Chemistry**, agree that the thesis entitled **Dynamics of potassium in the soil of *kole* lands** may be submitted by Mrs.K.N.Jyothikumari, in partial fulfilment of the requirement for the degree.



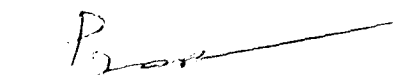
K.A. Mariam
Associate Professor
Dept. of Soil Science and Agricultural Chemistry
College of Horticulture
Vellanikkara
(Chairperson)



A.I. Jose
Associate Dean
College of Horticulture
Vellanikkara
(Member)



P.A. Korah
Professor
Dept. of Soil Science and
Agricultural Chemistry
College of Agriculture
Vellayani
(Member)



P.V. Prabhakaran
Professor and Head
Dept. of Agricultural Statistics
College of Horticulture
Vellanikkara
(Member)



30.9.96

External Examiner

ACKNOWLEDGEMENT

I express my deep sense of gratitude and indebtedness to **Dr.K.A.Mariam**, Associate Professor, Department of Soil Science and Agricultural Chemistry and Chairperson of my advisory committee for her inspiring guidance, timely and valuable suggestions, personal attention and encouragement throughout the course of this investigation.

My sincere thanks are due to **Dr.A.I.Jose**, Associate Dean, College of Horticulture, Vellanikkara for his constructive criticisms, valuable and timely help rendered by him throughout the course of my research work.

I am grateful to **Sri.P.A.Korah**, Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani for the patience he had shown in clearing doubts and for the valuable suggestions during the preparation of the thesis.

I thank sincerely **Sri.P.V.Prabhakaran**, Professor and Head, Department of Agricultural Statistics for the generous help and constructive suggestions rendered during the statistical analysis of the data.

Let me express my sincere thanks to **Smt.K.Leela**, Professor and Head, Department of Soil Science and Agricultural Chemistry and all the staff members of the Department of Soil Science and Agricultural Chemistry for the helps and cares extended to me during my study period.

I would like to thank sincerely Sri.T.Bhaskaran Nair, Secretary, Chathan kole - Puppilakkad kole for his generous help rendered to me during the collection of soil samples.

My sincere thanks are due to Mr.Joy for neat typing and prompt service.

I wish to express my sincere and heartfelt thanks to all my friends who were with me in my good and bad times.

I am always beholden to my parents and sister for their boundless affection, strong support and everlasting inspiration in all my endeavours. I remember with gratitude, the love and encouragement of my husband during the course of my study. I am extremely indebted to my little son who suffered much and sacrificed his infancy for the successful completion of my M.Sc.Programme.

The award of junior research fellowship by Kerala Agricultural University is gratefully acknowledged.


K.N.Jyothikumari

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Introduction

INTRODUCTION

Potassium is a major component of earth's crust and its concentration in soil normally varies from 0.5 to 2.5 per cent. Soil potassium exists in four forms namely mineral potassium, non-exchangeable potassium, exchangeable potassium and soil solution potassium. Potassium being highly susceptible to leaching, replenishment by weathering of soil minerals can not keep pace with the loss by leaching under intensive cropping. Crop removal is also a major form of loss from soil.

Potassium reserves and their availability to crops depend largely on mineralogy and the degree of weathering, which in turn determine the dynamic equilibrium between water soluble, exchangeable and non-exchangeable forms.

The *kole* lands of Kerala extends over an area of 13,682 ha in Trichur and Malappuram districts and this soil belongs to the soil order Entisols and Inceptisols. They lie between 0.5 to 2 m below mean sea level and are under submerged condition for most part of the year. Earlier studies carried out in Kerala revealed that these lands are mostly deficient in available potassium. Precise information about the forms of potassium and their relationship with soil properties as well as their interrelationship in different soil depths for this soil is meagre.

Owing to the intensification of agriculture, there is a wide spread response to fertilizer potassium. A knowledge of the nature and distribution of potassium in the different forms, is a prerequisite for assessing the availability of potassium to the crops. The study of pattern of release of potassium from the soil

with potassium application will be useful for better fertilizer management. Very little work has so far been done in this regard in *kole* soils occurring in this state.

Both chemical and biological methods are being used for assessing the available K status of the soil. Among the chemical extractants, neutral normal ammonium acetate is generally used for assessing the available potassium status of soils. The superiority of this method as an index of potassium availability over the others has not been studied for the *kole* lands.

Hence the present investigation was undertaken with the following objectives.

1. To study the physico-chemical characteristics of *kole* soils related to potassium availability and to study the forms and distribution of potassium in the *kole* soils.
2. To find out the retention of applied potassium with different periods of shaking.
3. To evaluate the changes in the dynamics of potassium with and without potassium application under submerged condition.
4. To evaluate suitable extractant for the estimation of available potassium in *kole* soils.

Review of Literature

REVIEW OF LITERATURE

A precise knowledge of the distribution, fixation and availability of potassium in soils is considered to be a pre-requisite to understand and interpret the behaviour of added potassium in the soils and it is influenced by physical and chemical characteristics of the soils. An attempt is made here to review some of the earlier work carried out in these aspects which is of relevance to the present study.

2.1 Physical Properties

Hameed (1975) from his study on the fertility investigations in *kole* soils reported that almost all the soils in the *kole* areas were clayey and the clay content in the profile ranged from 24.3 to 68.5 per cent. Coarse sand and fine sand fractions ranged from 0.9 to 27.4 per cent and 3.3 to 16.7 per cent respectively. Venugopal and Nair (1979) reported a high content of clay in *kole* soils and it ranged from 52.5 to 75.0 per cent in surface soils. The coarse sand, fine sand and silt fractions reported by them were ranged from 2.35 to 10, 3.72 to 9.9 and 15 to 25.6 per cent respectively. Sheela (1988) reported a range of 3.8 to 70.4 per cent for the coarse sand and 2.0 to 27.2 per cent for the fine sand fraction in the *kole* soils, whereas the range for the silt and clay contents were 5.6 to 47.0 and 2.4 to 70.0 per cent respectively. Krishnakumar (1991) reported a range of 23.8 to 40.0 per cent and 4.2 to 27.1 per cent of coarse sand and fine sand fractions in Konchira and Ayyanthole series of *kole* soils. The silt contents showed wide variation and it ranged from 10.5 to 36.0 per cent while clay content ranged from 18.5 to 44.0 per cent in the profile samples.

The bulk density and particle density values in *kole* areas were higher in top layers and lower in deeper layers and the values ranged from 0.7 to 1.2 g/cm³ and 1.3 to 2.83 g/cm³ respectively (Hameed, 1975). Almost all soils had high pore space (49.9 - 70.8%) and water holding capacity (41.1 - 81.7%). Krishnakumar (1991) reported that in Konchira and Ayyanthole series the bulk density varied from 0.96 to 1.65 g/cm³ and particle density from 1.91 to 2.64 g/cm³. Water holding capacity and pore space percentage varied from 25.5 to 57.6 and 38.7 to 57.3 per cent respectively. Singh *et al.* (1993) reported a gradual increase in bulk density (1.3 - 1.4 g/cm³) with depth in low land soils in Kullu Valleys of Himachal Pradesh indicating a progressive compaction due to filling of pores by alluvial materials.

Bulk density and particle density appeared to be a function of coarser particles while water holding capacity and porespace were related to finer particles of the soil in quantity and quality (Nair *et al.*, 1966). Sharma *et al.* (1980) and Mathan and Kannan (1993) found a significant negative correlation between clay content and bulk density. A high positive correlation of water holding capacity with silt + clay was reported by Chaudhary *et al.* (1989) in soils of some Inceptisols. A significant positive correlation between clay percentage and porespace was reported by Elsy (1989) in soils of forest ecosystem.

2.2 Chemical characteristics

Kole soils were grouped under acid saline soils. Venugopal and Koshy (1976a), from a profile study observed a pH of 4.5 to 5.0 for the *kole* lands. Venugopal and Nair (1979) reported that the pH of *kole* soils did not show much variation and were around 6.0 except for the organic layer of Konchira series with

a pH value of 4.0. Kabeerathumma and Patnaik (1980) reported a pH of 4.9 and EC of 5.2 dSm^{-1} and Sheela (1988) found a range from 3.4 to 5.4 for pH in the soils of *kole* lands. Krishnakumar (1991) reported that the pH of Konchira and Ayyanthole series varied from 3.0 to 7.0 and electrical conductivity from 0.112 to 0.35 dSm^{-1} .

Organic carbon content varied widely in the *kole* lands. It ranged from 1.2 to 2.4 per cent in surface soils (Hameed, 1975). Venugopal and Nair (1979) observed a range of 0.64 to 1.63 per cent of organic carbon while Sheela (1988) reported a range from 0.23 to 2.58 per cent for the *kole* soils. The organic matter content of surface layer varied from 2.07 to 4.16 per cent and for the sub-surface layer it varied from 1.37 to 9.7 per cent in *kole* lands (Johnkutty and Venugopal, 1993).

Alexander and Durairaj (1968) and Das *et al.* (1991) reported a significant negative correlation between organic carbon and pH. Velayutham and Raj (1971) reported a significant positive correlation between organic carbon and water holding capacity. A significant negative correlation of organic carbon with bulk density was reported by Mathan and Mahendran (1994).

Venugopal and Nair (1979) reported a total N content of 0.042 to 0.151 per cent, whereas Sheela (1988) reported a range of 0.04 to 0.26 per cent in the *kole* lands. Total N content of the Konchira and Ayyanthole series ranged from 0.04 to 0.22 per cent (Krishnakumar, 1991).

In the *kole* lands total P_2O_5 content ranged from 0.02 to 0.24 per cent (Hameed, 1975) and from 0.073 to 0.197 per cent (Venugopal and Nair (1979). Sheela (1988) reported a range of 0.09 to 0.36 per cent for total P in *kole* lands.

Verma *et al.* (1980) and Mathew (1986) reported a significant positive correlation between organic carbon and total nitrogen. Kanwar *et al.* (1983) reported a significant correlation of total P with pH, organic carbon and clay. Bhatia and Pal (1988) and Dongale (1993) reported a significant positive correlation of total P with clay and organic carbon. Sheela (1988) reported that the total P_2O_5 was significantly and negatively correlated with organic carbon, clay and silt.

Mathew (1986) reported that available nitrogen content of the acid saline soils ranged from 52 to 131 ppm and that of available P from 44 to 165 ppm. Krishnakumar (1991) reported a range of 60 to 160 ppm for available N and 2.0 to 30 ppm for available P in the Konchira and Ayyanthole series of *kole* lands. However, Sheela (1988) reported a value of 9 to 50 ppm of available P for this soil.

For acid soil a high positive and significant correlation between organic carbon and available N was reported by several workers (Palaniappan *et al.*, 1978; Verma *et al.*, 1980; Chibba and Sekhon, 1985).

Mathew (1986) reported that available P was negatively correlated with clay and organic matter in acid saline soils. In *kole* soils available P_2O_5 was negatively correlated with clay, but positively correlated with organic carbon, coarse sand and fine sand fractions (Sheela, 1988). Das *et al.* (1991) reported a significant positive correlation between available P and pH. Kanthaliya and Bhatt (1991) reported that the relationship between organic carbon and available P was not significant.

Calcium is the predominant exchangeable base in the surface layer followed by Mg in the *kole* soils (Venugopal and Koshy, 1976a). They have also

reported that the exchangeable K and Na contents were 1.24 and 0.27 $\text{cmol}(+) \text{kg}^{-1}$ soil respectively. Kabeerathumma and Patnaik (1980) reported a value of 2.8 $\text{cmol}(+) \text{kg}^{-1}$ for exchangeable Ca and 0.22 $\text{cmol}(+) \text{kg}^{-1}$ for exchangeable K contents in *kole* soils. The exchangeable Ca and Mg ranged from 1.37 to 3.0 $\text{cmol}(+) \text{kg}^{-1}$ and 0.05 to 1.92 $\text{cmol}(+) \text{kg}^{-1}$ respectively for Konchira and Ayyanthole series of *kole* soils (Krishnakumar, 1991).

Cation exchange capacity in a profile in the soils of *kole* lands ranged from 4.88 to 9.84 $\text{cmol}(+) \text{kg}^{-1}$ in *kole* soils (Venugopal and Koshy, 1976 b). Sheela (1988) reported a range of 5.0 to 21.6 $\text{cmol}(+) \text{kg}^{-1}$ and Johnkutty and Venugopal (1993) reported a range of 12.6 to 48.6 $\text{cmol}(+) \text{kg}^{-1}$ in the *kole* lands.

Krishnakumar (1991) observed a range of 21.4 to 63.65 per cent for the percentage base saturation in the Konchira and Ayyanthole series of the *kole* soils. Ambili (1995) reported a range of 22.45 to 78.29 per cent for the percentage base saturation in surface soils of *kole* lands.

Alexander and Durairaj (1968) reported that CEC was negatively correlated with pH in acid soils of Kerala. Lavti *et al.* (1969) reported a significant positive correlation of CEC with clay and organic carbon in Rajasthan soils. Venugopal and Koshy (1976a) suggested that exchangeable Ca content increases with increase in the content of clay and Humus. A significant positive correlation of CEC with clay and nonsignificant positive correlation with organic carbon was reported by Venugopal and Koshy (1976b). Elsy (1989) reported a highly significant correlation of CEC with organic carbon, exchangeable Ca, Mg, Na and K in the soils of forest ecosystem in Kerala. Percentage base saturation was also significantly correlated with exchangeable cations and pH. Jessymol (1991) reported a highly

significant correlation of cation exchange capacity with clay and organic carbon in low land laterites of Kerala.

2.3 Forms and availability of potassium

From a study on the potassium status of five major rice soils of Kerala viz., *Kari*, *Karapadom* and *Kayal* lands of Kuttanad region and *kole* lands of Trichur and low level laterites of ribbon valleys in the midland region Sreedevi and Aiyer (1974) reported that the magnitude of exchangeable K was higher in *Kari* soils followed by *Karapadom*, *Kayal*, *Kole* and least in low level laterites. Talati *et al.* (1974) observed a significant correlation between available and non-exchange forms of potassium.

Hameed (1975) reported that total K_2O content of *kole* soils ranged from 0.09 to 0.6 per cent and available K_2O was about 0.18 per cent. The depth wise variation in the distribution of potassium was attributed to the variations in the content of organic matter, clay and also due to constant flooding and leaching during drainage. Ram and Singh (1975) reported that in paddy soils of eastern Uttar Pradesh the available potassium had positive significant correlation with clay.

Sreedevi *et al.* (1975) observed appreciable quantities of total K in the coarser fractions of soil, in the rice growing soils of Kerala. The silt fractions of *kole* soils and low level laterites have the highest values of total K compared to the silt fractions of other soils.

Kansal and Sekhon (1976) reported that the potassium status of alluvial soils of Punjab was a function of clay + silt contents. Lepsch *et al.* (1978) reported that the total potassium content was greatest in the silt fraction followed by fine

sand, clay and coarse sand in soils of Pindorema and Brazil. They also showed that major portion of total potassium was present in primary minerals as feldspars and micas.

Negi *et al.* (1979) observed a highly significant positive correlation of nitric acid soluble potassium with sand and silt and a negative correlation with clay in alluvial soils of Uttar Pradesh. Chakravarty *et al.* (1979) reported a significant positive correlation of total K with clay and silt in the alluvium derived soils of southern bank of the river Brahmaputra in Assam. A significant positive correlation of K fixing capacity with pH, cation exchange capacity, clay and exchangeable Ca + Mg was reported by several workers. (Singh and Singh, 1979; Ranganathan and Satyanarayana, 1980; Sahu and Gupta, 1987; Ningappa and Vasuki, 1989; Talele *et al.*, 1993).

A significant positive correlation of total potassium with silt and clay fractions was reported by Iwuafor *et al.* (1980). From a study on the K status of the soils of Karnataka, Ranganathan and Satyanarayana (1980) reported that the water soluble and exchangeable K contents ranged from 0.003 to 0.009 cmol(+) kg⁻¹ and 0.13 to 0.33 cmol(+) kg⁻¹ respectively for the alluvial soils. They reported a significant positive correlation between water soluble and exchangeable K. Bolan and Ramulu (1981) reported a positive correlation between pH, EC, exchangeable (Ca and Mg)_{and} organic carbon with different forms of K in Nilgiris soils. Goswami and Sahrawat (1982) reported that alluvial and Black soils dominant in illite and montmorillonite clay minerals respectively have high K fixing capacity.

Singh *et al.* (1983) reported that different forms of K were positively correlated to each other except water soluble K which has positive correlation with

exchangeable K only in some soils of different agroclimatic regions of Eastern Haryana.

Brar and Sekhon (1985) and Dhillon *et al.* (1985) reported that the content of available potassium was influenced by fineness of texture in soils of Northern India. Prakash and Singh (1985a) found that total K had no significant relationship with organic carbon and pH. Singh *et al.* (1985) reported a significant relationship of available potassium with silt and clay in Western Haryana soils. A significant negative correlation of total K with coarse sand was reported by Prakash and Singh (1985b) in soils of Agra region of Uttar Pradesh.

In alluvial soils of Agra region Prakash and Singh (1986) found that the content of nitric acid soluble K ranged from 3.097 to 8.086 $\text{cmol}(+) \text{kg}^{-1}$ soil. Sharma and Mishra (1986) obtained higher contents of exchangeable and non exchangeable potassium in the fine textured soils compared to coarser ones. Coarse textured soils had higher amounts of water soluble K. Singh and Singh (1986) obtained significant positive correlation of organic carbon with total K and water soluble K.

Tarafdar and Mukhopadhyay (1986) reported that the different forms of K such as water soluble, exchangeable, labile, non-exchangeable and total K were positively correlated with each other except the interlayer K which did not significantly correlate with total K in alluvial zones of West Bengal. Singh and Datta (1986) reported that exchangeable K and water soluble K, on an average contribute 0.6 per cent and 0.06 per cent of total K in soils of Mizoram.

Ghamuah (1987) studied the potassium status of the alluvial soils of Assam. They reported that water soluble K decreases with depth while non-exchangeable K increases with depth in all the profiles. Ravikumar *et al.* (1987) found that all forms of K were inter related except total K with water soluble and HNO₃ extractable fractions. He also observed that all the forms of K had positive correlation with CEC.

From a study on the fixation of K in some alluvial soils under alternate wetting and drying conditions, Sahu and Gupta (1987) found that 31 to 65 per cent of added k was fixed and fixation increased with increasing rates of K application, but the percentage of added K fixed decreased gradually.

Rao and Sekhon (1988) reported that the alluvial soils from Western India had a low non-exchangeable K content and the proportion of non-exchangeable to exchangeable form of K was relatively greater in soils dominated by illite and smectite than in those rich in smectite alone.

Significant positive correlation between water soluble, exchangeable and HNO₃ extractable K was reported by several workers (Koria *et al.*, 1989; Rao and Sekhon, 1990; Sehgal *et al.*, 1992). Ningappa and Vasuki (1989) studied the K fixation in acid soils of Karnataka and they reported that K fixation in acid soils mainly lateritic ranges from 21.4 to 40.6 per cent.

Singh *et al.* (1989) reported that total and water soluble K was positively correlated with sand and negatively with silt and clay. Singh *et al.* (1989) reported a positive correlation of exchangeable and available K with clay. Singh and

Upadhyay (1989) reported that sand had a negative relationship with total K and positive correlation with silt and clay. They also reported that the HNO_3 soluble form was positively correlated with all the particle size fractions.

Mercykutty *et al.* (1990) reported that water soluble, exchangeable and available K were significantly correlated with fixed K in rubber growing soils of South India. They observed a positive correlation between clay content and total K in these soils and reported a significant positive correlation of organic carbon with water soluble K, exchangeable K, fixed K and available K.

Boruah *et al.* (1991) reported that 20.1 to 90.0 per cent of added K was fixed in three major soil orders of Assam namely Entisol, Inceptisol and Alfisol under alternate wetting and drying. Deshrugh *et al.* (1991) from a study on the content and forms of K in the surface and subsurface soil samples from the Entisols and Vertisols of Vidarbha region reported that total K values were high in the surface soils, but decreased in the subsurface soils.

Different forms of K in Ustochrept soils of Delhi was studied by Deshmukh and Khera (1991). The average values of water soluble, NH_4OAc extractable and non-exchangeable K were 3.57, 14.33 and 148 mg K/100 g soil and total K was 1.36 per cent. Krishnakumar (1991) reported that total K_2O content ranged from 0.17 to 1.1 per cent and available K ranged from 5.0 to 25 ppm in the Konchira and Ayyanthole series of the *kole* soils.

Mongia and Bandyopadhyay (1991) reported a significant correlation between total potassium and pH. Patiram (1991) reported that exchangeable K was positively correlated with CEC and exchangeable Ca + Mg. Rao and Sekhon

(1991) reported that available K had significant positive correlation with other forms of K in acid soils.

Basumatary and Bordoloi (1992) reported that different forms of potassium and K fixation capacity showed a positive relationship with clay, silt and base saturation and a negative relationship with sand. They observed that water soluble, exchangeable and non-exchangeable K were positively and total K and lattice K were negatively related to pH.

Pal and Mukhopadhyay (1992a) reported a highly significant correlation of total K with water soluble and non-exchangeable K in profiles of some Entisols and they reported that there is no trend in the distribution of K in the profile. They reported a highly significant positive relationship of clay with exchangeable, available and non exchangeable K.

In some Inceptisols, Pal and Mukhopadhyay (1992b) observed no definite trend in the distribution of exchangeable K in the profile. They observed a significant positive correlation of water soluble K with exchangeable K, available K, non exchangeable K and total K. Exchangeable K was significantly correlated with available K and non exchangeable K while non exchangeable K was positively correlated with total K in this soils.

Sutar *et al.* (1992) studied the forms of potassium in laterite soils of Maharashtra. The values of water soluble, exchangeable, non-exchangeable and total K were ranged from 6 to 30, 13 to 231, 76.4 to 374.4 and 2975 to 3250 ppm respectively.

Tripathy *et al.* (1992) obtained a positive relationship between the content of available potassium and organic carbon. Tiwari and Bansal (1992) studied the vertical distribution of forms of potassium in some soil series of Northern Madhya Pradesh. They reported that, water soluble and exchangeable K content increased with depth upto 135 cm in the alluvial soils. They observed no significant relation of total K with other forms of K.

Dixit *et al.* (1993) reported a significant positive correlation of HNO_3 extractable K with clay in soils of Western Uttar Pradesh. Masilamani *et al.* (1993) studied the potassium fixation in major soil series of Pudukottai district in Tamil Nadu. They reported that the highest fixation occurred in soil series containing higher amounts of clay and moderate CEC possessing higher portion of 2:1 type clay predominantly montmorillonite type and moderate fixation observed in soils having mixed mineralogy.

Venkatesh and Satyanarayana (1994) reported that water soluble, exchangeable non-exchangeable, lattice and total K were correlated with one another indicating the existence of dynamic equilibrium among all the forms of potassium in Vertisols of Karnataka.

Joseph and Saifudeen (1994) reported a significant positive correlation of available K with exchangeable K and HNO_3 -K. They also reported that available K was positively correlated with cation exchange capacity, base saturation, exchangeable Ca, Mg and Na.

2.4 Retention and transformation of applied potassium

Mishra and Shankar (1971) studied the potassium fixation capacity and fate of applied potassium in soils of Uttar Pradesh after incubating the soils with 2.5, 5 and 10 mg K per 10 g soil. Potassium fixation capacity varied from 11.92 to 51.52 per cent. Only 4 to 6.2 per cent of added K remained in water soluble form and exchangeable K content increased with increasing levels of potassium application.

Kabeerathumma and Biddappa (1975) reported that the exchangeable K was more in unlimed soils and it appeared to be decreased considerably with the application of lime up to 75th day. Kabeerathumma and Patnaik (1978) studied the effect of submergence on the availability of toxic and deficient nutrients in acid sulphate soils of Kerala. In *kole* soils they observed an initial increase in exchangeable K during the first 10 days of submergence and then a marked decrease in the next 20 days. After this period there was an increase in exchangeable K till the end of 70th day of flooding.

Ramanathan *et al.* (1981) reported that the fixation of K was more under alternate wetting and drying conditions than that under constant moisture level in laterite soils and the increased addition of K increased the quantity of K in the exchange complex which in turn increased the fixed K.

Cuttle (1983) reported that cation exchange capacity and pH were the most important chemical properties influencing retention of applied K in peat soils.

Datta and Sastry (1985) while studying the effect of different moisture treatments on available potassium status in soils growing rice reported that the

changes in the exchangeable potassium observed at different incubation periods among the different sites may be attributed to the variation in the mineralogical composition of the soils.

Dynamics of potassium in the alluvial soils of San Alberto was studied by Ollagnier and Otivin (1986). They reported that high CEC of the alluvial soils readily retains fertilizer K and of 96 per cent of K applied about half of it is the exchangeable form and the other half had been fixed by the clay fraction.

Singh *et al.* (1986) studied the transformation of applied K in relation to its availability in calcareous soils. They reported that the largest fraction of K applied was transformed into non exchangeable form followed by exchangeable and water soluble forms.

Chakravorti *et al.* (1988) studied the dynamics of potassium in submerged soils growing rice. In K depleted soils, under submerged conditions little soil K was converted into boiling 1N HNO₃ extractable form. Higher KCl doses increased the amount of solution K and exchangeable K. At high rates of K supply water soluble K exceeded exchangeable K in the more clayey soils.

Ndiaye and Yost (1989) reported that for any given K solution concentration, the amount of K held by the subsoil was twice than that retained by the top soil in the typic Hydrandept soil from the Islands of Hawaii.

Prakash and Singh (1989) studied the fate of applied K in soils of varying texture after incubating for 90 days. They found that exchangeable K content and the amounts of K fixed increased with levels and passage of time.

Dynamics of potassium in Mollisols from Uttar Pradesh as influenced by moisture regimes was studied by Singh and Singh (1992). They reported that both available and fixed K showed slight increase in the first two weeks and a sudden decrease in the fourth week. Generally more fixed K was released under submerged conditions than at field capacity.

Chakravorti (1992) reported that K addition increased the retained K in all the Ultisols, Alfisols and Vertisols and the potassium retention power did not change much in most of the cases due to exhaustive cropping. The amount of K retained by the colloids from the applied water soluble K solely depend on cation exchangeable capacity of the soil.

Jessymol and Mariam (1993) studied the transformation of added potassium in laterite soils for 3 months. At the end of the incubation period there was a remarkable increase in all the fractions of K viz., water soluble, ammonium acetate extractable and nitric acid soluble forms although slight fluctuations were noticed throughout the incubation period.

Talele *et al.* (1993) studied the effect of added K and incubation time on transformation of available K and non exchangeable K in different soils of Maharashtra for an incubation period of 30 days. They reported that exchangeable K fraction increased with increase in amount of added K and decreased with the increase in the period of incubation. In the case of non-exchangeable K, it increased with increase in the time of incubation.

Rao and Khera (1995) reported that longer period of equilibration reduced the retention of potassium in illitic alluvial soils by two step alternate method.

2.5 Availability indices of potassium

A great number of extractants were tried by different workers for extraction of available K from soils. Hanway and Heidal (1952) reported neutral 1N NH₄OAc as the best extractant for available potassium. The same was reported by Datta and Kalbande (1967), Mishra *et al.* (1970) and Bhadoria *et al.* (1986)

Halevy (1977) was of the opinion that extraction with CaCl₂ solution (0.01M) would be a better method for estimation of available K. The same was reported by Hagin and Feigenbaum (1962), Feigenbaum and Hagin (1967) and Russell (1967).

Ramanathan (1978) reported that 1N nitric acid was the most suitable extractant for predicting the K uptake by plants from the soil groups of South India. The correlation coefficient between laboratory estimates of K and K uptake by Neubauer crops were in the order of 1N HNO₃ > non exchangeable K > 1N NH₄OAc > 0.5N HCl > 6N H₂SO₄ > 0.01M CaCl₂ > water soluble.

Nagarajan (1981) reported that ammonium acetate, 0.1N HNO₃ and 0.1N H₂SO₄ methods were found to be closely related to uptake whereas ammonium acetate extractable K alone correlated significantly with grain yield. Singh and Ghosh (1982) observed a highly significant correlation of NH₄OAc-K with plant K.

Ram and Prasad (1983) and Singh *et al.* (1992) reported that 1N NH_4OAc extractable K and 0.1N HNO_3 extracted K were well correlated with each other. Boiling 1N HNO_3 soluble K recorded the highest value among all the extractants because, in addition to exchangeable K some of the non exchangeable K is brought into solution.

Devi and Jose (1986) reported that Mathew's triacid with a soil solution ratio of 1:10 and equilibrium period of 30 minutes had good correlation with NH_4OAc -K.

Husin *et al.* (1986) studied the plant response to K, related to soil tests for K fractions in 30 soils of Louisiana. They found that there was a high degree of relationship between plant uptake of K and exchangeable K in that soils.

Kene *et al.* (1987) reported that dry matter production by rice in Neubauer tests was better correlated with NH_4OAc extractable K and Barbier - Morgan K in soils of Vidarbha region. Mello (1987) reported a high correlation between exchangeable K and K extracted by Neubauer method using rice as test crop.

Sahu and Gupta (1987) reported that the efficiencies of the extractants for extracting non-exchangeable K from alluvial soils followed the order 1N HNO_3 > 1N NH_4OAc > 0.01M CaCl_2 .

Nath and Purkaystha (1988) reported the K extracting capacity of different extractants for assessing available K in alluvial soils of Assam in the order of 1N HNO_3 > 0.5N HCl > 1.38N H_2SO_4 > neutral 1N NH_4OAc > 0.025M CaCl_2 > Morgans reagent > 0.01M CaCl_2 > distilled water.

Tarafdar and Mukhopadhyay (1988) studied the most suitable indices of potassium availability in representative soils of West Bengal. They reported that the most suitable extractant for both coarse and medium textured soils was 1N NH_4OAc , but this extractant was not correlated with dry matter yield and uptake by maize for fine textured soils.

Relative efficacy of soil test methods to measure the status of available potassium in micaceous soil was studied by Krishnakumari and Khera (1989). They reported the order of extractants as 1N boiling HNO_3 > Neutral 1N NH_4OAc > Morgan's reagent > 0.01M CaCl_2 solution.

Patiram *et al.* (1989) based on a study on the suitability of extractants for available K for maize in acid soils of Sikkim reported that extraction by various extractants for available K was in the order of 1N NH_4OAc > Bray and Kurtz No.2 > Olsen > Mehlich > Bray and Kurtz No.1.

Perumal *et al.* (1991) studied the relationship between soil test methods and potassium fractions with sorghum as test crop. They reported that water soluble K showed closer significant relationship with yield/uptake followed by exchangeable K.

Sharma and Sekhon (1992) studied soil-plant K inter relationship in six soil series differing in K status through short term absorption studies with sorghum. They found a significant positive correlation of 1N NH_4OAc and HNO_3 -K with plant K.

Kumari and Aiyer (1993) evaluated suitable soil testing methods for available potassium in the lateritic/red loam soils of Kerala. They reported that neutral normal ammonium acetate, 0.01M CaCl₂ and 0.5N HCl were the best extractants for determining K availability. The correlation coefficient obtained between laboratory estimates of K and K uptake by the Neubauer technique were followed the order of Neutral N NH₄OAc > 0.01M CaCl₂ > 0.5N HCl > water > 6N H₂SO₄ > Morgans reagent > 1N HNO₃.

Islam *et al.* (1994) reported that NH₄OAc and boiling HNO₃ extractable K had the highest correlation coefficient with the dry matter yield and the K uptake by the rice plants.

Materials and Methods

MATERIALS AND METHODS

In order to study the forms, distribution, fixation and availability of potassium in the *kole* soils of Trichur district, soil samples were collected from 15 locations of Chathan *kole* - Puppilakkad *kole* area of Adat and Tholur Panchayaths. The locations were identified at a distance of about 2 km. Seven locations (L_1 to L_7) from Chittilappilly village and four each from Adat (L_8 to L_{11}) and Chalakkal (L_{12} to L_{15}) villages were selected for the study. From each location two sites were selected in nearby plots. The first site was represented as S_1 and the second one as S_2 . Both surface (0-20 cm) and subsurface (20-40 cm) samples were collected from each site after taking circular pits of about 50 cm diameter and 70 cm depth.

The soil samples were dried in shade, powdered, sieved through 2 mm sieve and used for undertaking the present study. The soils were analysed for the physico-chemical characteristics viz., particle size distribution, physical constants, pH, EC, organic carbon, CEC, total N, P, K, available N, P, K, exchangeable Ca, Mg, K, Na and K fixing capacity using standard procedures. Other studies conducted in these soils include a retention study, an incubation study and an evaluation of the laboratory indices of potassium availability.

3.1 Physico-chemical characteristics of the soils

3.1.1 Physical properties

Particle size analysis of the soil samples was carried out using International Pipette method (Piper, 1942). Physical constants were determined using keen Raczkowski box method (Wright, 1939).

3.1.2 Chemical properties

Organic carbon content of the samples were determined as per Walkley and Black method (Jackson, 1958).

The pH of the soil (1:2.5 soil water ratio) was determined using a pH meter (Jackson, 1958) and electrical conductivity (1:2.5 soil water ratio) was determined by conductivity bridge (Jackson, 1958).

Cation exchange capacity was determined by neutral normal ammonium acetate leaching and distillation of soil as described by Jackson (1958).

Total N was estimated using microkjeldhal digestion - distillation method (Jackson, 1958).

For estimating total P and K, the soil was digested with diacid mixture (Jackson, 1958). In the acid extract total P was determined by the vanado molybdophosphoric yellow colour method in nitric acid system (Jackson, 1958) and total K using flame photometer (Jackson, 1958).

Available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorus was extracted using Bray No.1 extractant and determined by ascorbic acid method (Watanabe and Olsen, 1965). Available K was extracted using neutral 1N ammonium acetate and determined using a flame photometer (Jackson, 1958).

The exchangeable cations were determined in the leachate obtained from the cation exchange determination, which was made up to a known volume. In

a portion of the leachate, exchangeable calcium and magnesium were determined by EDTA titration method (Hesse, 1971). Exchangeable sodium and potassium were estimated using a flame photometer. Potassium fixing capacity was determined by the method suggested by Ghosh *et al.* (1983).

3.1.3 Forms of potassium

Water soluble potassium

Air dried soil was shaken with distilled water in the ratio 1:5 for one hour and in the filtered extract, potassium was determined using flame photometer (Jackson, 1958).

Ammonium acetate extractable potassium

Air dried soil was shaken with neutral normal ammonium acetate in the ratio 1:5 for 5 minutes. In the filtered extract potassium was determined using a flame photometer (Jackson, 1958).

Nitric acid soluble potassium

Air dried soil was boiled with 1N nitric acid in the ratio 1:5 for 10 minutes and in the filtered extract potassium was determined using flame photometer (Wood & De Turk 1941).

3.2 Retention of potassium

Five gram soil was treated with 25 ml of 100 ppm potassium solution and it was shaken at constant speed for 0, 2, 4 and 6 hours. After shaking for the above intervals the extract was filtered and the K content in the filtrate was

determined using a flame photometer. Potassium retained in the soil was determined by the difference between the K added and K obtained in the filtrate.

3.3 **Change in the dynamics of potassium**

A laboratory incubation experiment was carried out using the surface samples of the 15 locations to delineate the pattern of changes in the different forms of K in submerged condition. To 600 g of soil, potassium was applied in the form of muriate of potash at the rate of 45 kg K_2O /ha and one sample was kept without K application. The soils were incubated for a period of three months at room temperature and soil samples were taken regularly at fortnightly intervals and these samples were analysed for water soluble, exchangeable and HNO_3 soluble potassium as per standard procedures.

3.4 **Evaluation of availability indices of potassium**

3.4.1 **Chemical extractants**

To evolve the best extractant for available K, various extractants were tried. The extractants were:

- (i) **Neutral normal NH_4OAc** (Hanway and Heidal, 1952; Datta and Kalbande, 1967; Mishra *et al.*, 1970). To 5 g soil, 25 ml of the extractant was added, shaken for 5 minutes and filtered through whatman No.1 filter paper and K content in the filtrate was determined using flame photometer.

- (ii) **0.06N H₂SO₄ + 0.06N HCl + 0.05N H₂C₂O₄ (Mathew's triacid)** (Devi and Jose, 1986). To 5 g soil, 50 ml of the extractant was added and shaken for 30 minutes, K content in the filtered extract was determined using flame photometer.
- (iii) **0.01M CaCl₂** (Hagin and Feigenbaum, 1962; Feigenbaum and Hagin, 1967). To 5 g soil 35 ml of the extractant was added and shaken intermittently for one hour and K was determined in the filtered extract using flame photometer.
- (iv) **1N HNO₃** (Wood and De Turk, 1941). To 5 g soil, 25 ml of 1N HNO₃ was added and boiled for 10 minutes and K content in the filtrate was determined using a flame photometer.

3.4.2 Biological method

Total uptake of K from the soils was determined by growing rice crop, in the soils taken in plastic containers as per the Neubauer seedling technique (Kanwar, 1976) with certain modifications.

Both the surface and subsurface soils from the 15 locations were used for the study. One hundred g of soil was taken in small plastic containers of 12 cm diameter and 5 cm depth and mixed with 50 g of acid washed sand. A control pot was maintained in which no soil was taken. A short duration high yielding variety of rice, viz., Hraswa was used as the test crop. Germinated seeds were used as the seed material and 100 seedlings were sown in the pots for a period of 27 days. The plants along with roots were harvested and the adhering soil particles were

completely removed. The harvested plant material was dried in an electric oven at 70 °C till constant weight was obtained.

The whole plant material was powdered, dried and 0.1 g of the plant sample was digested with tri acid mixture (10:1:4 nitric acid-sulphuric acid and perchloric acid mixture). K content in the digest was determined using a flame photometer. The percentage of K in the plant material was calculated and K uptake by the plants was then computed.

The potassium extracted by various chemical agents were correlated with potassium uptake using rice as a test crop grown under modified Neubauer technique.

3.5 Statistical analysis

Statistical analysis of the data on retention and incubation study was carried out using the analysis of variance techniques for ~~two~~ factor completely randomised design. Coefficients of simple linear correlation between the various soil characteristics and those between the amount of potassium extracted by various chemical agents and plant K uptake were worked out (Snedecor and Cochran, 1967).

Results and Discussion

RESULTS AND DISCUSSION

The results of the study on the physico-chemical characteristics, forms, retention, release and availability of potassium are presented and discussed in this chapter.

4.1 Physico-chemical characteristics of the soil

4.1.1 Physical characteristics

The data on the particle size distribution and single value constants of the soils collected from Chittilappilly, Adat and Chalakkal villages are presented in Table 1, 2 and 3 respectively.

The coarse sand fraction of the Chittilappilly village ranged from 15.9 (L_5S_1) to 69.9 (L_2S_1) per cent (mean=43.89%) in the surface and 2.71 (L_5S_1) to 75.6 (L_7S_2) per cent (mean=47.08%) in the subsurface. The fine sand fraction of the surface and subsurface soils ranged from 3.16 (L_1S_2) to 16.88 (L_1S_1) and 6.06 (L_1S_2) to 21.68 (L_5S_2) per cent with mean values of 11.17 and 10.13 per cent respectively. The silt content ranged from 2.0 (L_4S_2) to 20.5 (L_3S_1) per cent in the surface (mean=8.14%) and from 2.51 (L_7S_2) to 27.56 (L_5S_1) per cent (mean=10.47%) in the subsurface. The clay content also showed wide variation and it ranged from 14.5 (L_2S_2) to 66.87 (L_5S_1) per cent in the surface (mean=36.50%), whereas in the subsurface it ranged from 13.55 (L_7S_2) to 67.84 (L_1S_2) per cent (mean=31.89%). Majority of the soils are of sandy clay loam texture. Others are of clay and sandy loam in texture.

Table 1. Physical characteristics of the soils of Chittilappilly village

Location	Depth (cm)	Particle size distribution				Textural class	Bulk density Mg m ⁻³	Particle density Mg m ⁻³	Water holding capacity (%)	Percentage pore space
		Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)					
L ₁ S ₁	0-20	49.40	16.88	7.59	25.29	Sandy clay loam	1.37	2.17	29.08	38.25
	20-40	33.61	10.17	10.80	44.76	Clay	1.28	2.07	32.23	42.72
L ₁ S ₂	0-20	18.01	3.16	13.22	65.05	Clay	1.27	2.03	34.46	44.03
	20-40	13.68	6.06	11.66	67.84	Clay	1.24	2.04	39.25	42.68
L ₂ S ₁	0-20	69.90	8.33	3.53	16.63	Sandy loam	1.71	2.38	17.31	29.25
	20-40	68.85	8.81	5.53	17.63	Sandy loam	1.68	2.40	20.35	32.94
L ₂ S ₂	0-20	66.28	12.34	6.00	14.50	Sandy loam	1.49	2.31	24.44	33.66
	20-40	63.45	11.74	5.56	19.20	Sandy loam	1.52	2.23	22.74	32.99
L ₃ S ₁	0-20	38.05	5.70	20.50	34.82	Clay loam	1.30	2.19	33.20	44.25
	20-40	51.94	12.05	7.13	27.00	Sandy clay loam	1.39	2.04	31.01	37.51
L ₃ S ₂	0-20	30.97	11.24	2.61	54.78	Clay	1.26	2.29	30.96	41.99
	20-40	41.46	8.91	6.69	43.26	Sandy clay	1.22	2.02	40.59	41.65
L ₄ S ₁	0-20	24.27	8.97	4.77	63.60	Clay	1.24	2.11	37.60	49.06
	20-40	39.40	9.97	17.50	33.00	Sandy clay loam	1.28	2.24	38.52	48.17
L ₄ S ₂	0-20	45.16	11.23	2.00	40.80	Sandy clay	1.29	2.5	32.86	41.81
	20-40	34.78	12.42	19.00	33.50	Sandy clay loam	1.28	2.20	38.74	48.09
L ₅ S ₁	0-20	15.90	15.90	8.02	66.87	Clay	1.21	2.07	37.94	48.45
	20-40	2.71	7.03	27.56	60.90	Clay	1.19	2.03	43.75	52.66
L ₅ S ₂	0-20	53.24	12.69	2.04	30.57	Sandy clay loam	1.44	2.23	28.27	39.73
	20-40	47.55	21.68	7.50	24.00	Sandy clay loam	1.39	2.22	28.06	39.79
L ₆ S ₁	0-20	38.38	13.78	12.75	33.67	Sandy clay loam	1.48	2.27	27.25	39.92
	20-40	57.75	8.95	8.62	23.85	Sandy clay loam	1.42	2.28	26.15	38.67
L ₆ S ₂	0-20	61.55	10.15	6.60	20.30	Sandy clay loam	1.44	2.19	21.80	40.18
	20-40	64.83	10.08	9.00	16.00	Sandy loam	1.41	2.19	25.46	36.89
L ₇ S ₁	0-20	46.60	13.55	15.73	23.35	Sandy clay loam	1.40	2.18	25.41	39.15
	20-40	63.47	6.61	7.50	22.00	Sandy clay loam	1.39	2.17	25.93	37.07
L ₇ S ₂	0-20	56.71	12.50	8.63	20.81	Sandy clay loam	1.37	2.06	26.46	35.83
	20-40	75.60	7.34	2.51	13.55	Sandy loam	1.51	2.18	20.45	31.33
Mean	0-20	43.89	11.17	8.14	36.50		1.38	2.21	29.07	40.40
	20-40	47.08	10.13	10.47	31.89		1.37	2.17	30.95	40.23

*L₁ to L₇ locations of Chittilappilly village

The bulk density of the surface and subsurface soils ranged from 1.21 (L_5S_1) to 1.71 (L_2S_1) $Mg\ m^{-3}$ and 1.19 (L_5S_1) to 1.68 (L_2S_1) $Mg\ m^{-3}$ with mean values of 1.38 $Mg\ m^{-3}$ and 1.37 $Mg\ m^{-3}$ respectively. The particle density of the soils in surface varied from 2.03 (L_1S_2) to 2.38 (L_2S_1) $Mg\ m^{-3}$ (mean=2.21 $Mg\ m^{-3}$) while in the subsurface it ranged from 2.02 (L_3S_2) to 2.4 (L_2S_1) $Mg\ m^{-3}$ (mean=2.17 $Mg\ m^{-3}$). The water holding capacity and the percentage pore space of the surface soils varied from 17.31 (L_2S_1) to 37.94 (L_5S_1) per cent (mean=29.07%) and 29.25 (L_2S_1) to 49.06 (L_4S_1) per cent (mean=40.40%), while in the subsurface it ranged from 20.35 (L_2S_1) to 43.75 (L_5S_1) (mean=30.95%) and 31.33 (L_7S_2) to 52.66 (L_5S_1) per cent (mean=40.23%).

The high bulk density and particle density of L_2S_1 is attributed to the higher content of coarser fractions. Comparing the surface and subsurface samples of all locations some parameters like bulk density, particle density, coarse sand and fine sand fractions have higher values for the surface compared to subsurface. Similar results were also reported by Hameed (1975) and Krishnakumar (1991) for the *kole* lands.

The coarse sand fraction of Adat village ranged from 8.8 ($L_{10}S_1$) to 58.69 (L_8S_2) per cent in the surface (mean=31.98%) and from 6.58 ($L_{10}S_1$) to 53.27 (L_8S_2) per cent in the subsurface (mean=30.95%). The fine sand and silt fractions of the surface soils varied from 2.23 ($L_{10}S_1$) to 17.36 (L_9S_1) per cent and 5.50 (L_8S_1) to 11.7 ($L_{10}S_2$) per cent with mean values of 9.94 and 7.25 per cent respectively. In the subsurface it ranged from 4.05 ($L_{10}S_1$) to 16.82 (L_8S_2) per cent (mean=10.37%) and from 2.08 (L_9S_2) to 22.95 (L_8S_1) per cent (mean=8.08%). The clay content showed wide variation and it ranged from 17.71

Table 2. Physical characteristics of the soils of Adat village

Location	Depth (cm)	Particle size distribution				Textural class	Bulk density Mg m ⁻³	Particle density Mg m ⁻³	Water holding capacity (%)	Percentage pore space
		Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)					
L ₈ S ₁	0-20	36.77	7.01	5.50	50.00	Clay	1.25	2.06	35.54	43.68
	20-40	35.32	14.59	22.95	23.46	Sandy clay loam	1.22	2.11	38.29	45.23
L ₈ S ₂	0-20	58.69	15.46	6.07	17.71	Sandy clay loam	1.32	2.03	29.07	36.87
	20-40	53.27	16.82	8.12	20.26	Sandy clay loam	1.30	2.12	29.57	41.01
L ₉ S ₁	0-20	39.99	17.36	8.00	34.69	Sandy clay loam	1.26	2.12	33.50	44.39
	20-40	31.83	11.24	2.57	52.53	Clay	1.30	2.25	36.67	46.23
L ₉ S ₂	0-20	19.34	9.76	8.41	61.52	Clay	1.24	2.09	40.53	47.13
	20-40	20.82	11.06	2.08	65.00	Clay	1.25	2.16	42.04	48.77
L ₁₀ S ₁	0-20	8.80	2.23	6.27	81.10	Clay	1.18	2.02	40.91	49.80
	20-40	6.58	4.05	4.36	84.47	Clay	1.23	1.84	38.55	47.33
L ₁₀ S ₂	0-20	37.50	9.69	11.70	40.88	Sandy clay	1.21	2.09	40.24	45.30
	20-40	33.96	7.59	6.50	49.50	Clay	1.21	2.06	39.22	44.77
L ₁₁ S ₁	0-20	25.73	7.52	7.35	57.75	Clay	1.34	2.06	27.33	38.67
	20-40	29.43	7.20	9.09	64.73	Clay	1.01	1.77	49.90	51.80
L ₁₁ S ₂	0-20	28.99	10.50	4.73	55.27	Clay	1.26	2.01	27.90	40.60
	20-40	36.41	10.44	9.00	43.00	Sandy clay	1.28	2.02	33.07	41.08
Mean	0-20	31.98	9.94	7.25	49.87		1.26	2.06	34.38	43.31
	20-40	30.95	10.37	8.08	50.37		1.23	2.04	38.41	45.78

*L₈ to L₁₁ locations of Adat village

to 81.1 per cent in surface (mean=49.87%) and from 20.26 to 84.47 per cent in the subsurface (mean=50.37%). The minimum and maximum values were recorded by L₈S₂ and L₁₀S₁ respectively for both the surface and subsurface. The soils of Adat village comprise mainly of clayey immediately followed by sandy clay loam. The other class represented in one sample was sandy clay.

The bulk and particle density values ranged from 1.18 (L₁₀S₁) to 1.34 (L₁₁S₁) Mg m⁻³ (mean=1.26 Mg m⁻³) and 2.01 (L₁₁S₂) to 2.12 (L₉S₁) Mg m⁻³ (mean=2.06 Mg m⁻³) in surface while in the subsurface it ranged from 1.01 (L₁₁S₁) to 1.30 (L₈S₂ and L₉S₁) Mg m⁻³ (mean=1.23 Mg m⁻³) and 1.77 (L₁₁S₁) to 2.25 (L₉S₁) Mg m⁻³ (mean=2.04 Mg m⁻³) respectively. Water holding capacity of the surface soils ranged from 27.33 (L₁₁S₁) to 40.91 (L₁₀S₁) per cent (mean=34.38%) and in the subsurface it ranged from 29.57 (L₈S₂) to 49.90 (L₁₁S₁) per cent (mean=38.41%). The percentage pore space values of the surface and subsurface soils ranged from 36.87 (L₈S₂) to 49.80 (L₁₀S₁) and 41.01 (L₈S₂) to 51.8 (L₁₁S₁) per cent with mean values of 43.31 and 45.78 per cent respectively. It was observed that clay content increases with soil depth and the high content of clay accounts for the low bulk density and particle density and the high water holding capacity and percentage pore space for the subsurface samples.

For the Chalakkal village, coarse sand and fine sand fractions of the surface soils varied from 18.29 (L₁₃S₁) to 48.13 (L₁₄S₂) per cent and 7.85 (L₁₃S₁) to 14.15 (L₁₄S₂) per cent with mean values of 33.78 and 11.73 per cent respectively. In the subsurface the coarse sand fraction varied from 14.33 (L₁₃S₁) to 85.88 (L₁₅S₁) per cent (mean=41.56%) and the fine sand fraction varied from 5.0 (L₁₅S₁) to 19.74 (L₁₂S₁) per cent (mean=10.60%). Silt content of the

Table 3. Physical characteristics of the soils of Chalakkal village

Location	Depth	Particle size distribution				Textual class	Bulk density Mg m ⁻³	Particle density Mg m ⁻³	Water holding capacity (%)	Percentage pore space
		Coars sand (%)	Fine sand (%)	Silt (%)	Clay (%)					
L ₁₂ S ₁	0-20	28.92	14.12	4.68	52.10	Clay	1.24	2.22	39.57	49.52
	20-40	41.43	19.74	7.49	29.64	Sandy clay loam	1.31	2.07	26.90	40.10
L ₁₂ S ₂	0-20	20.90	10.01	2.10	67.39	Clay	1.21	2.12	41.65	49.76
	20-40	35.64	9.82	5.50	47.00	Sandy clay	1.23	2.04	33.82	44.89
L ₁₃ S ₁	0-20	18.29	7.85	6.28	67.53	Clay	1.16	2.00	39.36	47.88
	20-40	14.33	11.46	21.73	48.23	Clay	1.21	1.99	38.42	47.38
L ₁₃ S ₂	0-20	47.87	13.15	4.60	32.23	Sandy clay loam	1.20	2.06	36.85	44.84
	20-40	61.72	5.01	7.00	32.00	Sandy clay loam	1.31	2.06	28.92	38.97
L ₁₄ S ₁	0-20	46.02	13.30	2.55	38.17	Sandy clay	1.33	2.03	28.46	40.44
	20-40	17.01	5.66	7.80	68.18	Clay	1.14	1.76	44.63	37.41
L ₁₄ S ₂	0-20	48.13	14.15	5.14	32.89	Sandy clay loam	1.26	2.02	30.87	43.27
	20-40	53.30	10.83	3.50	31.50	Sandy clay loam	1.24	1.91	30.78	38.41
L ₁₅ S ₁	0-20	28.79	8.23	20.32	38.09	Clay loam	1.42	2.14	23.13	35.34
	20-40	85.88	5.00	1.50	7.55	Sandy	1.51	2.13	19.19	29.49
L ₁₅ S ₂	0-20	31.35	13.02	17.28	36.60	Clay loam	1.32	2.15	31.71	44.40
	20-40	23.17	17.28	7.02	52.38	Clay	1.06	2.11	49.23	56.54
Mean	0-20	33.78	11.73	7.87	45.63		1.27	2.09	33.95	44.43
	20-40	41.56	10.60	7.69	39.56		1.25	2.01	33.99	41.65

*L₁₂ to L₁₅ - locations of Chalakkal village

surface and subsurface soils varied from 2.1 (L₁₂S₂) to 20.32 (L₁₅S₁) per cent and 1.50 (L₁₅S₁) to 21.73 (L₁₃S₁) per cent with mean values of 7.87 and 7.69 per cent respectively. Clay content of the soils varied widely and it ranged from 32.23 (L₁₃S₂) to 67.53 (L₁₃S₁) per cent (mean=45.63%) in the surface and from 7.55 (L₁₅S₁) to 68.18 (L₁₄S₁) per cent (mean=39.56%) in the subsurface. The soils of Chalakkal village comprise mainly of clayey immediately followed by sandy clay loam and clay loam. The variations in the textural composition observed in these soils may be attributed to the sedimentary process of soil formation in the flood plains.

Bulk density and particle density values of the surface samples varied from 1.16 (L₁₃S₁) to 1.42 (L₁₅S₁) Mg m⁻³ (mean=1.27 Mg m⁻³) and 2.0 (L₁₃S₁) to 2.22 (L₁₂S₁), Mg m⁻³ (mean=2.09 Mg m⁻³), while in the subsurface the values ranged from 1.14 (L₁₄S₁) to 1.51 (L₁₅S₁) Mg m⁻³ (mean=1.25 Mg m⁻³) and 1.76 (L₁₄S₁) to 2.13 (L₁₅S₁) Mg m⁻³ (mean=2.01 Mg m⁻³) respectively. Water holding capacity varied from 23.13 (L₁₅S₁) to 41.65 (L₁₂S₂) per cent and from 19.19 (L₁₅S₁) to 49.23 (L₁₅S₂) per cent with mean values of 33.95 and 33.99 per cent respectively for the surface and subsurface. The percentage pore space of the surface soils ranged from 35.34 (L₁₅S₁) to 49.76 (L₁₂S₂) per cent (mean=44.43%) and of the subsurface it ranged from 29.49 (L₁₅S₁) to 56.54 (L₁₅S₂) per cent (mean=41.65%).

4.1.2 Chemical characteristics

The chemical characteristics of Chittilappilly village are presented in Tables 4a and 4b and that of Adat and Chalakkal villages are presented in Table 5a, 5b and 6a, 6b respectively.

pH of the surface soils of Chittilappilly village ranged from 4.0 to 5.4 (mean=4.6) and in the subsurface it ranged from 3.5 to 4.8 (mean=4.1). Electrical conductivity of the surface and subsurface soils ranged from 0.096 (L_2S_1) to 0.324 (L_5S_1) dSm^{-1} (mean=0.195 dSm^{-1}) and 0.034 (L_7S_2) to 0.408 (L_5S_2) dSm^{-1} (mean=0.132 dSm^{-1}).

Organic carbon content showed wide variation in the surface and subsurface soils. It ranged from 0.16 (L_2S_1) to 1.48 (L_5S_1) per cent in surface (mean=0.76%), while in the subsurface it ranged from 0.18 (L_2S_1) to 2.72 (L_3S_2) per cent (mean=0.69%). Cation exchange capacity was less in these soils and it ranged from 3.3 (L_2S_1) to 10.5 (L_1S_2) $cmol(+) kg^{-1}$ in the surface (mean=6.5 $cmol(+) kg^{-1}$) and from 3.8 (L_7S_2) to 12.8 (L_1S_2) $cmol(+) kg^{-1}$ for the subsurface (mean=7.4 $cmol(+) kg^{-1}$). The low cation exchange capacity of the surface was attributed to the low content of clay and low organic matter content for the respective soils (Venugopal and Koshy, 1976a).

The mean values for total N and P in surface soils were 0.124 and 0.0508 per cent and subsurface soils were 0.084 and 0.0472 per cent respectively. The higher value of nitrogen and phosphorus observed in certain samples was attributed to high organic matter content. Total K content ranged from 0.030 (L_2S_2) to 0.265 (L_1S_2) per cent (mean=0.125%) in surface while in the subsurface it ranged from 0.052 (L_7S_2) to 0.287 (L_5S_1) per cent (mean=0.148%).

The range of available N content in the surface and subsurface comes under low to medium fertility class. The mean values for the surface and

Table 4a. Chemical characteristics of the soils of Chittilappilly village

Location	Depth	pH	EC dS m ⁻¹	Organic carbon (%)	CEC cmol(+) kg ⁻¹ soil	Total N (%)	Total P (%)	Total K (%)
L ₁ S ₁	0-20	4.8	0.242	0.58	6.0	0.170	0.0540	0.111
	20-40	4.2	0.090	0.65	9.7	0.072	0.0402	0.175
L ₁ S ₂	0-20	4.5	0.312	1.07	10.5	0.237	0.0553	0.265
	20-40	3.8	0.175	1.03	12.8	0.164	0.0465	0.235
L ₂ S ₁	0-20	5.4	0.096	0.16	3.3	0.056	0.0230	0.045
	20-40	4.8	0.038	0.18	7.0	0.028	0.0285	0.081
L ₂ S ₂	0-20	5.1	0.100	0.34	4.2	0.071	0.0242	0.030
	20-40	3.9	0.074	0.28	4.3	0.028	0.0308	0.111
L ₃ S ₁	0-20	4.8	0.130	0.69	7.3	0.186	0.0594	0.051
	20-40	4.3	0.075	0.62	7.3	0.083	0.0389	0.133
L ₃ S ₂	0-20	4.4	0.183	0.99	7.6	0.161	0.0517	0.146
	20-40	4.1	0.117	2.72	11.7	0.216	0.0902	0.186
L ₄ S ₁	0-20	4.0	0.241	1.44	8.4	0.179	0.0487	0.128
	20-40	3.6	0.202	0.75	5.7	0.075	0.0668	0.161
L ₄ S ₂	0-20	4.0	0.226	0.71	5.4	0.072	0.0549	0.123
	20-40	3.5	0.224	0.52	5.6	0.073	0.0546	0.162
L ₅ S ₁	0-20	4.1	0.324	1.48	8.5	0.166	0.1128	0.216
	20-40	3.9	0.178	1.13	9.6	0.224	0.0893	0.287
L ₅ S ₂	0-20	4.3	0.157	0.81	7.4	0.043	0.0567	0.092
	20-40	3.6	0.408	0.38	5.2	0.043	0.0421	0.112
L ₆ S ₁	0-20	4.6	0.184	0.75	7.6	0.100	0.0489	0.173
	20-40	4.3	0.106	0.49	9.0	0.057	0.0398	0.132
L ₆ S ₂	0-20	4.9	0.206	0.68	4.9	0.100	0.0431	0.162
	20-40	4.4	0.091	0.36	4.2	0.045	0.0387	0.117
L ₇ S ₁	0-20	4.8	0.105	0.42	5.3	0.071	0.0420	0.091
	20-40	4.7	0.042	0.28	7.7	0.028	0.0319	0.121
L ₇ S ₂	0-20	4.7	0.220	0.54	4.5	0.128	0.0364	0.112
	20-40	4.8	0.034	0.29	3.8	0.042	0.0219	0.052
Mean	0-20	4.6	0.195	0.76	6.5	0.124	0.0508	0.125
	20-40	4.1	0.132	0.69	7.4	0.084	0.0472	0.148

Table 4b. Chemical characteristics of the soils of Chittilappilly village

Location	Depth (cm)	Avail N kg ha ⁻¹	Avail P kg ha ⁻¹	Avail K kg ha ⁻¹	Exchangeable cations (cmol(+) kg ⁻¹ soil)			Percentage base saturation	K fixing capacity (%)
					Ca	Mg	Na		
L ₁ S ₁	0-20	156.8	24.75	67.2	2.86	1.30	0.196	73.88	14.7
	20-40	156.8	18.23	100.8	3.38	0.78	0.142	45.54	14.0
L ₁ S ₂	0-20	392.0	21.68	116.48	5.33	0.91	0.294	63.50	15.3
	20-40	141.0	13.31	120.96	4.03	1.17	0.240	41.97	15.2
L ₂ S ₁	0-20	109.8	12.81	17.92	2.08	0.52	0.054	81.05	14.7
	20-40	78.4	15.28	26.88	1.56	1.04	0.055	38.36	14.4
L ₂ S ₂	0-20	78.4	17.25	26.88	2.73	0.39	0.131	78.14	14.2
	20-40	62.7	12.32	33.60	1.82	0.26	0.033	50.03	14.1
L ₃ S ₁	0-20	188.2	18.23	71.68	4.16	0.26	0.174	64.06	14.7
	20-40	156.8	15.28	40.32	2.34	1.04	0.076	47.98	13.3
L ₃ S ₂	0-20	141.1	19.22	64.96	3.12	1.30	0.207	61.86	14.9
	20-40	78.4	23.16	69.44	3.12	1.04	0.153	45.28	13.9
L ₄ S ₁	0-20	219.5	11.83	82.36	3.64	0.78	0.240	56.60	14.1
	20-40	109.8	13.80	53.76	2.60	1.04	0.153	82.01	13.3
L ₄ S ₂	0-20	219.5	13.79	53.76	2.60	0.78	0.120	65.95	13.5
	20-40	141.1	13.31	58.24	2.08	1.56	0.153	68.92	14.4
L ₅ S ₁	0-20	250.9	12.81	96.32	3.38	0.64	0.240	51.42	14.5
	20-40	203.8	14.29	112.00	3.90	1.82	0.294	63.98	14.8
L ₅ S ₂	0-20	125.4	15.28	94.96	1.82	1.30	0.131	44.94	13.4
	20-40	203.8	21.19	62.72	1.82	0.78	0.185	54.74	14.2
L ₆ S ₁	0-20	125.4	17.25	71.68	3.12	0.78	0.262	55.84	13.4
	20-40	94.1	16.75	51.52	2.08	1.30	0.109	29.57	14.3
L ₆ S ₂	0-20	188.2	20.20	53.76	2.21	1.43	0.174	79.09	13.8
	20-40	109.8	13.80	31.36	1.56	0.26	0.044	45.24	14.1
L ₇ S ₁	0-20	407.7	8.38	51.52	2.73	1.43	0.142	82.28	15.8
	20-40	62.7	13.31	35.84	1.82	1.04	0.076	38.66	11.4
L ₇ S ₂	0-20	207.9	25.63	40.32	2.60	1.04	0.185	86.03	13.5
	20-40	62.7	14.78	21.28	1.56	1.04	0.055	70.51	13.7
Mean	0-20	200.77	17.08	64.99	3.03	0.92	0.182	67.47	14.3
	20-40	118.71	15.63	58.48	2.41	1.01	0.126	51.63	13.9

L₁ to L₇ - Locations of Chittilappilly village

subsurface soils were 200.77 and 118.71 kg ha⁻¹ respectively. The available P content comes under low to medium fertility class and it was minimum for L₇S₁ (8.38 kg ha⁻¹) in surface and for L₂S₂ (12.32 kg ha⁻¹) in subsurface, while maximum content was recorded by L₇S₂ (25.63 kg ha⁻¹) and L₃S₂ (23.16 kg ha⁻¹) with mean values of 17.08 and 15.63 kg ha⁻¹ for surface and subsurface samples respectively. Available K varied from 17.92 (L₂S₁) to 116.48 (L₁S₂) in surface and from 21.28 (L₇S₂) to 120.96 (L₁S₂) kg ha⁻¹ for the subsurface. The mean values for this fraction in the surface and the subsurface soils were 64.99 and 58.48 kg ha⁻¹ respectively and these soils comes under low to medium fertility class. The low content of this fraction may be attributed to the low percentage of clay and organic matter in the above soils.

Among the exchangeable cations, exchangeable Ca is the predominant mineral and its content ranged from 1.82 to 5.33 cmol(+) kg⁻¹ in the surface (mean=3.03 cmol(+) kg⁻¹) and the content was high compared to the subsurface (mean=2.41 cmol(+) kg⁻¹). The percentage base saturation of these soils ranged from 44.94 (L₅S₂) to 86.03 (L₇S₂) per cent in the surface with mean values of 67.47 and 51.63 per cent in surface and subsurface respectively. The K fixing capacity of the soils was low and it varied from 13.4 (L₅S₂ & L₆S₁) to 15.8 (L₇S₁) per cent in surface (mean=14.3%) and from 11.4 (L₇S₁) to 15.2 (L₁S₂) per cent in the subsurface (mean=13.9%).

Comparing the surface and subsurface samples of Adat village, the subsurface samples recorded low pH and EC values. The range of the pH in the surface was 4.1 to 4.8 (mean=4.6) and in the subsurface it ranged from 3.6 to 4.8 (mean=4.3). Electrical conductivity values of the surface and subsurface soils

Table 5a. Chemical characterisation of the soils of Adat village

Location	Depth	pH	EC dS m ⁻¹	Organic carbon (%)	CEC cmol(+) kg ⁻¹ soil	Total N (%)	Total P (%)	Total K (%)
L ₈ S ₁	0-20	4.1	0.168	0.90	6.8	0.085	0.0721	0.163
	20-40	4.0	0.145	0.46	4.1	0.129	0.0737	0.169
L ₈ S ₂	0-20	4.5	0.163	0.41	3.9	0.043	0.0519	0.101
	20-40	3.6	0.147	0.18	4.3	0.057	0.0409	0.142
L ₉ S ₁	0-20	4.5	0.175	0.81	6.8	0.135	0.0919	0.203
	20-40	4.5	0.066	0.82	5.5	0.116	0.0811	0.186
L ₉ S ₂	0-20	4.3	0.158	1.62	9.7	0.206	0.0779	0.137
	20-40	4.4	0.086	0.90	10.1	0.131	0.0705	0.188
L ₁₀ S ₁	0-20	4.4	0.455	1.69	10.0	0.227	0.0884	0.313
	20-40	4.4	0.201	0.96	10.2	0.245	0.0537	0.301
L ₁₀ S ₂	0-20	5.7	0.322	0.80	6.6	0.143	0.1014	0.138
	20-40	4.8	0.091	0.23	6.9	0.100	0.0915	0.169
L ₁₁ S ₁	0-20	4.6	0.182	1.56	8.9	0.191	0.0886	0.095
	20-40	4.2	0.130	1.38	9.1	0.181	0.0365	0.238
L ₁₁ S ₂	0-20	4.8	0.213	1.17	9.4	0.162	0.0953	0.084
	20-40	4.3	0.073	0.47	6.1	0.117	0.0844	0.126
Mean	0-20	4.6	0.230	1.12	7.8	0.149	0.0834	0.154
	20-40	4.3	0.117	0.68	7.0	0.135	0.0665	0.190

ranged from 0.158 (L₉S₂) to 0.455 (L₁₀S₁) and 0.066 (L₉S₁) to 0.201 (L₁₀S₁) dSm⁻¹ with mean values of 0.230 and 0.117 dSm⁻¹ respectively. Dewatering at the time of cultivation reduces the salt content to a low level in this area. Organic carbon content varied from 0.41 (L₈S₂) to 1.69 (L₁₀S₁) in the surface (mean=1.12%) and from 0.18 (L₈S₂) to 1.38 (L₁₁S₁) per cent in the subsurface (mean=0.68%). The cation exchange capacity for the surface and subsurface is almost the same and it was in the range of 3.9 (L₈S₂) to 10.0 (L₁₀S₁) cmol(+) kg⁻¹ for the surface with a mean value of 7.8 cmol(+) kg⁻¹. For the subsurface the mean value was 7.0 cmol(+) kg⁻¹.

The mean values for total N and P contents in the surface soils were 0.149 and 0.0834 per cent whereas the subsurface values were 0.135 and 0.0665 per cent respectively. Total K content ranged from 0.084 (L₁₁S₂) to 0.313 (L₁₀S₁) per cent for the surface (mean=0.154%) and from 0.126 (L₁₁S₂) to 0.301 (L₁₀S₁) per cent for the subsurface (mean=0.190%). There is no linear trend in the distribution of total K between surface and subsurface layers and the variation in its content may be attributed to the particle size distribution in different layers.

For the soils of Adat village available N and P contents of the samples comes under low to high fertility class. The mean values for available N in the surface and subsurface soils were 360.63 and 162.69 kg ha⁻¹. However, certain samples recorded very high values (L₁₀S₁ and L₁₀S₂). This may be a location where some nitrogenous fertilizer must have been applied a few days prior to sampling. The mean value for available P content in surface soil was 19.53 kg ha⁻¹ and for the subsurface soil the value comes to 13.98 kg ha⁻¹.

Available K content of majority of the soils comes under the low fertility class. However, for L₁₀S₂ the value comes to 143.36 kg ha⁻¹ and it may be due to

Table 5b. Chemical characteristics of the soils of Adat village

Location	Depth (cm)	Avail N kg ha ⁻¹	Avail P kg ha ⁻¹	Avail K kg ha ⁻¹	Exchangeable Cations (cmol(+) kg ha ⁻¹ soil)			Percentage base saturation	K fixing capacity (%)
					Ca	Mg	Na		
L ₈ S ₁	0-20	172.5	15.77	100.80	2.34	1.56	0.131	60.98	13.1
	20-40	141.1	14.29	87.36	2.34	0.52	0.065	73.78	13.8
L ₈ S ₂	0-20	156.8	14.78	62.72	2.08	0.39	0.076	67.12	14.0
	20-40	94.1	15.77	53.76	2.34	1.04	0.044	81.06	13.2
L ₉ S ₁	0-20	360.6	20.69	71.68	2.47	0.65	0.153	49.34	12.2
	20-40	172.5	14.29	116.48	2.60	1.30	0.153	76.11	15.8
L ₉ S ₂	0-20	235.2	18.73	80.64	4.16	1.30	0.262	59.94	16.2
	20-40	156.8	18.73	71.68	2.86	1.82	0.196	49.09	16.1
L ₁₀ S ₁	0-20	689.9	7.89	100.80	4.81	3.25	0.534	87.09	15.9
	20-40	141.1	10.84	73.92	4.68	3.38	0.501	84.76	16.0
L ₁₀ S ₂	0-20	533.1	34.49	143.36	4.29	0.91	0.207	84.41	14.4
	20-40	141.1	14.78	96.32	3.64	1.56	0.153	79.18	13.0
L ₁₁ S ₁	0-20	376.3	25.13	76.16	3.12	1.04	0.164	49.56	14.0
	20-40	266.6	10.84	56.00	3.38	1.30	0.142	53.69	13.4
L ₁₁ S ₂	0-20	360.6	18.78	80.64	3.25	0.91	0.207	47.44	14.3
	20-40	188.2	12.32	53.76	1.56	1.56	0.120	54.12	15.0
Mean	0-20	360.63	19.53	89.60	3.32	1.25	0.217	63.24	14.3
	20-40	162.69	13.98	76.16	2.93	1.56	0.172	68.97	14.5

higher content of clay dominated with 2:1 minerals. The mean value for available K content in the surface soil was 89.6 kg ha^{-1} and for the subsurface it was 76.16 kg ha^{-1} .

Calcium is the dominant one among the exchangeable cations and its content in the surface and subsurface samples ranged from 2.08 (L_8S_2) to 4.81 ($L_{10}S_1$) and 1.56 ($L_{11}S_2$) to 4.68 ($L_{10}S_1$) $\text{cmol}(+) \text{ kg}^{-1}$ with mean values of 3.32 and $2.93 \text{ cmol}(+) \text{ kg}^{-1}$ respectively.

The percentage base saturation comes in the low to high fertility range similar to the soils of Chittilappilly village. The mean values for the percentage base saturation in the surface and subsurface soils were 63.24 and 68.97 per cent respectively. The K fixing capacity of the surface and subsurface soils varied from 12.2 (L_9S_1) to 16.2 (L_9S_2) and 13.0 ($L_{10}S_2$) to 16.1 (L_9S_2) with mean values of 14.3 and 14.5 per cent respectively.

pH of the surface and subsurface soils of Chalakkal village varied from 4.2 ($L_{15}S_1$) to 5.0 ($L_{13}S_2$) and 2.8 ($L_{15}S_1$) to 4.7 ($L_{13}S_2$) with mean values of 4.5 and 4.1 respectively. The electrical conductivity of the surface samples varied from 0.141 to 0.380 dSm^{-1} (mean=0.206) as in Chittilappilly soils. Organic carbon content of the surface soils decreases with soil depth except $L_{14}S_1$ and $L_{14}S_2$. It ranged from 0.5 ($L_{15}S_1$) to 1.72 ($L_{12}S_2$) per cent in the surface (mean=1.03%) and from 0.45 ($L_{15}S_1$) to 2.15 ($L_{14}S_2$) per cent in the subsurface (mean=1.02%). The high content of organic carbon in $L_{14}S_1$ and $L_{14}S_2$ is due to existence of organic layer in the subsurface. Cation exchange capacity ranged from 4.8 to $10.5 \text{ cmol}(+) \text{ kg}^{-1}$ in the surface (mean= $7.5 \text{ cmol}(+) \text{ kg}^{-1}$) and the minimum and maximum values were recorded by $L_{13}S_2$ and $L_{13}S_1$ respectively. In the

Table 6a. Chemical characteristics of the soils of Chalakkal village

Location	Depth (cm)	pH	EC dSm ⁻¹	Organic carbon (%)	CEC cmo(+) kg ⁻¹ soil	Total N (%)	Total P (%)	Total K (%)
L ₁₂ S ₁	0-20	4.8	0.245	1.21	7.0	0.146	0.1023	0.125
	20-40	4.5	0.111	0.56	6.5	0.073	0.0631	0.188
L ₁₂ S ₂	0-20	4.3	0.230	1.72	10.4	0.026	0.0976	0.169
	20-40	4.1	0.272	1.60	9.4	0.089	0.0471	0.200
L ₁₃ S ₁	0-20	4.5	0.151	1.43	10.5	0.279	0.1209	0.199
	20-40	4.5	0.152	0.85	7.7	0.149	0.0824	0.218
L ₁₃ S ₂	0-20	5.0	0.141	0.70	4.8	0.100	0.1149	0.113
	20-40	4.7	0.057	0.21	4.2	0.057	0.0924	0.177
L ₁₄ S ₁	0-20	4.6	0.166	0.75	8.0	0.130	0.0484	0.144
	20-40	3.9	0.152	1.48	10.9	0.117	0.0790	0.251
L ₁₄ S ₂	0-20	4.5	0.156	0.76	5.5	0.115	0.0560	0.113
	20-40	4.0	0.088	2.15	8.1	0.086	0.1002	0.164
L ₁₅ S ₁	0-20	4.2	0.380	0.50	5.6	0.114	0.0476	0.127
	20-40	2.8	0.977	0.45	9.6	0.028	0.0296	0.061
L ₁₅ S ₂	0-20	4.4	0.176	1.20	8.2	0.147	0.0983	0.068
	20-40	3.9	0.186	0.87	7.3	0.106	0.1097	0.227
Mean	0-20	4.5	0.206	1.03	7.5	0.132	0.0858	0.132
	20-40	4.1	0.249	1.02	8.0	0.088	0.0754	0.186

L₁₂ to L₁₅ - Locations of Chalakkal village

subsurface it ranged from 4.2 to 10.9 $\text{cmol}(+) \text{kg}^{-1}$ (mean=8.0 $\text{cmol}(+) \text{kg}^{-1}$) and the minimum and maximum values were recorded by $L_{13}S_2$ and $L_{14}S_1$.

The total N content of the surface samples is higher and it varied from 0.100 ($L_{13}S_2$) to 0.279 ($L_{13}S_1$) per cent in the surface (mean=0.132%). Total P content ranged from 0.0476 ($L_{15}S_1$) to 0.1209 ($L_{13}S_1$) per cent in surface (mean=0.0858%) and from 0.0296 ($L_{15}S_1$) to 0.1097 ($L_{15}S_2$) per cent in the subsurface (mean=0.0754%). Total K content ranged from 0.068 to 0.199 per cent and 0.061 to 0.251 per cent with mean values of 0.132 and 0.186 per cent in the surface and subsurface soils respectively. The minimum value was recorded by $L_{15}S_2$ and $L_{15}S_1$ and the maximum value by $L_{13}S_1$ and $L_{14}S_1$ for the surface and subsurface soils respectively.

Available N content comes under low to medium range and it ranged from 141.8 ($L_{15}S_1$) to 470.4 ($L_{12}S_1$) kg ha^{-1} in the surface (mean=241.16 kg ha^{-1}) and from 31.4 ($L_{15}S_1$) to 407.7 ($L_{13}S_1$) kg ha^{-1} in the subsurface (mean=164.65 kg ha^{-1}). Available P content of the surface and subsurface samples ranged from 8.38 ($L_{15}S_2$) to 33.02 ($L_{13}S_2$) kg ha^{-1} and 9.86 ($L_{15}S_1$) to 16.75 ($L_{13}S_2$) kg ha^{-1} with mean values of 17.80 and 13.86 kg ha^{-1} respectively. The range for available K content was 58.23 to 125.44 kg ha^{-1} in the surface (mean=82.88 kg ha^{-1}) and 20.16 to 125.44 kg ha^{-1} in the subsurface (mean=70.28 kg ha^{-1}). The minimum and maximum values were recorded by $L_{15}S_2$ and $L_{13}S_1$ in surface and by $L_{15}S_1$ and $L_{13}S_1$ in the subsurface.

Exchangeable Ca content decreases with soil depth and it ranged from 2.60 ($L_{13}S_2$) to 4.42 ($L_{12}S_1$) $\text{cmol}(+) \text{kg}^{-1}$ in the surface (mean=3.38 $\text{cmol}(+) \text{kg}^{-1}$). Exchangeable Mg content ranged from 0.26 ($L_{12}S_1$) to 1.17 ($L_{15}S_2$)

Table 6b. Chemical characteristics of the soils of Chalakkal village

Location	Depth (cm)	Avail N kg ha ⁻¹	Avail P kg ha ⁻¹	Avail K kg ha ⁻¹	Exchangeable cations (cmol(+) kg ⁻¹ soil)			Percentage base saturation	K fixing capacity (%)
					Ca	Mg	Na		
L ₁₂ S ₁	0-20	470.4	28.09	89.60	4.42	0.26	0.196	71.12	12.2
	20-40	297.9	15.28	31.36	2.08	1.04	0.120	50.40	14.1
L ₁₂ S ₂	0-20	266.6	14.29	87.36	3.38	0.65	0.392	43.38	15.9
	20-40	94.1	15.77	109.76	2.34	1.56	0.523	48.39	14.7
L ₁₃ S ₁	0-20	313.6	9.36	125.44	4.16	0.65	0.240	49.46	13.5
	20-40	407.7	12.32	125.44	3.64	1.30	0.185	68.42	12.9
L ₁₃ S ₂	0-20	219.5	33.02	71.68	2.60	1.04	0.131	80.27	14.6
	20-40	109.8	16.75	47.04	2.34	0.78	0.131	78.69	14.6
L ₁₄ S ₁	0-20	156.8	18.23	89.60	3.12	0.78	0.153	51.95	14.4
	20-40	172.5	13.80	62.72	3.38	1.82	0.174	49.96	14.1
L ₁₄ S ₂	0-20	156.8	15.77	62.72	3.38	0.52	0.185	43.29	12.9
	20-40	78.4	16.26	53.76	1.82	1.56	0.065	43.29	12.9
L ₁₅ S ₁	0-20	141.8	15.28	78.40	2.73	0.39	0.196	60.82	14.1
	20-40	31.4	9.86	20.16	1.56	1.04	0.022	27.55	13.7
L ₁₅ S ₂	0-20	203.8	8.38	58.23	3.25	1.17	0.251	57.78	14.7
	20-40	125.4	10.84	112.00	2.34	1.82	0.131	60.54	13.8
Mean	0-20	241.16	17.80	82.88	3.38	0.68	0.218	57.26	14.0
	20-40	164.65	13.86	70.28	2.44	1.37	0.169	53.41	13.9

cmol(+) kg⁻¹ in surface (mean=0.68 cmol(+) kg⁻¹) and from 0.78 (L₁₃S₂) to 1.82 (L₁₄S₁ and L₁₅S₂) cmol(+) kg⁻¹ in the subsurface (mean=1.37 cmol(+) kg⁻¹). Percentage base saturation comes in the low to medium range with mean values of 57.26 and 53.41 per cent respectively for the surface and subsurface. K fixing capacity of the surface layer ranged from 12.2 (L₁₂S₁) to 15.9 (L₁₂S₂) per cent (mean=14.0%) and from 12.9 (L₁₃S₁ and L₁₄S₂) to 14.7 (L₁₂S₂) per cent for the subsurface (mean=13.9%).

Among the 15 locations most of the soils were clayey and some of them containing even more than 84 per cent clay. The other samples were sandy clay loam and sandy loam. The percentage pore space and water holding capacity was high for the clayey soils. Comparing the surface and subsurface samples of all locations, some parameters like bulk density, particle density, Coarse sand, fine sand and silt fractions have higher values for the surface compared to subsurface, whereas certain parameters viz., water holding capacity, percentage pore space and the clay percentage increases with soil depth. Similar observations were also reported by Hameed (1975) and Krishnakumar (1991) for the *kole* lands. Heavy rainfall and subsequent illuviation have resulted in the accumulation of clay in the lower horizons. The variations in water holding capacity observed in the samples may be attributed to the mineralogical composition of the clay fraction.

There were wide variation for almost all the soil characteristics for the two sites of the same location. Among the soil characteristics particle size distribution, water holding capacity and percentage pore space were highly varied among the two sites. For example in L₁₅, there was not much variation in the particle size distribution of the surface soils of the two sites, whereas it varied

widely for the subsurface. S_1 was purely sandy and S_2 was clayey in texture. Similarly in L_{12} variations were observed in the distribution of finer fractions of the surface and subsurface layers of the two sites.

The soils were generally acidic in nature and for a few locations the pH was very low. Comparing the surface and subsurface samples the subsurface samples recorded low pH and low EC values in all the sites. The low values for these parameters were attributed to the acidic nature of the parent rock, intense weathering conditions and sea water inundation.

For most of the soils, the organic carbon content was less than 1 per cent, but for some locations it was more than 1 per cent. There was no linear relationship in the distribution of organic carbon in the surface and subsurface layers. However, in certain sites the content of the subsurface was about two times than that of the surface soils and this was attributed to the presence of highly decomposable organic matter in the subsurface and the soil is supposed to be formed by alluvial sedimentation over forest vegetation (Hameed, 1975; Ambili, 1995).

The cation exchange capacity was highly related to the clay and organic matter content of the soil. L_2S_1 recorded a cation exchange capacity of $3.3 \text{ cmol}(+) \text{ kg}^{-1}$ while L_1S_2 and $L_{13}S_1$ recorded a value of $10.5 \text{ cmol}(+) \text{ kg}^{-1}$ in surface. In the subsurface it ranged from 4.2 ($L_{13}S_2$) to 12.8 (L_1S_2) $\text{cmol}(+) \text{ kg}^{-1}$. The low cation exchange capacity was attributed to the low content of clay (16.63%) and low organic matter content (0.16%). Higher cation exchange capacity values of L_1S_2 and $L_{13}S_1$ was attributed to the higher clay (62.05 and 67.53%) and organic matter content (1.07 and 1.43%) (Venugopal and Koshy, 1976a).

Generally there was a decreasing trend in the distribution of total N and P with soil depths. The higher value of total N in certain samples was attributed to high organic matter content and the lower value recorded by certain samples was attributed to the high content of sand in the soils.

High variation was observed in the content of total K among the 15 locations. Among the 15 locations surface soil of L₁₀S₁ recorded maximum percentage of total K (0.313%) and the lowest was recorded (0.030%) by L₂S₂. The higher content in L₁₀ is attributed to the higher percentage of clay, about 81 per cent and the lowest value for L₂ is due to higher content of coarse sand.

The difference in total K content in the soil could be due to the variation in the amount of potassium bearing minerals like feldspars and mica and also the degree of weathering (Singh and Datta, 1986; Basumatary and Bordoloi, 1992; Islam *et al.*, 1994). In some of the locations the total K increases with depth and in some it decreases. The variation in depthwise distribution pattern of total K might be due to changes in particle size distribution in the different layers. It also depends on the relative effects of the factors such as parent material and intensity of weathering of the soil (Sharma and Mishra, 1986; Venkatesh and Satyanarayana, 1994).

Available P and N status of the soil comes under low to medium range. The variations noticed in the content of these nutrients was attributed to the variations in the pH and organic carbon content.

Available K content of almost all the locations comes in the lower range except a few. The maximum amount of 143.36 kg ha⁻¹ was recorded by

L₁₀S₂ and the minimum amount of 17.92 kg ha⁻¹ was recorded by L₂S₁ in the surface. In the subsurface the maximum amount of 125.44 kg ha⁻¹ was recorded by L₁₃S₁ and the minimum amount of 20.16 kg ha⁻¹ was recorded by L₁₅S₁. The higher value observed in L₁₀S₂ may be due to the high content of clay dominated with 2:1 minerals. Most of the soils comes under low to medium fertility range for the available nutrients and fertilizer recommendations should be made only based on soil test studies.

For the surface samples the exchangeable Ca content was high compared to the subsurface, while exchangeable Mg content showed no such trend (Venugopal and Koshy, 1976a). The soils with high cation exchange capacity recorded higher values for the exchangeable Ca. Percentage base saturation showed a wide variation among the different locations and the maximum was recorded in L₁₀S₁ and this was due to the high cation exchange capacity of the soil.

Potassium fixing capacity was generally low for the *kole* lands and it comes below 20 per cent. There was not much variation between the surface and subsurface samples. The low K fixing capacity of the soil may be due to the absence of K fixing minerals like illite and vermiculite in the clay fraction of the soil. The clay fraction may be dominated with smectitic and kaolinitic type of minerals (Masilamani *et al.*, 1993).

Correlation studies were carried out between the different soil characteristics. The simple linear correlation values (r) between important soil characteristics were given in Appendix I, II and III. Bulk density and particle density showed a negative relationship with clay percentage (r=-0.702** and -0.440* for surface and -0.746** and -0.630** for subsurface respectively) whereas

the water holding capacity showed a positive correlation with clay percentage ($r=0.736^{**}$; 0.813^{**} for surface and subsurface). This was in conformity with the findings of Velayutham and Raj (1971).

Total N was positively correlated with organic carbon in surface and subsurface soils ($r=0.762^{**}$; 0.425^{**}). This was in conformity with the findings of Verma *et al.* (1980). Total N was positively correlated with available N, clay content and cation exchange capacity.

The soils with high content of organic carbon recorded higher percentage of total P and found to be positively correlated ($r=0.668^{**}$; 0.421^* for the surface and subsurface). Sheela (1988) obtained similar results in *kole* soils.

Available N was positively and significantly correlated with organic carbon ($r=0.471^{**}$ in surface) (Chibba and Sekhon, 1985). The close relationship between organic carbon and available N may be due to the association of N with organic matter and adsorption of ammoniacal N by humus complex in the soil (Verma *et al.*, 1980).

Available P was significantly and positively correlated to pH ($r=0.528^{**}$; 0.439^* for surface and subsurface respectively). The same results were obtained by Das *et al.* (1991). The relationship of organic carbon with available P was not significant. This is possibly due to the fact that available P included mostly inorganic P and the proportion of organic P is very low in this fraction (Kanthaliya and Bhatt, 1991).

Total K content showed significant positive correlation with organic carbon ($r=0.519^{**}$, 0.538^{**} for surface and subsurface respectively), exchangeable

Ca ($r=0.493^{**}$, 0.827^{**}), exchangeable Mg ($r=0.503^{**}$; 0.658^{**}), exchangeable Na ($r=0.688^{**}$, 0.681^{**}). Similar results were obtained by Dixit *et al.* (1993) in soils of Western Uttar Pradesh. This form of K showed highly significant correlation with cation exchange capacity of the soil. This is in conformity with the findings of Prakash and Singh (1985a) and Pal and Mukhopadhyay (1992b) in Inceptisols of West Bengal. Total K showed negative correlation with pH ($r=-0.179^{**}$; -0.057 for surface and subsurface respectively). Similar result was obtained by Basumatary and Bordoloi (1992) in alluvial soils of Assam.

Total K content showed positive correlation with the clay ($r=0.659^{**}$, 0.906^{**} for surface and subsurface respectively) and silt content in the subsurface ($r=0.361^*$ for subsurface). Similar results were obtained by Pal and Mukhopadhyay (1992a) in Entisols of West Bengal. The significant positive correlation of total K with clay and silt indicates that substantial quantities of K bearing minerals are present in silt and clay fractions of soils (Chakravarti *et al.*, 1979). In this soils significant negative correlation of total K was observed with coarse sand ($r=-0.627^{**}$, -0.929^{**} for surface and subsurface respectively) indicating absence of K bearing primary minerals viz., micas and feldspars in the coarser fraction of soils. Similar observations were reported by Prakash and Singh (1985b) in soils of Agra region.

Potassium fixing capacity was positively correlated with cation exchange capacity, clay, silt and negatively correlated with coarse sand and fine sand in the surface and subsurface (Prakash and Singh, 1989; Masilamani *et al.*, 1993). This indicates that K fixing minerals are mostly present in the finer fractions of soil.



4.1.3 Forms of potassium in soil

The data on different forms of potassium viz., water soluble, exchangeable and HNO_3 soluble K contents observed in Chittilappilly, Adat and Chalakkal villages are given in Tables 7, 8 and 9.

4.1.3.1 Water soluble K

In Chittilappilly village water soluble fraction of potassium ranged from 0.0128 (L_2S_1 , L_2S_2 and L_7S_1) to 0.0282 (L_5S_1) $\text{cmol}(+) \text{kg}^{-1}$ in surface (mean=0.0196 $\text{cmol}(+) \text{kg}^{-1}$) and from 0.0077 (L_2S_1) to 0.0436 (L_4S_2) $\text{cmol}(+) \text{kg}^{-1}$ in the subsurface (mean=0.0179 $\text{cmol}(+) \text{kg}^{-1}$), whereas it was in the range of 0.0154 (L_9S_2) to 0.0436 ($L_{10}S_2$) $\text{cmol}(+) \text{kg}^{-1}$ and from 0.0103 ($L_{10}S_1$ and $L_{11}S_1$) to 0.0282 (L_8S_1) $\text{cmol}(+) \text{kg}^{-1}$ with mean values of 0.0269 and 0.0176 $\text{cmol}(+) \text{kg}^{-1}$ in surface and subsurface respectively for Adat village. Samples collected from Chalakkal village showed a range from 0.0154 ($L_{12}S_2$ and $L_{15}S_2$) to 0.0538 $\text{cmol}(+) \text{kg}^{-1}$ in the surface (mean=0.0253 $\text{cmol}(+) \text{kg}^{-1}$) and from 0.0077 ($L_{15}S_1$) to 0.0333 ($L_{12}S_2$) $\text{cmol}(+) \text{kg}^{-1}$ in the subsurface (mean=0.0183 $\text{cmol}(+) \text{kg}^{-1}$).

The mean values of water soluble K in surface and subsurface soils at the different locations in the three villages is given in Table 10 and it is represented in Fig. 1. Comparing the three villages the surface soils of Chittilappilly recorded very low values of this fraction of potassium.

On an average this fraction constituted 0.61 per cent of total K in surface soils and 0.47 per cent in subsurface soils of Chittilappilly village. In Adat and

Table 7. Different forms of Potassium in the soils of Chittilappilly village ($\text{cmol}(+) \text{kg}^{-1}$)

Location	Depth (cm)	Water soluble K	Exchangeable K	
			(NH_4OAc extractable)	HNO_3 soluble K
L ₁ S ₁	0-20	0.0256	0.0769	0.1795
	20-40	0.0154	0.1154	0.2436
L ₁ S ₂	0-20	0.0256	0.1333	0.3333
	20-40	0.0154	0.1385	0.3654
L ₂ S ₁	0-20	0.0128	0.0205	0.1026
	20-40	0.0077	0.0308	0.1218
L ₂ S ₂	0-20	0.0128	0.0308	0.1410
	20-40	0.0128	0.0385	0.1538
L ₃ S ₁	0-20	0.0154	0.0821	0.2051
	20-40	0.0103	0.0462	0.1410
L ₃ S ₂	0-20	0.0154	0.0744	0.1987
	20-40	0.0231	0.0795	0.1667
L ₄ S ₁	0-20	0.0231	0.0949	0.1667
	20-40	0.0205	0.0615	0.1603
L ₄ S ₂	0-20	0.0205	0.0615	0.1346
	20-40	0.0436	0.0667	0.1538
L ₅ S ₁	0-20	0.0282	0.1103	0.2308
	20-40	0.0231	0.1282	0.2500
L ₅ S ₂	0-20	0.0231	0.0744	0.1538
	20-40	0.0333	0.0718	0.1987
L ₆ S ₁	0-20	0.0205	0.0821	0.1987
	20-40	0.0128	0.0590	0.1538
L ₆ S ₂	0-20	0.0205	0.0615	0.1474
	20-40	0.0128	0.0359	0.1474
L ₇ S ₁	0-20	0.0128	0.0590	0.1859
	20-40	0.0090	0.0410	0.1346
L ₇ S ₂	0-20	0.0179	0.0462	0.1282
	20-40	0.0103	0.0244	0.1154
Mean	0-20	0.0196	0.0720	0.1790
	20-40	0.0179	0.0670	0.1790

Table 8. Different forms of Potassium in the soils of Adat village (cmol(+) kg⁻¹)

Location	Depth (cm)	Water soluble K	Exchangeable K (NH ₄ OAc extractable)	HNO ₃ soluble K
L ₈ S ₁	0-20	0.0308	0.1154	0.2564
	20-40	0.0282	0.1000	0.1731
L ₈ S ₂	0-20	0.0308	0.0718	0.2500
	20-40	0.0231	0.0615	0.2051
L ₉ S ₁	0-20	0.0231	0.0821	0.2564
	20-40	0.0231	0.1333	0.3397
L ₉ S ₂	0-20	0.0154	0.0923	0.1731
	20-40	0.0154	0.0821	0.1731
L ₁₀ S ₁	0-20	0.0256	0.1154	0.3269
	20-40	0.0103	0.0846	0.2308
L ₁₀ S ₂	0-20	0.0436	0.0641	0.2051
	20-40	0.0179	0.1103	0.2821
L ₁₁ S ₁	0-20	0.0282	0.0872	0.1987
	20-40	0.0103	0.0641	0.1538
L ₁₁ S ₂	0-20	0.0179	0.0923	0.1667
	20-40	0.0128	0.0615	0.1538
Mean	0-20	0.0269	0.0901	0.2292
	20-40	0.0176	0.0872	0.2139

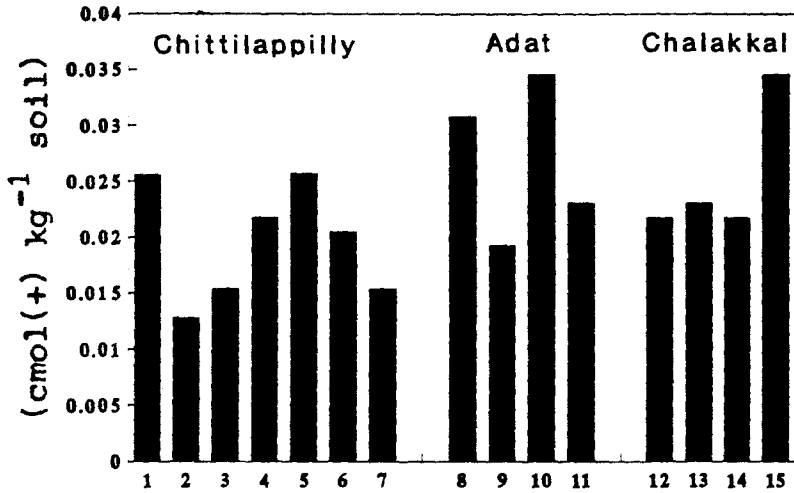
Table 9. Different forms of Potassium in the soils of Chalakkal village ($\text{cmol}(+) \text{kg}^{-1}$)

Location	Depth (cm)	Water soluble K	Exchangeable K (NH_4OAc extractable)	HNO_3 soluble K
L ₁₂ S ₁	0-20	0.0282	0.1026	0.1603
	20-40	0.0128	0.0359	0.1410
L ₁₂ S ₂	0-20	0.0154	0.1000	0.1410
	20-40	0.0333	0.1256	0.3782
L ₁₃ S ₁	0-20	0.0256	0.1436	0.2372
	20-40	0.0256	0.1436	0.3462
L ₁₃ S ₂	0-20	0.0205	0.0821	0.1795
	20-40	0.0128	0.0538	0.1731
L ₁₄ S ₁	0-20	0.0231	0.1026	0.2115
	20-40	0.0103	0.0718	0.2308
L ₁₄ S ₂	0-20	0.0205	0.0718	0.1410
	20-40	0.0154	0.0615	0.1538
L ₁₅ S ₁	0-20	0.0538	0.0897	0.2308
	20-40	0.0077	0.0231	0.1154
L ₁₅ S ₂	0-20	0.0154	0.0667	0.1795
	20-40	0.0282	0.1282	0.3333
Mean	0-20	0.0253	0.0949	0.1851
	20-40	0.0183	0.0804	0.2340

Table 10. Mean values of different forms of potassium in the surface and subsurface soils at different locations in the three villages ($\text{cmol}(+) \text{kg}^{-1}$ soil)

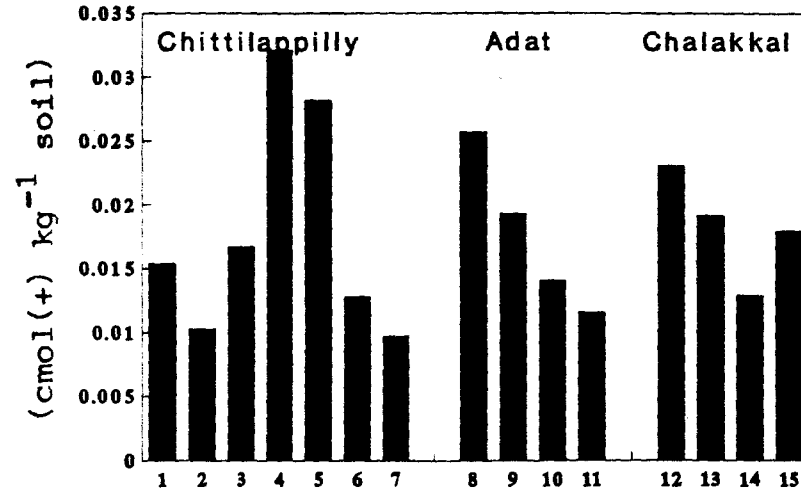
Village	Location	Water soluble K	NH_4OAc exchangeable K	HNO_3 soluble K	
Chittilappilly	L ₁	0-20	0.0256	0.1051	0.2566
		20-40	0.0154	0.1270	0.3045
	L ₂	0-20	0.0128	0.0256	0.1218
		20-40	0.0103	0.0347	0.1378
	L ₃	0-20	0.0154	0.0782	0.2019
		20-40	0.0167	0.0629	0.1539
	L ₄	0-20	0.0218	0.0782	0.1507
		20-40	0.0321	0.0641	0.1571
	L ₅	0-20	0.0257	0.0924	0.1923
		20-40	0.0282	0.1000	0.2244
	L ₆	0-20	0.0205	0.0718	0.1731
		20-40	0.0128	0.0475	0.1506
	L ₇	0-20	0.0154	0.0503	0.1571
		20-40	0.0097	0.0327	0.1250
Adat	L ₈	0-20	0.0308	0.0936	0.2532
		20-40	0.0257	0.0808	0.1891
	L ₉	0-20	0.0193	0.0872	0.1891
		20-40	0.0193	0.1077	0.2564
L ₁₀	0-20	0.0346	0.1398	0.2917	
	20-40	0.0141	0.0975	0.2565	
L ₁₁	0-20	0.0231	0.0898	0.1827	
	20-40	0.0116	0.0628	0.1538	
Chalakkal	L ₁₂	0-20	0.0218	0.1013	0.1507
		20-40	0.0231	0.0808	0.2596
	L ₃	0-20	0.0231	0.1128	0.2084
		20-40	0.0192	0.0987	0.2597
	L ₄	0-20	0.0218	0.0872	0.1763
		20-40	0.0129	0.0667	0.1923
	L ₁₅	0-20	0.0346	0.0782	0.2052
		20-40	0.0180	0.0757	0.2244

Surface



Location

Subsurface



Location

Fig.1. Mean values of water soluble potassium at different locations of Chittilappilly, Adat and Chalakkal villages

Chalakkal villages this fraction constituted 0.68 and 0.75 per cent in surface and 0.36 and 0.38 per cent in the subsurface. The higher content of water soluble K in the surface horizon is probably due to more intensive weathering, release of labile K from organic residues, application of K bearing fertilizers and upwards translocation of the element from lower depths with capillary rise of ground water (Pal and Mukhopadhyay, 1992a). There was not much variation between the two sites of the same location except for L₁₅S₁ for which a wide variation was observed.

Simple linear correlation have worked out between this form of K with other forms in the surface and subsurface. The correlation (r) values were given in Appendix I and II. For surface and subsurface soils water soluble potassium was significantly correlated with exchangeable ($r=0.554^{**}$; 0.515^{**}) and HNO₃ soluble K ($r=0.513^{**}$; 0.431^{*}). Similar results were obtained by Sharma and Mishra (1986) in alluvial soils of Western Uttar Pradesh.

4.1.3.2 Exchangeable K (NH₄OAc extractable)

Exchangeable potassium content showed wide variation in Chittilappilly soils and it ranged from 0.0205 (L₂S₁) to 0.1333 cmol(+) kg⁻¹ (L₁S₂) in the surface (mean=0.0720 cmol(+) kg⁻¹) and from 0.0244 (L₇S₂) to 0.1385 cmol(+) kg⁻¹ (L₁S₂) in the subsurface (mean=0.0670 cmol(+) kg⁻¹). This fraction was very low for L₂ and this is expected as the soil is coarser in texture. In Adat soils this fraction ranged from 0.0642 (L₁₀S₂) to 0.1154 (L₈S₁ and L₁₀S₁) cmol(+) kg⁻¹ (mean=0.0901 cmol(+) kg⁻¹) in surface and from 0.0615 (L₈S₂ and L₁₁S₂) to 0.1333 (L₉S₁) cmol(+) kg⁻¹ in subsurface (mean=0.0872 cmol(+) kg⁻¹) whereas the range for this fraction in Chalakkal village was 0.0667 (L₁₅S₂) to 0.1436 (L₁₃S₁) cmol(+) kg⁻¹ in the surface (mean=0.0949 cmol(+) kg⁻¹) and 0.0231

(L₁₅S₁) to 0.1435 (L₁₃S₁) cmol(+) kg⁻¹ in the subsurface (mean=0.0804 cmol(+) kg⁻¹).

From the mean values of this fraction in the different locations of the three villages (Table 10), it was observed that the surface soils of Adat village have higher value for this fraction of potassium (Fig. 2).

On an average this fraction constituted 2.25, 2.29 and 2.81 per cent of total K in surface soils of Chittilappilly, Adat and Chalakkal villages respectively, while the percentage of this fraction of K to total K were 1.77, 1.79 and 1.69 per cent respectively in the subsurface soils. Its contribution towards total K was relatively more in surface layers. Release of K from organic residues and application of fertilizers might be the reason for more amount of exchangeable K in the surface layers (Ranganathan and Satyanarayana, 1980; Sharma and Mishra, 1986).

For the surface and subsurface soils exchangeable K was positively correlated with clay content ($r=0.698^{**}$; 0.658^{**}), silt ($r=0.084$; 0.390^{*}) and cation exchange capacity ($r=0.671^{**}$; 0.371^{*}). Similar results were obtained by Negi *et al.* (1979) for acidic brown hill soils of Assam and Brar and Sekhon (1985) for soils from northern India. This shows that the finer fractions are the primary source of variability in soil potassium. Positive correlation of exchangeable K with organic carbon was also observed and it was significant only for the surface ($r=0.570^{**}$). The increase in the availability of K with increase in organic carbon contents of the soils may be attributed to the release of K from organic complexes (Kanthaliya and Bhatt, 1991).

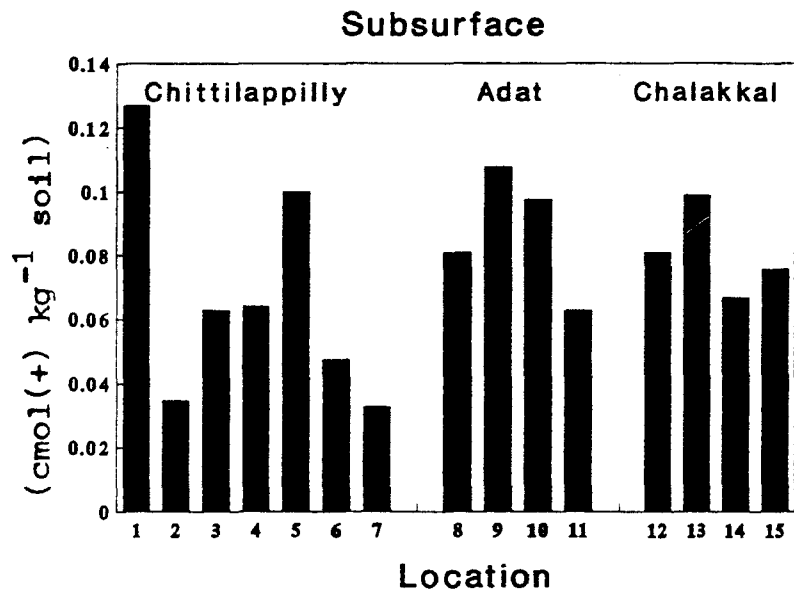
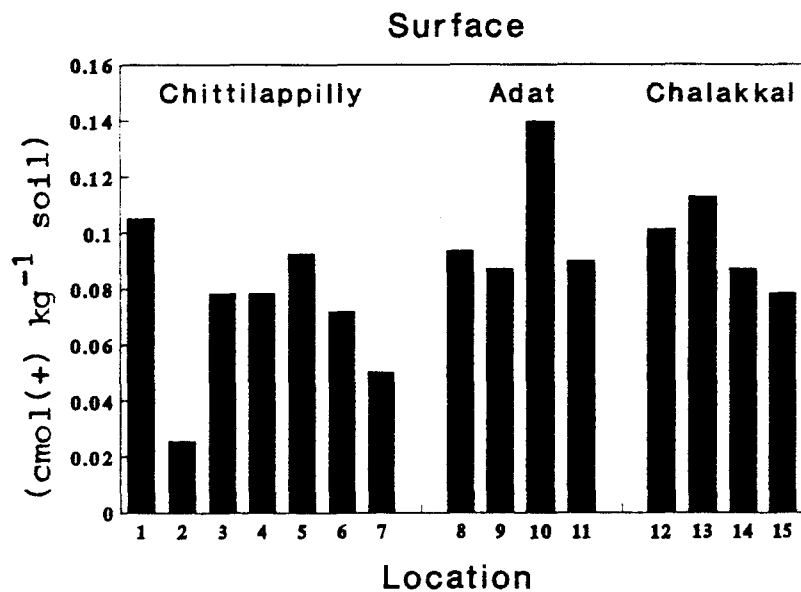


Fig.2. Mean values of exchangeable potassium at different locations of Chittilappilly, Adat and Chalakkal villages

This form of K was also positively and significantly correlated to exchangeable Ca ($r=0.666^{**}$; 0.617^{**}) and exchangeable Na ($r=0.477^{**}$; 0.553^{**}) in surface and subsurface soils. This was in conformity with that reported by Singh *et al.* (1985) in soils of Western Haryana and Dixit *et al.* (1993) in soils of Western Uttar Pradesh.

Exchangeable K showed significant positive correlation with HNO_3 soluble K ($r=0.714^{**}$; 0.912^{**}) and total K ($r=0.627^{**}$; 0.725^{**}) for surface and subsurface soils.

4.1.3.3 HNO_3 soluble potassium

The HNO_3 soluble K content in the soils of Chittilappilly village varied from 0.1026 (L_2S_1) to 0.3333 (L_1S_2) $\text{cmol}(+) \text{kg}^{-1}$ in surface soils (mean=0.1790 $\text{cmol}(+) \text{kg}^{-1}$) and from 0.1218 (L_2S_1) to 0.3654 (L_1S_2) $\text{cmol}(+) \text{kg}^{-1}$ in the subsurface soils (mean=0.1790 $\text{cmol}(+) \text{kg}^{-1}$). The low value of exchangeable and HNO_3 soluble K recorded in L_2 may be due to the low content of total K. This is expected as the soil is of sandy loam texture containing less of K bearing minerals. In Adat village this fraction ranged from 0.1667 ($L_{11}S_2$) to 0.3269 ($L_{10}S_1$) in surface (mean=0.2292 $\text{cmol}(+) \text{kg}^{-1}$) and from 0.1538 ($L_{11}S_1$ and $L_{11}S_2$) to 0.3397 (L_9S_1) $\text{cmol}(+) \text{kg}^{-1}$ in the subsurface (mean=0.2139 $\text{cmol}(+) \text{kg}^{-1}$). This fraction ranged from 0.1410 ($L_{12}S_2$ and $L_{14}S_2$) to 0.2372 ($L_{13}S_1$) $\text{cmol}(+) \text{kg}^{-1}$ in surface (mean=0.1851 $\text{cmol}(+) \text{kg}^{-1}$) and from 0.1154 ($L_{15}S_1$) to 0.3782 ($L_{12}S_2$) $\text{cmol}(+) \text{kg}^{-1}$ in the subsurface (mean=0.2340 $\text{cmol}(+) \text{kg}^{-1}$) in Chalakkal village.

The surface soils of Adat village recorded higher value for this fraction of potassium (Table 10) and the variation in this form of potassium at the different locations of the three villages are presented in Fig. 3.

The proportion of HNO_3 soluble K to total K in the surface soils of Chittilappilly, Adat and Chalakkal villages were 5.59, 5.82 and 5.48 per cent respectively, while in the subsurface it constituted 4.73, 4.40 and 4.92 per cent. Similar results were obtained by Dhillon *et al.* (1985) in soils of North West India and Sharma and Mishra (1986) in alluvial soils of Western Uttar Pradesh.

The distribution of non exchangeable K in the profile is largely regulated by the fineness of texture and degree of weatherability (Dhillon *et al.*, 1985; Pal and Mukhopadhyay, 1992b). The maximum value recorded in L_1S_2 and $L_{12}S_2$ may be attributed to the presence of K fixing minerals in the clay fraction. The lowest value was reported by L_2S_1 and this might be due to the absence of K fixing minerals.

The positive significant correlation observed between HNO_3 soluble K and cation exchange capacity ($r=0.448^*$; 0.307) indicated that some K adsorbed on edges of inner sites on the lattice which could be extracted with HNO_3 was a part of the exchange complex. Similar results were obtained by Singh *et al.* (1985) in soils of Haryana and Islam *et al.* (1994) in soils of Bangladesh. Similarly this fraction was positively and significantly correlated with clay ($r=0.487^{**}$; 0.593 **) and non significantly correlated with organic carbon ($r=0.281$; 0.239). Similar results were obtained by Basumatary and Bordoloi (1992) in soils of Assam and Dixit *et al.* (1993) in soils of Western Uttar Pradesh. This might be due to the fact that with an increase in organic matter in soils, the clay-humus complex become

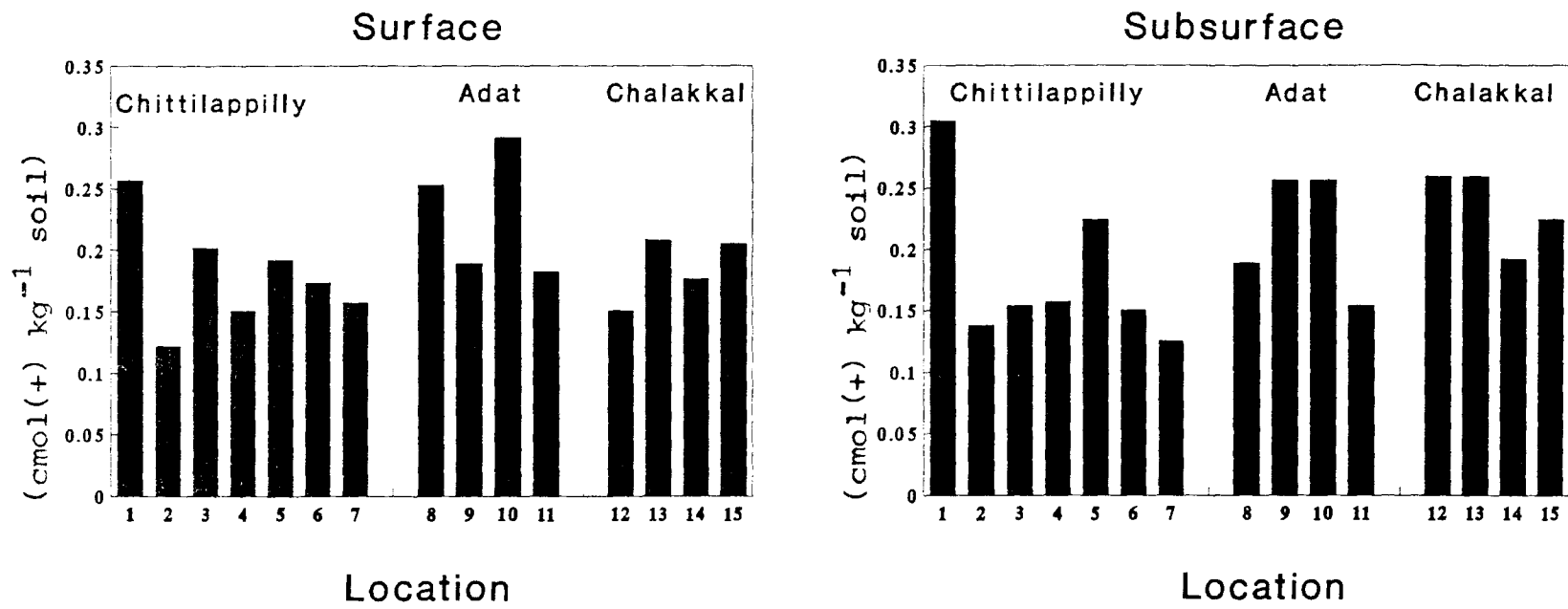


Fig.3. Mean values of nitric acid soluble potassium at different locations of Chittilappilly, Adat and Chalakkal villages

more active there by providing more exchange sites and access to potassium. The positive correlation of HNO_3 soluble K with clay and silt indicates that it occupied inner lattice sites which could be extracted with more drastic acid treatment. This K was significantly and positively correlated with exchangeable Ca ($r=0.532^{**}$; 0.533^{**}), exchangeable Na ($r=0.441^*$; 0.592^{**}) and exchangeable Mg ($r=0.393^*$; 0.313). Similar results were obtained by Dixit *et al.* (1993) in soils of Western Uttar Pradesh.

HNO_3 soluble K showed significant positive correlation with water soluble, exchangeable and total K. The coefficient of correlation (r) of this form of K with total K was 0.690^{**} for surface and 0.622^{**} for subsurface. Similar results were obtained by Tiwari and Bansal (1992) for alluvial soils of Madhya Pradesh and Islam *et al.* (1994) in soils of Bangladesh. However, Dixit *et al.* (1993) observed positive and significant correlation between all the forms of K except water soluble K in alluvial soils of Western Uttar Pradesh. The positive correlation exist between different forms of K suggests that K exist in thermodynamic equilibrium in different pools (Singh *et al.*, 1983; Koria *et al.*, 1989; Basumatary and Bordoloi, 1992). All these suggests that the change in one fraction bring about variations in the other forms of potassium in soil.

4.2 Retention of potassium

Quantity of potassium retained in the soil after shaking for the specified period of time in surface and subsurface soils are given in Tables 11 and 12.

In the surface and subsurface maximum retention was observed in $L_{10}S_1$ at all the different periods of shaking while minimum was observed in L_2S_1 in

Table 11. Potassium retained by the surface soils at different periods of shaking (cmol (+) kg⁻¹ soil)

Location	Period of shaking(hours)				Mean values for location
	0	2	4	6	
L ₁ S ₁	0.3077	0.3847	0.3334	0.2821	
S ₂	0.5642	0.7180	0.6924	0.6667	0.4937
L ₂ S ₁	0.1795	0.2303	0.1795	0.1411	
S ₂	0.2308	0.2861	0.2052	0.2052	0.2073
L ₃ S ₁	0.4103	0.5129	0.4872	0.4488	
S ₂	0.4872	0.5385	0.5642	0.5129	0.4953
L ₄ S ₁	0.4616	0.5770	0.6154	0.5000	
S ₂	0.3077	0.3462	0.3847	0.2465	0.4299
L ₅ S ₁	0.5129	0.5900	0.6154	0.4872	
S ₂	0.3334	0.3206	0.3590	0.2565	0.4344
L ₆ S ₁	0.4103	0.4872	0.4616	0.4103	
S ₂	0.2565	0.3206	0.3077	0.2949	0.3685
L ₇ S ₁	0.4359	0.4488	0.4616	0.4103	
S ₂	0.3590	0.3847	0.3334	0.3077	0.3927
L ₈ S ₁	0.4103	0.4231	0.4616	0.3718	
S ₂	0.2052	0.2052	0.2821	0.1026	0.3077
L ₉ S ₁	0.4103	0.5000	0.5900	0.3718	
S ₂	0.4359	0.6795	0.7180	0.6411	0.5433
L ₁₀ S ₁	0.6411	0.7821	0.7949	0.7308	
S ₂	0.5385	0.6283	0.7052	0.6154	0.6795
L ₁₁ S ₁	0.5385	0.6795	0.7308	0.6924	
S ₂	0.5129	0.6411	0.6667	0.5898	0.6315
L ₁₂ S ₁	0.5385	0.6667	0.7180	0.5898	
S ₂	0.5388	0.6795	0.7180	0.6026	0.6315
L ₁₃ S ₁	0.5129	0.6667	0.6667	0.5898	
S ₂	0.5129	0.5385	0.5129	0.4616	0.5578
L ₁₄ S ₁	0.4103	0.4616	0.4359	0.3975	
S ₂	0.4359	0.4488	0.4359	0.3847	0.4263
L ₁₅ S ₁	0.1795	0.1539	0.2052	0.0898	
S ₂	0.4616	0.5770	0.5385	0.5642	0.3462
Mean	0.4180	0.4959	0.5060	0.4322	
		SEm ±		CD (0.05)	
For hours of shaking		0.0239		0.0670	
For location		0.0463		0.1298	

surface and $L_{15}S_1$ in subsurface. The results showed that in soils with least amount of exchangeable K, the retention first increased after two hours of shaking but afterwards retention of K was less even with four and six hours of shaking. In soils with higher amount of exchangeable K the retention increased linearly up to four hours of shaking and then decreased after shaking for a period of six hours, but the amount retained was higher than that retained at zero hour of shaking (Islam *et al.*, 1994). When the saturation capacity of the soil is less the maximum amount of K will be retained even with short period of shaking. But with high saturation capacity, the retention capacity is low and hence longer duration of time is essential for maximum retention.

Statistical analysis showed that the quantity retained after shaking for a period of two hours and four hours is significantly greater than that retained in soil with zero hour of shaking and maximum retention was obtained in soils after shaking for a period of four hours. The decrease in retention after shaking for a period of six hours is significant compared to that retained after four hours of shaking, but it is non significant compared that retained at two hours of shaking. However there was a slight increase in the amount of K retained in the soil after six hours of shaking compared to that without shaking.

In subsurface there was no significant difference in the amount of K retained at different periods of shaking. An increase was noticed after shaking for a period of of two hours. Then it decreased after four hours of shaking but the amount retained was higher than that with zero hour of shaking. When the soil was shaken for six hours, the amount of K retained decreased further and it was less than that retained at two hours of shaking.

Table 12. Potassium retained by the subsurface soils at different periods of shaking (cmol (+) kg⁻¹)

Location	Periods of shaking (hours)				Mean values for location
	0	2	4	6	
L ₁ S ₁	0.5385	0.6026	0.5900	0.5642	
S ₂	0.6154	0.7180	0.7180	0.6667	0.6267
L ₂ S ₁	0.3077	0.3206	0.3077	0.3077	
S ₂	0.2565	0.4103	0.2821	0.2308	0.3029
L ₃ S ₁	0.3590	0.4744	0.4103	0.3847	
S ₂	0.4359	0.5642	0.4359	0.7949	0.4824
L ₄ S ₁	0.4103	0.4872	0.4103	0.3334	
S ₂	0.3334	0.4488	0.3334	0.2436	0.3751
L ₅ S ₁	0.7180	0.7565	0.7436	0.6154	
S ₂	0.3590	0.4231	0.3334	0.2565	0.5257
L ₆ S ₁	0.3334	0.4103	0.3590	0.3206	
S ₂	0.3590	0.3975	0.3334	0.4103	0.3654
L ₇ S ₁	0.3847	0.4231	0.3847	0.3077	
S ₂	0.1795	0.2308	0.1539	0.3077	0.2965
L ₈ S ₁	0.3847	0.5000	0.4103	0.3334	
S ₂	0.2565	0.3590	0.2565	0.1795	0.3029
L ₉ S ₁	0.5642	0.5780	0.5900	0.5385	
S ₂	0.5898	0.6667	0.7180	0.6282	0.6092
L ₁₀ S ₁	0.7108	0.8462	0.8975	0.8206	
S ₂	0.5642	0.6026	0.6154	0.5513	0.7011
L ₁₁ S ₁	0.4616	0.7436	0.7180	0.7180	
S ₂	0.4103	0.5000	0.4872	0.4488	0.5609
L ₁₂ S ₁	0.5129	0.5000	0.4616	0.3846	
S ₂	0.4872	0.6026	0.5385	0.4616	0.4936
L ₁₃ S ₁	0.6924	0.7180	0.7436	0.6795	
S ₂	0.4103	0.4103	0.4872	0.4103	0.5690
L ₁₄ S ₁	0.5385	0.6539	0.6667	0.6154	
S ₂	0.3590	0.4616	0.4359	0.3975	0.5161
L ₁₅ S ₁	0.0513	0.0770	0.0513	0.0898	
S ₂	0.5129	0.5898	0.5642	0.5129	0.3062
Mean	0.4366	0.5159	0.4813	0.4505	
		SEm±	CD (0.05)		
For hours of shaking		0.0284	0.0796		
For location		0.0551	0.1544		

Table 13. Mean values of potassium retained in the surface and subsurface soils of the three villages at different periods of shaking

Name of village	Depth (cm)	Period of shaking (h)			
		0	2	4	6
		(cmol(+) kg ⁻¹ soil)			
Chittilappilly	0-20	0.3755	0.4390	0.4286	0.3693
	20-40	0.3993	0.4762	0.4140	0.4103
Adat	0-20	0.4616	0.5674	0.6187	0.5145
	20-40	0.4928	0.5995	0.5866	0.5273
Chalakkal	0-20	0.4488	0.5241	0.5289	0.4600
	20-40	0.4456	0.5016	0.4936	0.4439

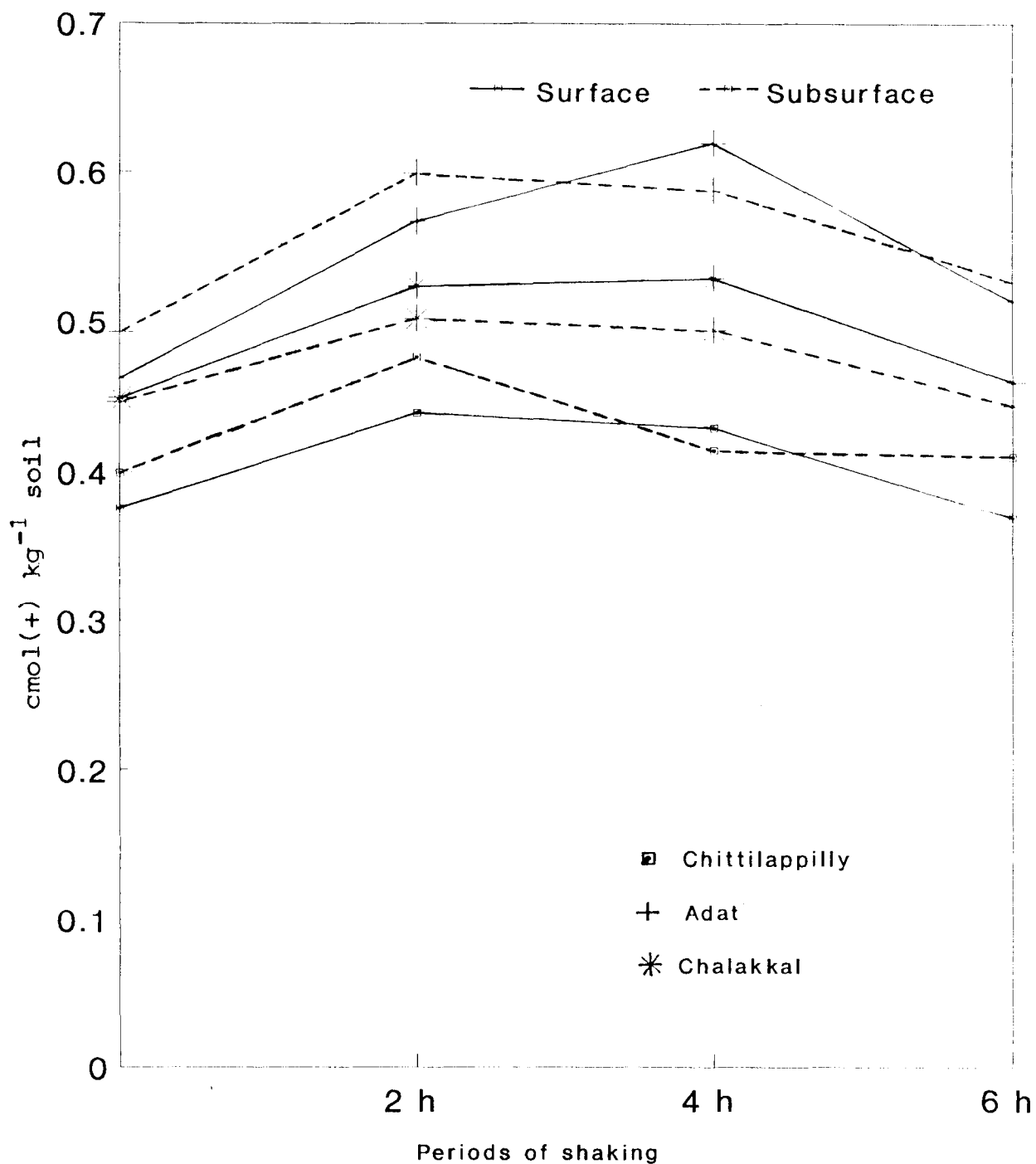


Fig.4. Retention of potassium at different periods of shaking in surface and subsurface soils of Chittilappilly, Adat and Chalakkal villages

The mean values of potassium retained at different hours of shaking in the surface and subsurface samples of the three villages are given in Table 13 and it is represented in Fig. 4. High content of clay accounts for the maximum retention of applied potassium in the soils of Adat village.

Among the 15 locations the mean value for retention of K in the surface was in the increasing order of L₂, L₈, L₁₅, L₆, L₇, L₁₄, L₄, L₅, L₁, L₃, L₉, L₁₃, L₁₁, L₁₂ and L₁₀. There was a highly significant difference in the retention of K for L₂, L₁₂ and L₁₀ from the other locations. The minimum retention in L₂ is attributed to the high sand content and low cation exchange capacity of the soil and the high retention in L₁₁, L₁₂ and L₁₀ was attributed to the high clay content and high cation exchange capacity of the soil.

In the subsurface the mean value for retention of K in the 15 locations were in the increasing order of L₇, L₂, L₈, L₁₅, L₆, L₄, L₃, L₁₂, L₁₄, L₅, L₁₁, L₁₃, L₉, L₁ and L₁₀. The low retention of potassium in L₇, L₂ and L₈ from most of the other locations is due to the higher content of sand and low cation exchange capacity of the soils. High content of clay and high CEC accounts for the maximum retention by L₁ and L₁₀. The amount of K retained by the soil colloids from the applied water soluble K depend on cation exchange capacity of the soil (Chakravorti, 1992).

The data on the percentage of K retained in soils of different locations are given in Tables 14 and 15. For zero hour shaking the retention varied from 16 to 46 and 20 to 50 per cent for surface and subsurface respectively. In two hours of shaking the range is between 20 to 55 per cent and 26 to 56 per cent. For four hours

Table 14. Mean amount and percentage of K retained at different periods of shaking in the surface soils of different locations (cmol (+) kg⁻¹)

Location	Periods of shaking (hours)			
	0	2	4	6
L ₁	0.4360 (31.01%)	0.5514 (43.01%)	0.5132 (40.03%)	0.4744 (37.0%)
L ₂	0.2052 (16.01%)	0.2565 (20.01%)	0.1924 (15.0%)	0.1732 (13.51%)
L ₃	0.4488 (35.01%)	0.5257 (41.0%)	0.5257 (41.0%)	0.4809 (37.51%)
L ₄	0.3847 (30.0%)	0.4616 (36.0%)	0.5001 (39.01%)	0.3783 (29.51%)
L ₅	0.4232 (33.01%)	0.4553 (35.51%)	0.4872 (38.0%)	0.3719 (29.01%)
L ₆	0.3334 (26.0%)	0.4039 (31.5%)	0.3847 (30.0%)	0.3526 (27.5%)
L ₇	0.3975 (31.0%)	0.4168 (32.51%)	0.3975 (31.0%)	0.3590 (28.0%)
L ₈	0.3078 (24.01%)	0.3142 (24.51%)	0.3719 (29.01%)	0.2372 (18.5%)
L ₉	0.4231 (33.0%)	0.5898 (46.0%)	0.6540 (51.01)	0.5065 (39.51%)
L ₁₀	0.5898 (46.0%)	0.7052 (55.0%)	0.7052 (55.0%)	0.6731 (52.5%)
L ₁₁	0.5257 (41.0%)	0.6103 (47.6%)	0.6988 (54.5%)	0.6411 (50.0%)
L ₁₂	0.5385 (42.0%)	0.6731 (52.5%)	0.7180 (56.0%)	0.5962 (46.5%)
L ₁₃	0.5129 (40.0%)	0.6026 (47.0%)	0.5899 (46.01%)	0.5257 (41.0%)
L ₁₄	0.4231 (33.0%)	0.4552 (35.5%)	0.4359 (34.0%)	0.3911 (30.5%)
L ₁₅	0.3206 (25.01%)	0.3655 (28.51%)	0.3719 (29.01%)	0.3270 (25.51%)

Table 15. Mean amount and percentage of K retained at different periods of shaking in the subsurface soils of different locations (cmol (+) kg⁻¹)

Location	Periods of shaking (h)			
	0	2	4	6
L ₁	0.577 (45.0%)	0.6603 (51.5%)	0.6542 (51.01%)	0.6155 (48.01%)
L ₂	0.2821 (22.0%)	0.3655 (28.51%)	0.2949 (23.0%)	0.2693 (21.0%)
L ₃	0.3975 (31.0%)	0.5193 (40.5%)	0.4231 (33.0%)	0.5898 (46.0%)
L ₄	0.3719 (29.01%)	0.4680 (36.5%)	0.3719 (29.01%)	0.2885 (22.5%)
L ₅	0.5380 (41.96%)	0.5898 (46.0%)	0.5385 (42.0%)	0.4360 (34.0%)
L ₆	0.3462 (27.0%)	0.4039 (31.5%)	0.3462 (27.0%)	0.3655 (28.51%)
L ₇	0.2821 (22.0%)	0.3270 (25.51%)	0.2693 (21.0%)	0.3077 (24.0%)
L ₈	0.3206 (25.01%)	0.4295 (33.5%)	0.3334 (26.0%)	0.2665 (20.79%)
L ₉	0.5770 (45.0%)	0.6224 (48.55%)	0.654 (51.01%)	0.5834 (45.5%)
L ₁₀	0.6411 (50.0%)	0.7244 (56.5%)	0.7565 (59.0%)	0.6860 (53.5%)
L ₁₁	0.436 (34.0%)	0.6218 (48.5%)	0.6026 (47.0%)	0.5834 (45.5%)
L ₁₂	0.5001 (39.01%)	0.5513 (43.0%)	0.5001 (39.0%)	0.4231 (33.0%)
L ₁₃	0.5514 (43.0%)	0.5642 (44.0%)	0.6154 (48.0%)	0.5449 (42.5%)
L ₁₄	0.4488 (35.0%)	0.5578 (43.5%)	0.5513 (43.01%)	0.5065 (39.51%)
L ₁₅	0.2821 (22.0%)	0.3334 (26.0%)	0.3078 (24.01%)	0.3014 (23.51%)

of shaking it varied from 15 to 56 and 23 to 59 per cent, whereas for six hours of shaking the retention percentage varied from 13 to 52 and 21 to 53 per cent. In all the treatments L₂ retained minimum per cent of K and the highest by L₁₀ except for that with four hours of shaking.

Thus for both the surface and subsurface samples the retention is maximum in short period of time. Soils with high initial K retained higher amounts of K than soils with low initial K. In soils with minimum initial K maximum per cent of retention take place at two hours of equilibration and longer period of equilibration reduced the retention of K. In high K soils four hours of equilibration gives more time for retention and hence more retention take place at longer periods of equilibration. Rao and Khera (1995) observed similar results while studying the fixation characteristics and fertilizer K requirements of illitic alluvial soils by two step alternate method.

4.3 Dynamics of potassium

A laboratory incubation experiment was carried out to delineate the pattern of release of different forms of potassium from the native soil potassium as well as from the applied potassium for a period of three months. The surface samples of the 15 locations were used for the study. Soil samples were drawn at fortnightly intervals and it was analysed for the different forms of potassium.

4.3.1 Native potassium

4.3.1.1 Water soluble potassium

The data on the content of water soluble potassium for the different period of incubation is given in Table 16. The result showed that there was

Table 16. Water soluble potassium at different periods of incubation in the untreated samples

Location	Days of incubation						Mean values for location
	15th	30th	45th ($\text{cmol}(+) \text{ kg}^{-1}$ soil)	60th	75th	90th	
L ₁ S ₁	0.0256	0.0333	0.0282	0.0205	0.0256	0.0131	
S ₂	0.0333	0.0192	0.0256	0.0179	0.0282	0.0218	0.0253
L ₂ S ₁	0.0192	0.0256	0.0154	0.0231	0.0179	0.0154	
S ₂	0.0256	0.0269	0.0231	0.0154	0.0179	0.0115	0.0188
L ₃ S ₁	0.0179	0.0269	0.0333	0.0205	0.0205	0.0128	
S ₂	0.0256	0.0231	0.0179	0.0154	0.0179	0.0141	0.0198
L ₄ S ₁	0.0282	0.0256	0.0256	0.0256	0.0360	0.0372	
S ₂	0.0192	0.0205	0.0205	0.0231	0.0346	0.0295	0.0264
L ₅ S ₁	0.0321	0.0282	0.0308	0.0256	0.0462	0.0333	
S ₂	0.0218	0.0244	0.0231	0.0205	0.0308	0.0218	0.0279
L ₆ S ₁	0.0167	0.0167	0.0231	0.0154	0.0179	0.0179	
S ₂	0.0231	0.0167	0.0231	0.0179	0.0205	0.0141	0.0189
L ₇ S ₁	0.0218	0.0256	0.0205	0.0154	0.0244	0.0115	
S ₂	0.0333	0.0256	0.0359	0.0282	0.0192	0.0154	0.0220
L ₈ S ₁	0.0269	0.0295	0.0308	0.0256	0.0360	0.0308	
S ₂	0.0269	0.0308	0.0282	0.0256	0.0346	0.0385	0.0304
L ₉ S ₁	0.0179	0.0179	0.0154	0.0154	0.0308	0.0256	
S ₂	0.0154	0.0128	0.0154	0.0282	0.0218	0.0282	0.0202
L ₁₀ S ₁	0.0179	0.0231	0.0179	0.0179	0.0308	0.0218	
S ₂	0.0282	0.0449	0.0385	0.0410	0.0487	0.0397	0.0314
L ₁₁ S ₁	0.0333	0.0308	0.0256	0.0410	0.0256	0.0256	
S ₂	0.0243	0.0346	0.0256	0.0154	0.0256	0.0179	0.0265
L ₁₂ S ₁	0.0218	0.0256	0.0231	0.0231	0.0282	0.0167	
S ₂	0.0154	0.0141	0.0154	0.0128	0.0192	0.0128	0.0194
L ₁₃ S ₁	0.0218	0.0169	0.0205	0.0154	0.0282	0.0218	
S ₂	0.0243	0.0154	0.0154	0.0128	0.0246	0.0167	0.0200
L ₁₄ S ₁	0.0269	0.0205	0.0231	0.0179	0.0218	0.0192	
S ₂	0.0256	0.0179	0.0205	0.0256	0.0231	0.0154	0.0215
L ₁₅ S ₁	0.0590	0.0385	0.0462	0.0410	0.0330	0.0359	
S ₂	0.0218	0.0141	0.0179	0.0256	0.0154	0.0167	0.0310
Mean	0.0250	0.0242	0.0242	0.0223	0.0268	0.0221	
		SEm \pm		CD(0.05)			
For incubation period		0.0014		N.S			
For location		0.0020		0.0056			

no linearity among the fifteen locations for the release of this fraction during the incubation period. For most of the sites initially there was a sudden increase either at 30th or 45th day of incubation, followed by a decrease at 75th day of incubation and then it increased to higher level. For certain locations the increase was noticed only at 75th day of incubation. However, for a few locations the content was more or less the same throughout the incubation period. It was observed that soils with very low content of water soluble potassium have a tendency to increase its content and this increase might be due to the release of exchangeable K from the soil complex. But for soils with high initial potassium there was no change in the content throughout the entire period of incubation. Statistical analysis showed that there was no significant change for this form of potassium throughout the incubation period.

4.3.1.2 Exchangeable potassium (NH_4OAc extractable)

The data on the content of exchangeable potassium for the different incubation periods is given in Table 17. The result showed that this fraction of potassium was increasing throughout the incubation period. However, on 15th day a decrease was noticed and it was not statistically significant. Then it increased significantly to a higher level at 30th and 75th day of incubation. For these samples the content at the end of the incubation period was less than that of the previous fortnight. In certain sites the maximum content was noticed only at the end of the incubation period, whereas for a few sites the content was more or less same throughout the incubation period. It was observed that the soils with high content of exchangeable potassium have a tendency to increase its content and this increase might be due to the release of potassium from the soil complex. But for soils with

Table 17. Exchangeable potassium at different periods of incubation in the untreated samples

Location	Days of incubation						Mean values for location
	15th	30th	45th	60th (cmol(+) kg ⁻¹ soil)	75th	90th	
L ₁ S ₁	0.0641	0.0795	0.0769	0.0808	0.0795	0.0769	
S ₂	0.1256	0.1731	0.1410	0.1269	0.1436	0.1410	0.1085
L ₂ S ₁	0.0231	0.0333	0.0321	0.0321	0.0308	0.0256	
S ₂	0.0282	0.0359	0.0321	0.0372	0.0410	0.0256	0.0306
L ₃ S ₁	0.0795	0.1026	0.0962	0.0756	0.1013	0.0769	
S ₂	0.0742	0.0820	0.0769	0.0808	0.0769	0.0769	0.0826
L ₄ S ₁	0.0949	0.1051	0.1026	0.1013	0.1269	0.1538	
S ₂	0.0526	0.0615	0.0705	0.0500	0.1077	0.0833	0.0905
L ₅ S ₁	0.1128	0.1282	0.1154	0.1192	0.1385	0.1410	
S ₂	0.0615	0.0744	0.0641	0.0679	0.0974	0.0769	0.0987
L ₆ S ₁	0.0808	0.0769	0.0769	0.0846	0.0846	0.0833	
S ₂	0.0474	0.0513	0.0513	0.0372	0.0538	0.0385	0.0650
L ₇ S ₁	0.0513	0.0667	0.0513	0.0641	0.0846	0.0577	
S ₂	0.0487	0.0487	0.0897	0.0462	0.0667	0.0641	0.0600
L ₈ S ₁	0.1038	0.1256	0.1026	0.1141	0.1308	0.1346	
S ₂	0.0885	0.0769	0.0641	0.0744	0.0821	0.0833	0.0977
L ₉ S ₁	0.0833	0.1026	0.0769	0.0795	0.1231	0.1026	
S ₂	0.1026	0.1179	0.1026	0.1077	0.1154	0.1218	0.1007
L ₁₀ S ₁	0.1385	0.1667	0.1410	0.1385	0.1641	0.1474	
S ₂	0.1474	0.2051	0.1667	0.1410	0.1744	0.1731	0.1560
L ₁₁ S ₁	0.0821	0.1179	0.1154	0.1103	0.1333	0.1385	
S ₂	0.0833	0.1026	0.0897	0.0967	0.1154	0.1090	0.1053
L ₁₂ S ₁	0.0897	0.1026	0.1026	0.0948	0.1205	0.1090	
S ₂	0.0910	0.1103	0.1026	0.0872	0.1179	0.1026	0.1024
L ₁₃ S ₁	0.1346	0.1795	0.1538	0.1462	0.1641	0.1667	
S ₂	0.0744	0.0821	0.0769	0.0731	0.0872	0.0961	0.1186
L ₁₄ S ₁	0.0885	0.1090	0.0897	0.0846	0.0948	0.1026	
S ₂	0.0603	0.0769	0.0641	0.0538	0.0718	0.0513	0.0801
L ₁₅ S ₁	0.0962	0.0769	0.0641	0.0641	0.0654	0.0641	
S ₂	0.0718	0.0846	0.0769	0.0615	0.0846	0.0769	0.0745
Mean	0.0827	0.0985	0.0889	0.0844	0.1026	0.0967	
		SEm ±	CD(0.05)				
For incubation period :		0.0048	0.0135				
For location :		0.0071	0.0199				

low exchangeable potassium there was not much change in the content throughout the entire incubation period.

4.3.1.3 HNO₃ soluble potassium

The data on the content of HNO₃ soluble potassium for the different incubation periods is given in Table 18. The result showed that this fraction was decreasing either in 15th or 45th day of incubation and there onwards it was increasing either in 60th or 75th days of incubation and this was significant compared to the initial level. At the end of the incubation period a decrease was noticed for this fraction compared to that in 75th day of incubation but it was significantly higher than the initial level. Soils with low content of initial potassium have a tendency to decrease after 45th day of incubation. For these samples a steep increase was noticed at 75th day whereas for soils with high content of initial potassium, maximum level was observed in 60th or 75th days of incubation. However for certain soils there was no linear change for this fraction throughout the incubation period.

4.3.2 Applied potassium

4.3.2.1 Water soluble potassium

The data on the content of water soluble potassium for the different incubation periods is given in Table 19. In L₁S₁, the water soluble form of potassium increased to a level of 0.0359 cmol(+) kg⁻¹ soil at 30th day and then it decreased. Maximum level was noticed in 60th day and there onwards it decreased. However at the end of the incubation period, the level was higher than the initial level. In L₁S₂ and L₂S₁ there was an increase in this fraction on 15th day of incubation, but generally there was a decreasing trend during the incubation period.

Table 18. HNO₃ soluble potassium at different periods of incubation in the untreated samples

Location	Days of incubation						Mean value for location
	15th	30th	45th (cmol(+) kg ⁻¹ soil)	60th	75th	90th	
L ₁ S ₁	0.1859	0.1859	0.2179	0.2308	0.2564	0.2949	
S ₂	0.3782	0.3269	0.3782	0.3333	0.5128	0.5448	0.3114
L ₂ S ₁	0.1026	0.1218	0.1026	0.1410	0.1603	0.1731	
S ₂	0.1603	0.1282	0.1538	0.1346	0.1923	0.1923	0.1433
L ₃ S ₁	0.2372	0.2308	0.1795	0.3205	0.3846	0.3077	
S ₂	0.2308	0.2115	0.2628	0.2756	0.3205	0.2821	0.2605
L ₄ S ₁	0.1923	0.3013	0.2308	0.3077	0.2885	0.2864	
S ₂	0.1474	0.1795	0.1859	0.2179	0.3205	0.2564	0.2276
L ₅ S ₁	0.2628	0.3077	0.3205	0.3205	0.3045	0.3590	
S ₂	0.1859	0.1987	0.2308	0.2179	0.2244	0.2692	0.2562
L ₆ S ₁	0.2115	0.2500	0.3013	0.2564	0.3205	0.2885	
S ₂	0.1859	0.2692	0.2051	0.1731	0.2885	0.3141	0.2436
L ₇ S ₁	0.2308	0.2115	0.1667	0.2179	0.2564	0.2372	
S ₂	0.1410	0.1410	0.2821	0.2051	0.2564	0.2756	0.2097
L ₈ S ₁	0.2949	0.2179	0.1987	0.3141	0.4327	0.3013	
S ₂	0.2949	0.3141	0.2628	0.3333	0.3205	0.2756	0.2905
L ₉ S ₁	0.2115	0.3077	0.3462	0.3718	0.3527	0.3462	
S ₂	0.1923	0.2308	0.2949	0.2756	0.3527	0.3782	0.2885
L ₁₀ S ₁	0.3462	0.3654	0.3974	0.3782	0.3846	0.5577	
S ₂	0.2885	0.2564	0.3782	0.4167	0.5447	0.4231	0.3800
L ₁₁ S ₁	0.2500	0.3077	0.3141	0.2756	0.3526	0.3526	
S ₂	0.1859	0.2692	0.3141	0.3590	0.2885	0.2885	0.2802
L ₁₂ S ₁	0.1795	0.1795	0.1859	0.3077	0.2724	0.3013	
S ₂	0.1538	0.2885	0.2500	0.1923	0.2244	0.2179	0.2182
L ₁₃ S ₁	0.2564	0.3013	0.4231	0.4359	0.5128	0.3526	
S ₂	0.1923	0.2756	0.3462	0.2885	0.4487	0.3013	0.3251
L ₁₄ S ₁	0.2244	0.3205	0.2949	0.3077	0.2564	0.3141	
S ₂	0.1603	0.2115	0.2051	0.2564	0.2885	0.2436	0.2454
L ₁₅ S ₁	0.2564	0.2548	0.2244	0.1987	0.2564	0.2564	
S ₂	0.2051	0.2564	0.2436	0.2372	0.2244	0.2564	0.2372
Mean	0.2182	0.2487	0.2633	0.2767	0.3199	0.3073	
		SEm ±	CD(0.05)				
For incubation period :		0.0104	0.0291				
For location :		0.0152	0.0426				

Table 19. Water soluble potassium at different periods of incubation in the treated samples

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Location	Days of incubation						Mean value for location
	15th	30th	45th	60th	75th	90th	
	(cmol(+) kg ⁻¹ soil)						
L ₁ S ₁	0.0346	0.0359	0.0333	0.0385	0.0282	0.0333	
S ₂	0.0410	0.0308	0.0282	0.0205	0.0333	0.0245	0.0310
L ₂ S ₁	0.0295	0.0282	0.0154	0.0231	0.0245	0.0231	
S ₂	0.0295	0.0333	0.0231	0.0256	0.0231	0.0192	0.0231
L ₃ S ₁	0.0346	0.0385	0.0372	0.0256	0.0282	0.0179	
S ₂	0.0269	0.0282	0.0231	0.0231	0.0269	0.0205	0.0258
L ₄ S ₁	0.0333	0.0321	0.0333	0.0282	0.0436	0.0385	
S ₂	0.0282	0.0333	0.0360	0.0308	0.0410	0.0372	0.0328
L ₅ S ₁	0.0385	0.0397	0.0436	0.0385	0.0603	0.0423	
S ₂	0.0282	0.0360	0.0360	0.0360	0.0397	0.0269	0.0369
L ₆ S ₁	0.0244	0.0282	0.0256	0.0231	0.0321	0.0256	
S ₂	0.0282	0.0346	0.0282	0.0205	0.0372	0.0308	0.0271
L ₇ S ₁	0.0231	0.0321	0.0256	0.0205	0.0244	0.0179	
S ₂	0.0346	0.0372	0.0372	0.0282	0.0333	0.0282	0.0266
L ₈ S ₁	0.0436	0.0436	0.0436	0.0333	0.0487	0.0359	
S ₂	0.0436	0.0436	0.0410	0.0385	0.0462	0.0462	0.0406
L ₉ S ₁	0.0269	0.0269	0.0282	0.0256	0.0360	0.0282	
S ₂	0.0205	0.0167	0.0154	0.0282	0.0244	0.0179	0.0238
L ₁₀ S ₁	0.0231	0.0244	0.0256	0.0231	0.0321	0.0244	
S ₂	0.0436	0.0590	0.0564	0.0512	0.0526	0.0410	0.0376
L ₁₁ S ₁	0.0333	0.0308	0.0256	0.0462	0.0295	0.0308	
S ₂	0.0269	0.0397	0.0360	0.0269	0.0308	0.0205	0.0302
L ₁₂ S ₁	0.0282	0.0269	0.0282	0.0231	0.0360	0.0231	
S ₂	0.0244	0.0244	0.0308	0.0154	0.0256	0.0205	0.0250
L ₁₃ S ₁	0.0282	0.0308	0.0256	0.0256	0.0346	0.0282	
S ₂	0.0308	0.0282	0.0256	0.0256	0.0282	0.0205	0.0270
L ₁₄ S ₁	0.0308	0.0321	0.0308	0.0256	0.0333	0.0256	
S ₂	0.0295	0.0321	0.0282	0.0256	0.0359	0.0282	0.0287
L ₁₅ S ₁	0.0667	0.0744	0.0590	0.0564	0.0641	0.0468	
S ₂	0.0225	0.0231	0.0256	0.0205	0.0218	0.0218	0.0409
Mean	0.0296	0.0342	0.0317	0.0291	0.0352	0.0282	
		SEm ±	CD(0.05)				
For incubation period :		0.0018	0.0050				
For location :		0.0026	0.0073				

For L_2S_2 , L_3S_1 and L_3S_2 maximum level was noticed at 30th day and then it decreased. But at the end of the incubation period it was higher than the initial level. In L_4S_1 and L_4S_2 it increased up to 45th day, then decreased, again followed an increase and a maximum level was attained at 75th day of incubation. In L_5 and L_6 it increased up to 30th day and then afterwards it decreased. After 75th day of incubation a value which is much higher than the initial level was noticed. In L_7S_1 maximum level was noticed in 30th day and then it decreased and at the end the content was $0.0179 \text{ cmol}(+) \text{ kg}^{-1}$ soil. In L_7S_2 up to 45th day it increased and then it decreased.

In L_8 it goes on increasing and attains a maximum value at 75th day of incubation. For L_9S_1 and L_9S_2 this fraction increased linearly. However the content was maximum on 75th day for S_1 ($0.0360 \text{ cmol}(+) \text{ kg}^{-1}$) and at 60th day for S_2 ($0.0282 \text{ cmol}(+) \text{ kg}^{-1}$). In $L_{10}S_1$ there was not much variation up to 60th day, but at the end of 75th day there was a slight increase. For $L_{10}S_2$ an increase was noticed from 30th day onwards, but at the end, the content was less than the initial level. In $L_{11}S_1$ this fraction showed an increase and maximum level of $0.0462 \text{ cmol}(+) \text{ kg}^{-1}$ was obtained at 60th day and then it decreased but it was in the 30th day for $L_{11}S_2$.

In $L_{12}S_1$ this fraction does not show much variation, but at 75th day there was an increase. In $L_{12}S_2$ up to 45th day there was an increase and then it decreased. In $L_{13}S_1$ it increased up to 30th day and afterwards it decreased. At the end of 75th day a level which was much higher than the initial level was noticed. For $L_{14}S_1$ and $L_{14}S_2$ it increased up to the 30th day and then decreased. But for $L_{14}S_2$ at 75th day of incubation the content was much higher than the initial level.

In $L_{15}S_1$ this fraction was increasing and attains a maximum value on 30th day of incubation and for $L_{15}S_2$ maximum value was obtained at 45th day of incubation.

Statistical analysis showed a significant increase in 15th and 30th days of incubation and thereafter a decrease in the 45th and 60th days of incubation, but it was non significant. Then a significant increase was noticed in 75th day followed by a significant decrease in 90th day of incubation. But the level at the end was significantly higher than the initial level. The variation in the level observed is attributed to the mineralogical composition of the soils, predominance of trioctahedral or dioctahedral structural units, development of wedge zones, expanded layers and amount of non-exchangeable potassium (Jessymol, 1991).

4.3.2.2 Exchangeable potassium (NH_4OAc extractable)

The data on the content of exchangeable potassium for the different incubation periods is given in Table 20. In L_1S_1 , the exchangeable K increases throughout the incubation period and maximum content was observed at the end, but for S_2 it increased to a value of $0.2051 \text{ cmol}(+) \text{ kg}^{-1}$ at 30th day of incubation and then decreased slowly and attains a value higher than the initial level. The same trend was observed for L_2 . For L_3S_1 and L_4S_1 it increased linearly throughout the incubation period and the level at the end was much higher than the initial level. But for L_3S_2 and L_4S_2 the maximum was recorded on 75th day of incubation. In L_5S_1 this fraction increased at the end of the incubation period and the maximum level was noticed in 30th day of incubation, but for S_2 only slight increase was noticed throughout the incubation period. In L_6S_1 and L_7S_1 it increased to a higher value at 30th day and then decreased and attains a value higher than the initial level. In L_6S_2 there was not much increase throughout the incubation period, while in L_7S_2

Table 20. Exchangeable potassium at different periods of incubation in the treated samples

Location	Days of incubation						Mean values for location
	15th	30th	45th	60th	75th	90th	
L ₁ S ₁	0.0859	0.1051	0.1026	0.1115	0.1128	0.1218	
S ₂	0.1795	0.2051	0.1795	0.1487	0.1692	0.1859	0.1370
L ₂ S ₁	0.0474	0.0718	0.0358	0.0590	0.0667	0.0705	
S ₂	0.0731	0.0846	0.0577	0.0744	0.0718	0.0769	0.0603
L ₃ S ₁	0.0974	0.1154	0.1346	0.1256	0.1333	0.1346	
S ₂	0.0885	0.1179	0.0897	0.1205	0.1231	0.1218	0.1114
L ₄ S ₁	0.1128	0.1346	0.1410	0.1077	0.1513	0.1667	
S ₂	0.0667	0.0949	0.0769	0.0897	0.1205	0.1026	0.1087
L ₅ S ₁	0.1333	0.1859	0.1538	0.1564	0.1564	0.1795	
S ₂	0.0808	0.1077	0.0897	0.0923	0.1026	0.1154	0.1242
L ₆ S ₁	0.0872	0.1231	0.1026	0.1051	0.1128	0.1026	
S ₂	0.0526	0.0872	0.0641	0.0846	0.0872	0.0962	0.0892
L ₇ S ₁	0.0718	0.1154	0.0769	0.0910	0.0974	0.0962	
S ₂	0.0590	0.0923	0.0641	0.0782	0.0821	0.0897	0.0796
L ₈ S ₁	0.1538	0.1602	0.1410	0.1308	0.1538	0.1538	
S ₂	0.0897	0.1179	0.0897	0.1103	0.1000	0.1282	0.1226
L ₉ S ₁	0.0974	0.1154	0.1282	0.1192	0.1282	0.1410	
S ₂	0.1244	0.1282	0.1282	0.1154	0.1487	0.1474	0.1212
L ₁₀ S ₁	0.1538	0.1795	0.1795	0.1717	0.1846	0.1859	
S ₂	0.1731	0.2051	0.2048	0.1949	0.1846	0.2051	0.1787
L ₁₁ S ₁	0.1282	0.1256	0.1474	0.1128	0.1487	0.1410	
S ₂	0.1179	0.1538	0.1410	0.1308	0.1487	0.1218	0.1284
L ₁₂ S ₁	0.1244	0.1410	0.1282	0.1128	0.1385	0.1410	
S ₂	0.1154	0.1282	0.1282	0.1308	0.1462	0.1474	0.1275
L ₁₃ S ₁	0.1667	0.1923	0.1923	0.1846	0.1946	0.1731	
S ₂	0.0872	0.1051	0.1026	0.0974	0.1051	0.1474	0.1410
L ₁₄ S ₁	0.1090	0.1538	0.1282	0.1333	0.1436	0.1474	
S ₂	0.0821	0.1179	0.1026	0.0936	0.1103	0.1026	0.1142
L ₁₅ S ₁	0.1064	0.1131	0.0897	0.1031	0.0923	0.1090	
S ₂	0.0795	0.1154	0.1154	0.1141	0.1077	0.1154	0.1013
Mean	0.1048	0.1298	0.1173	0.1167	0.1274	0.1323	
		SEm ±	CD(0.05)				
For incubation period :		0.0051	0.0143				
For location :		0.0074	0.0207				

an increase was noticed up to 45th day and afterwards it decreased, but at the end the content was higher than the initial level.

For L_8S_1 and L_8S_2 the exchangeable K increased throughout the incubation period and the maximum level was noticed on 30th day of incubation for S_1 . In L_9S_1 and $L_{10}S_1$ it increased throughout the incubation period and attained a much high value at the end. In $L_{10}S_1$ the increase was rapid and it increased to a level of $0.1538 \text{ cmol}(+) \text{ kg}^{-1}$ soil at the end of first fortnight. For L_9S_2 and $L_{10}S_2$ the maximum value was recorded at 75th day and 30th day of incubation respectively. In $L_{11}S_1$ it increased throughout the incubation period and maximum was recorded in 75th day. But for S_2 a higher value was obtained at 30th day and then decreased slowly.

In L_{12} for both the sites a linear increase was recorded throughout the incubation period. For both the sites of L_{13} , it increased throughout the incubation period and maximum was recorded on 75th day ($0.1946 \text{ cmol}(+) \text{ kg}^{-1}$ soil) and on 90th day ($0.1474 \text{ cmol}(+) \text{ kg}^{-1}$ soil) of incubation respectively. In L_{14} for both the sites, this fraction increased to a higher value on 30th day of incubation and then decreased slowly, but at the end the value was higher than the initial level. For both the sites of L_{15} this fraction attained maximum value on 30th day of incubation. From 45th day onwards a decreasing trend was observed for S_1 and no change for S_2 .

Statistical analysis showed that the increase observed at 30th and 75th day of incubation were highly significant and the decrease at 60th day of incubation was non significant. The maximum content was observed at the end of the incubation period but the increase was non significant compared to that in the 75th day of

incubation. The changes in exchangeable potassium observed at different incubation periods among the different sites may be attributed to the variations in the mineralogical composition of the soils (Datta and Sastry, 1985).

4.3.2.3 HNO₃ soluble potassium

The data on the content of HNO₃ soluble potassium for the different incubation periods is given in Table 21. In L₁S₁ there was an increase in this fraction throughout the incubation period while in L₁S₂ initially there was an increase and afterwards it decreased. For L₂S₁, L₃S₁ and L₃S₂ this fraction increased up to the end of 60th day of incubation and afterwards it decreased, but for L₂S₂ maximum level (0.2564 cmol(+) kg⁻¹ soil) was noticed at 75th day of incubation. In L₄S₁ an increasing trend was noticed up to 60th day of incubation and followed a decrease. However, at the end of 45th day it was less than that on 30th day. In L₄S₂ it increased throughout the incubation period and attained a maximum on 75th day of incubation.

For both the sites of L₅ this fraction was increasing up to 45th day and then it was decreasing. For L₆S₁ the content increased throughout the incubation period eventhough slight variation was observed and maximum value was obtained on 75th day of incubation. For L₆S₂ it increased up to the end of 30th day and then it showed a decreasing trend, but after 75th day of incubation it increased. In L₇S₁ and L₇S₂ it was increasing throughout the incubation period except on 75th day of incubation.

In L₈S₁ there was an increase at 30th day of incubation and afterwards it was decreasing up to 75th day of incubation. In L₈S₂ and L₉S₁ up to 60th day of

Table 21. HNO₃ soluble potassium at different periods of incubation in the treated samples

Location	Days of incubation						Mean values for location
	15th	30th	45th	60th	75th	90th	
L ₁ S ₁	0.2308	0.2308	0.2244	0.2436	0.2564	0.3141	
S ₂	0.4103	0.3718	0.4231	0.3269	0.4647	0.5641	0.3267
L ₂ S ₁	0.1346	0.0962	0.1667	0.2179	0.1923	0.1987	
S ₂	0.1731	0.1731	0.1923	0.1923	0.2564	0.2051	0.1745
L ₃ S ₁	0.3718	0.2885	0.3077	0.4231	0.4167	0.2855	
S ₂	0.3462	0.2756	0.2628	0.3333	0.2404	0.2821	0.3029
L ₄ S ₁	0.2244	0.3077	0.2115	0.3397	0.3045	0.2500	
S ₂	0.1474	0.1923	0.1538	0.3077	0.4487	0.3365	0.2518
L ₅ S ₁	0.2821	0.3141	0.3462	0.3269	0.2885	0.3141	
S ₂	0.1987	0.2179	0.2628	0.2308	0.2564	0.2115	0.2596
L ₆ S ₁	0.3077	0.3205	0.3526	0.2756	0.3846	0.3590	
S ₂	0.1859	0.3077	0.2179	0.2179	0.2404	0.2692	0.2704
L ₇ S ₁	0.2436	0.2436	0.2821	0.3333	0.2564	0.3718	
S ₂	0.2115	0.2244	0.3590	0.2372	0.2564	0.2949	0.2592
L ₈ S ₁	0.3141	0.2308	0.2821	0.3590	0.3846	0.2949	
S ₂	0.3077	0.2500	0.2885	0.3462	0.3205	0.3141	0.2999
L ₉ S ₁	0.2179	0.3526	0.3654	0.4615	0.3869	0.3333	
S ₂	0.1987	0.2692	0.3077	0.3846	0.5128	0.3392	0.3220
L ₁₀ S ₁	0.3782	0.3718	0.4167	0.4487	0.6410	0.6410	
S ₂	0.2244	0.2821	0.3846	0.6410	0.5769	0.3782	0.4263
L ₁₁ S ₁	0.2628	0.3205	0.4103	0.4615	0.3846	0.3910	
S ₂	0.2115	0.3013	0.3526	0.2949	0.2885	0.2244	0.3050
L ₁₂ S ₁	0.2372	0.2179	0.2372	0.3461	0.2564	0.3141	
S ₂	0.2115	0.2949	0.2885	0.2885	0.2436	0.2308	0.2477
L ₁₃ S ₁	0.2628	0.3397	0.4231	0.3333	0.3205	0.3846	
S ₂	0.2244	0.2885	0.3526	0.3782	0.4167	0.3205	0.3187
L ₁₄ S ₁	0.2564	0.3782	0.3205	0.3462	0.2885	0.2692	
S ₂	0.2115	0.2628	0.3333	0.4615	0.2564	0.2692	0.2862
L ₁₅ S ₁	0.3077	0.2948	0.2436	0.2821	0.2244	0.3205	
S ₂	0.2500	0.2564	0.3141	0.3077	0.2885	0.2628	0.2688
Mean	0.2515	0.2759	0.3028	0.3382	0.3351	0.3182	
	SEm ±	CD(0.05)					
For incubation period :	0.0119	0.0333					
For location :	0.0174	0.0488					

incubation there was an increasing trend and afterwards it was decreasing. But for L_9S_2 this fraction was increasing and maximum value of $0.5928 \text{ cmol}(+) \text{ kg}^{-1}$ was obtained on 75th days of incubation. In $L_{10}S_1$ it was increasing throughout the incubation period and the content was more or less the same on 75th and 90th day of incubation. For $L_{10}S_2$ initially there was a decrease and afterwards it was increasing and attained a maximum value on 60th day and then decreasing. Same trend was observed for $L_{11}S_1$. In $L_{11}S_2$ it was increasing and after 45th day of incubation it was decreasing.

There was no linear trend for $L_{12}S_1$ but for $L_{12}S_2$ initially there was an increase up to 30th day and afterwards it was decreasing. For $L_{13}S_1$ and $L_{13}S_2$ it was increasing up to 60th and 75th days of incubation respectively and afterwards it decreased. For $L_{14}S_1$ maximum value was obtained on 30th day and afterwards it was decreasing. At the end it was $0.2692 \text{ cmol}(+) \text{ kg}^{-1}$ which was less than that of the control, but was higher than the initial level. $L_{14}S_2$ showed an increasing trend throughout the incubation period and maximum was noticed at 60th day of incubation. In $L_{15}S_1$ it attained a maximum value on 15th day of incubation and afterwards no linear trend was noticed. In $L_{15}S_2$ there was an increasing trend up to 45th day of incubation and afterwards it decreased. For most of the sites this fraction of potassium attained a maximum value on 60th or 75th day of incubation except a few soils. Eventhough after 75th day there was a decreasing trend the final value was much higher than the initial.

Statistical analysis showed that the increase noticed on 60th day was significant whereas the decrease observed on 75th and 90th days were non significant. However the fixation of potassium increased with increase in the period of incubation (Ramanathan *et al.*, 1981).

It was observed that there was an increase in water soluble, exchangeable and HNO_3 soluble K fractions of potassium in these soils with K application eventhough some variation was noticed in their release throughout the incubation period. The same results were also observed by Jessymol and Mariam (1993) for laterite soils. The location which is having a lower value of initial water soluble K releases less of this fraction and those with high exchangeable and non exchangeable K releases higher content of both the fractions during the incubation period in the untreated samples. The slight increase noticed in one of the fraction may be attributed to a consequent decrease in other fractions.

In the treated samples there was a wide variation in the mean amount of the three fractions of K released from the different locations. The mean amount of the water soluble K released from the locations is in the increasing order of L₂, L₉, L₁₂, L₃, L₇, L₁₃, L₆, L₁₄, L₁₁, L₁, L₄, L₅, L₁₀, L₈ and L₁₅ (Table 19). L₅, L₁₀ and L₁₅ showed significant difference in the mean content of K released from other locations. This difference is due to the variation in the initial amount of water soluble K. The soils with high initial water soluble K showed a higher release during the incubation period. While considering the mean content of water soluble K released from L₁₀ and L₈ maximum amount of release was observed in L₈ eventhough a high initial content was observed in L₁₀.

Mean values of exchangeable K released from the K treated samples in the 15 locations were in the increasing order of L₂, L₇, L₆, L₁₅, L₄, L₃, L₁₄, L₉, L₈, L₅, L₁₂, L₁₁, L₁, L₁₃ and L₁₀ (Table 20). L₁₀ showed highly

significant difference in the K released from the other locations. L₂ showed highly significant variation in the mean amount of K release from other locations except from L₇. The high content of exchangeable K in L₁₀ is attributed to higher clay content and high cation exchange capacity of the clay fraction.

The mean values of HNO₃ soluble K released from different locations is in the increasing order of L₂, L₁₂, L₄, L₇, L₅, L₁₅, L₆, L₁₄, L₈, L₃, L₁, L₁₃, L₉, L₁₁ and L₁₀ (Table 21). L₁₀ showed highly significant difference in the mean amount of K released from other locations and this was attributed to the presence of K fixing minerals in the clay fraction.

On an average, the percentage increase of water soluble K over the initial content vary from 8.6 to 80.6 per cent. This was maximum for L₂ which is a sandy loam whereas the minimum increase was noticed in L₁₀ which is a clay soil. In the case of exchangeable K, the percentage increase over the initial content was maximum for L₂ for which the exchangeable K was very low since it is a sandy loam. It was observed that the percentage increase was less for those soils with high base saturation. Thus the percentage increase of both the water soluble and exchangeable potassium over the initial was minimum for L₁₀. The percentage increase in the HNO₃ soluble K vary from 18.4 to 70.3 per cent. The highest increase was attributed to the presence of K fixing minerals in the clay fraction. Among the 15 locations, L₁₀ was seen to be highly fertile as compared to the other locations and the soils has high retention capacity for potassium.

The mean values of water soluble, exchangeable and HNO_3 soluble fractions of potassium in the three villages at different periods of incubation are given in Tables 22, 23 and 24 respectively. The changes in the three fractions of potassium at different periods of incubation in Chittilappilly village is represented in Fig. 5 and that of Adat and Chalakkal villages are represented in Fig. 6 and 7. In all the three villages up to 30th day of incubation both water soluble and exchangeable K was increasing and there onwards no significant change was noticed for the next two fortnights in the K applied samples. However the maximum release was noticed on 75th day of incubation for the water soluble fraction and on 90th day for the exchangeable form. The HNO_3 soluble fraction of K goes on increasing up to 60th day of incubation and there afterwards it was decreasing. This fraction was maximum on 75th day of incubation in Chittilappilly and Adat villages and on 60th day for Chalakkal village. The variability in the K determining factors of the soil accounts for the slight differences observed in the recovery of the different forms of K in the three villages during the incubation period. So with the application of K fertilizer, the equilibrium was affected and the movement of potassium occurs towards the different forms so as to maintain the equilibrium.

4.4 Availability indices of potassium

In order to assess the K supplying power of the soils some of the chemical extraction methods have been tried and correlation studies have been worked out with the uptake of K by rice plants.

The extractants used were neutral 1N NH_4OAc , Mathews triacid, 0.01M CaCl_2 and 1N boiling HNO_3 and the results are presented in Table 25.

Table 22. Mean values of water soluble K at different periods of incubation in untreated and K treated soils of the three villages ($\text{cmol}(+) \text{kg}^{-1}$ soil)

Name of village	Level of potassium	Days of incubation					
		15th	30th	45th	60th	75th	90th
Chittilappilly	K ₀	0.0245	0.0242	0.0247	0.0203	0.0255	0.0200
	K ₁	0.0310	0.0334	0.0304	0.0273	0.0340	0.0276
Adat	K ₀	0.0239	0.0281	0.0247	0.0263	0.0317	0.0285
	K ₁	0.0327	0.0356	0.0340	0.0341	0.0375	0.0306
Chalakkal	K ₀	0.0271	0.0204	0.0228	0.0218	0.0242	0.0194
	K ₁	0.0326	0.0340	0.0317	0.0272	0.0349	0.0268

Table 23. Mean values of exchangeable K at different periods of incubation in the untreated and K treated soils of the three villages ($\text{cmol}(+) \text{kg}^{-1}$ soil)

Name of village	Levels of K	Periods of incubation					
		15th	30th	45th	60th	75th	90th
Chittilappilly	K ₀	0.0675	0.0799	0.0769	0.0717	0.0881	0.0801
	K ₁	0.0883	0.1172	0.0980	0.1032	0.1134	0.1186
Adat	K ₀	0.1037	0.1269	0.1074	0.1078	0.1298	0.1263
	K ₁	0.1298	0.1482	0.1450	0.1357	0.1497	0.1530
Chalakkal	K ₀	0.0883	0.1027	0.0913	0.0832	0.1008	0.0962
	K ₁	0.1088	0.1334	0.1234	0.1212	0.1298	0.1354

Table 24. Mean values of HNO_3 soluble K at different periods of incubation in the untreated and treated soils of the three villages ($\text{cmol}(+) \text{kg}^{-1}$ soil)

Name of village	Levels of potassium	Days of incubation					
		15th	30th	45th	60th	75th	90th
Chittilappilly	K_0	0.2038	0.2189	0.2299	0.2395	0.2395	0.2894
	K_1	0.2477	0.2546	0.2688	0.2862	0.3045	0.3043
Adat	K_0	0.2580	0.2837	0.3133	0.3405	0.3786	0.3654
	K_1	0.2644	0.2973	0.3510	0.4247	0.4370	0.3645
Chalakkal	K_0	0.2035	0.2660	0.2717	0.2781	0.3105	0.2805
	K_1	0.2452	0.2917	0.3141	0.3430	0.2869	0.2965

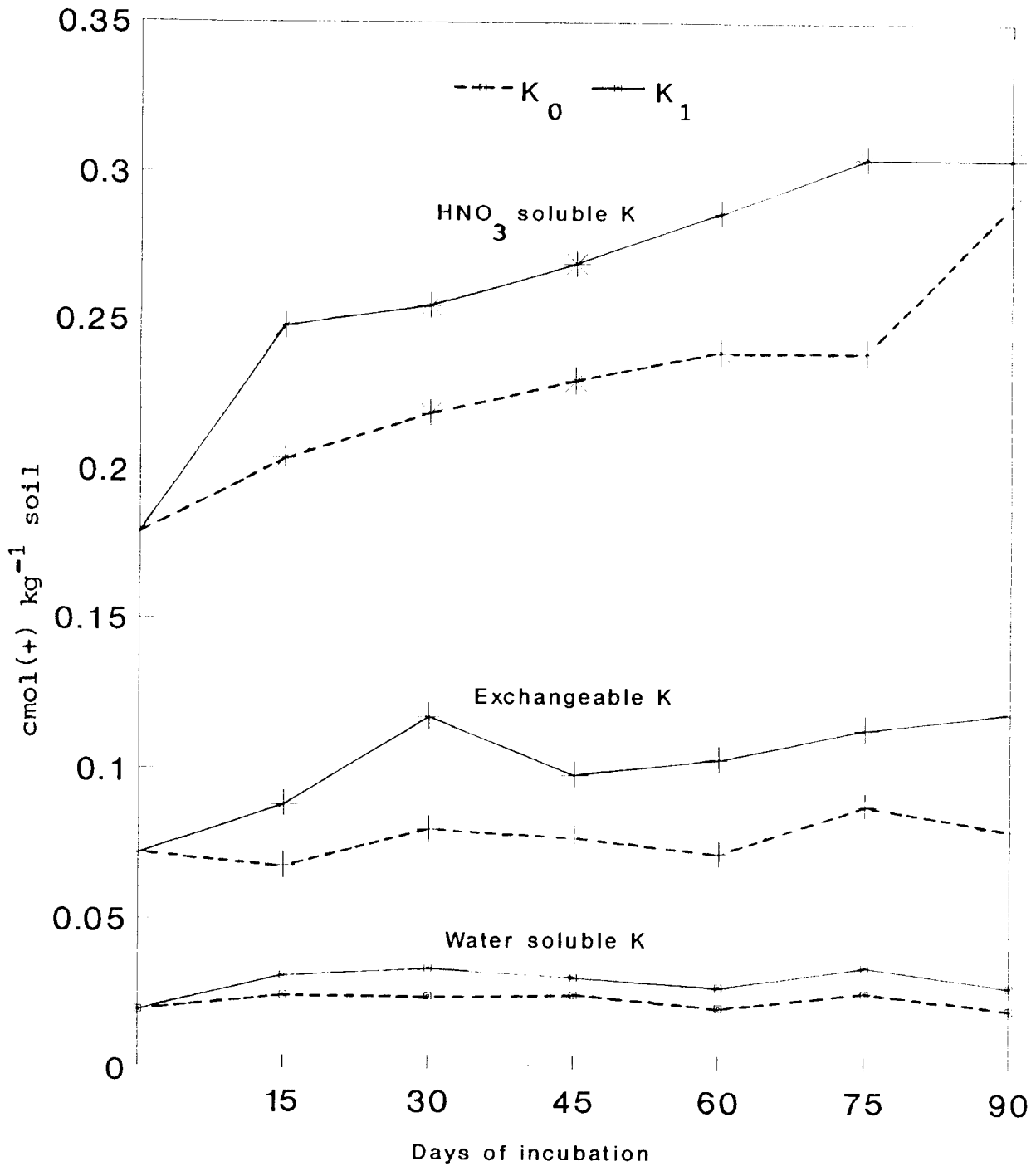


Fig.5. Water soluble, exchangeable and nitric acid soluble potassium at different periods of incubation in Chittilappilly village

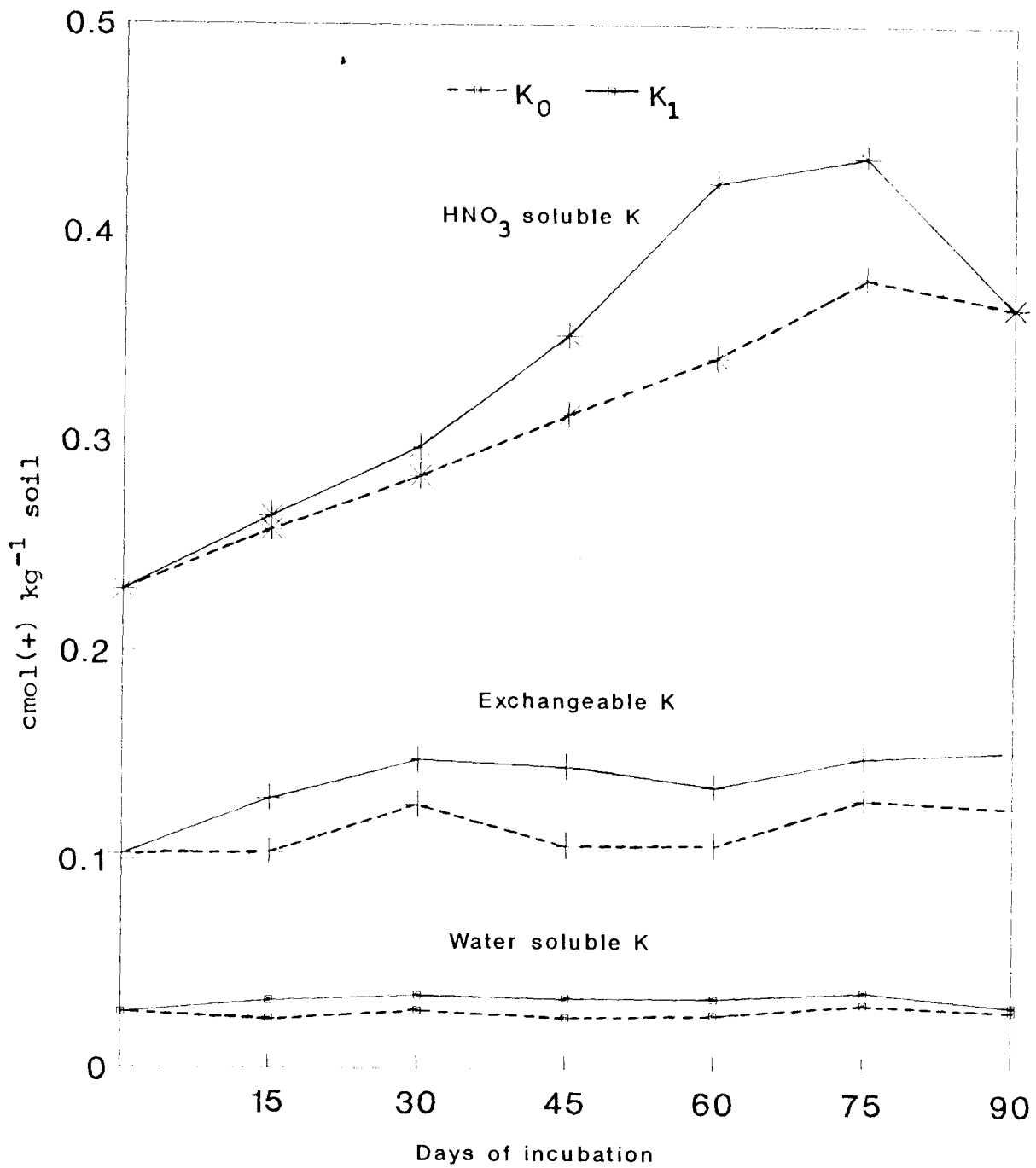


Fig.6. Water soluble, exchangeable and nitric acid soluble potassium at different periods of incubation in Adat village

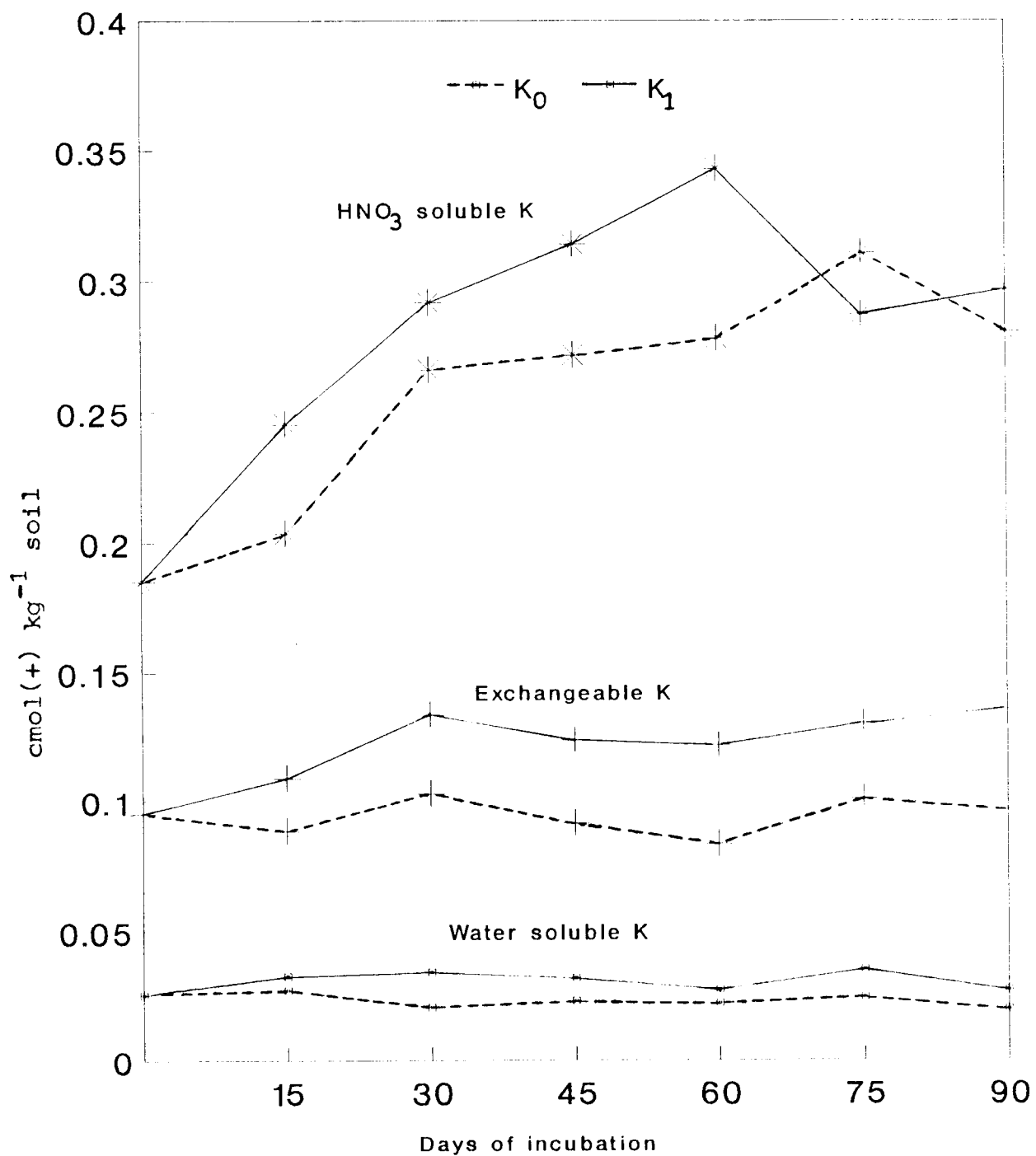


Fig.7. Water soluble, exchangeable and nitric acid soluble potassium at different periods of incubation in Chalakkal village

Table 25. Potassium extracted by the different extractants from the surface and subsurface soils (cmol(+) kg⁻¹ soil)

Location	Depth (cm)	1N NH ₄ OAC	Mathew's triacid	0.01M CaCl ₂	1M HNO ₃
		(a)	(b)	(c)	(d)
L ₁ S ₁	0-20	0.0769	0.0667	0.0449	0.1795
	20-40	0.1154	0.0872	0.0449	0.2436
L ₁ S ₂	0-20	0.1333	0.0974	0.0646	0.3333
	20-40	0.1385	0.0872	0.0431	0.3641
L ₂ S ₁	0-20	0.0205	0.0256	0.0215	0.1026
	20-40	0.0308	0.0308	0.0179	0.1205
L ₂ S ₂	0-20	0.0308	0.0308	0.0251	0.1410
	20-40	0.0385	0.0308	0.0287	0.1538
L ₃ S ₁	0-20	0.0821	0.0821	0.0431	0.2051
	20-40	0.0462	0.0359	0.0287	0.1410
L ₃ S ₂	0-20	0.0744	0.0667	0.0431	0.1987
	20-40	0.0795	0.0667	0.0377	0.1667
L ₄ S ₁	0-20	0.0949	0.0718	0.0503	0.1667
	20-40	0.0615	0.0410	0.1359	0.1603
L ₄ S ₂	0-20	0.0615	0.0513	0.0359	0.1346
	20-40	0.0667	0.0718	0.0359	0.1538
L ₅ S ₁	0-20	0.1103	0.0923	0.0646	0.2308
	20-40	0.1282	0.0923	0.0718	0.2500
L ₅ S ₂	0-20	0.0744	0.0667	0.0431	0.1538
	20-40	0.0718	0.0821	0.0574	0.1987
L ₆ S ₁	0-20	0.0821	0.0667	0.0431	0.1987
	20-40	0.0590	0.0359	0.0287	0.1538
L ₆ S ₂	0-20	0.0615	0.0564	0.0395	0.1474
	20-40	0.0359	0.0308	0.0144	0.1474
L ₇ S ₁	0-20	0.0590	0.0615	0.0377	0.1859
	20-40	0.0410	0.0308	0.0287	0.1346
L ₇ S ₂	0-20	0.0462	0.0410	0.0377	0.1282
	20-40	0.0244	0.0256	0.0215	0.1154
L ₈ S ₁	0-20	0.1154	0.1077	0.0662	0.2564
	20-40	0.1000	0.0769	0.0431	0.1731

Cont.

Table 25. Continued

		(a)	(b)	(c)	(d)
L ₈ S ₂	0-20	0.0718	0.0615	0.0359	0.2500
	20-40	0.0615	0.0513	0.0359	0.2051
L ₉ S ₁	0-20	0.0821	0.0821	0.0503	0.2051
	20-40	0.1333	0.1128	0.0933	0.3397
L ₉ S ₂	0-20	0.0923	0.0769	0.0538	0.1731
	20-40	0.0821	0.0667	0.0467	0.1731
L ₁₀ S ₁	0-20	0.1154	0.0974	0.0610	0.3269
	20-40	0.0846	0.0564	0.0359	0.2308
L ₁₀ S ₂	0-20	0.1641	0.1590	0.0826	0.2564
	20-40	0.1103	0.0923	0.0646	0.2821
L ₁₁ S ₁	0-20	0.0872	0.0769	0.0574	0.1987
	20-40	0.0641	0.0462	0.0287	0.1538
L ₁₁ S ₂	0-20	0.0923	0.0769	0.0574	0.1667
	20-40	0.0615	0.0462	0.0323	0.1538
L ₁₂ S ₁	0-20	0.1026	0.1026	0.0646	0.1603
	20-40	0.0359	0.0308	0.0251	0.1410
L ₁₂ S ₂	0-20	1.0000	0.0769	0.0467	0.1410
	20-40	0.1256	0.1128	0.0826	0.3782
L ₁₃ S ₁	0-20	0.1436	0.1436	0.0790	0.2372
	20-40	0.1436	0.1231	0.0897	0.3462
L ₁₃ S ₂	0-20	0.0821	0.0769	0.0503	0.1795
	20-40	0.0538	0.0462	0.0323	0.1731
L ₁₄ S ₁	0-20	0.1026	0.0923	0.0556	0.2115
	20-40	0.0718	0.0513	0.0305	0.2308
L ₁₄ S ₂	0-20	0.0718	0.0615	0.0431	0.1410
	20-40	0.0615	0.0513	0.0323	0.1538
L ₁₅ S ₁	0-20	0.0897	0.0821	0.0574	0.2308
	20-40	0.0231	0.0205	0.0179	0.1154
L ₁₅ S ₂	0-20	0.0667	0.0564	0.0431	0.1795
	20-40	0.1282	0.0923	0.0503	0.3333
Mean	0-20	0.0863	0.0769	0.0499	0.1938
	20-40	0.0759	0.0609	0.0412	0.2029

4.4.1 Neutral 1N NH₄OAc

The potassium extracted by neutral 1N NH₄OAc include exchangeable and water soluble fraction. It varied from 0.0205 cmol(+) kg⁻¹ to 0.1641 cmol(+) kg⁻¹ soil in the surface and the maximum was obtained for L₁₀S₂ and the minimum was obtained for L₂S₁. In the subsurface it varied from 0.0231 to 0.1436 cmol(+) kg⁻¹ soil and the maximum was obtained for L₁₃S₁ and the minimum was obtained for L₁₅S₁. It is seen that the 1N NH₄OAc extracted K decreased with depth (L₃S₁, L₁₂S₁). The average value of K extracted by this extractant for the surface and subsurface was 0.0863 cmol(+) kg⁻¹ soil and 0.0759 cmol(+) kg⁻¹ soil respectively.

4.4.2 Mathew's triacid

The potassium extracted by Mathew's triacid varied from 0.0256 cmol(+) kg⁻¹ soil (L₂S₁) to 0.1590 cmol(+) kg⁻¹ soil (L₁₀S₂) in the surface. In the subsurface it varied from 0.0256 cmol(+) kg⁻¹ soil (L₇S₂) to 0.1231 cmol(+) kg⁻¹ soil (L₁₃S₁). The amount of K extracted by this extractant is slightly less than that extracted by 1N NH₄OAc and the amount decreased with depth. The average value of K extracted by this extractant was 0.0769 cmol(+) kg⁻¹ soil for surface and 0.0609 cmol(+) kg⁻¹ soil for the subsurface.

4.4.3 0.01 M CaCl₂

The amount of potassium extracted by this extractant was minimum compared to that extracted by others in all the locations. In the surface the K extracted by this extractant varied from 0.0215 cmol(+) kg⁻¹ soil to 0.0826

cmol(+) kg⁻¹ soil. The minimum was recorded by L₂S₁ and maximum by L₁₀S₂. In the subsurface the minimum value of 0.0144 cmol(+) kg⁻¹ soil was obtained for L₆S₂ and the maximum value of 0.0933 cmol(+) kg⁻¹ soil was obtained for L₉S₁. The average value of K extracted by this extractant was 0.0499 cmol(+) kg⁻¹ soil for surface and 0.0412 cmol(+) kg⁻¹ soil for the subsurface.

4.4.4 1N boiling HNO₃

This extractant is usually used to calculate the fixed K by subtracting the sum of exchangeable and water soluble K from the K extracted by this method. The amount of K extracted by this extractant varied from 0.1026 cmol(+) kg⁻¹ soil to 0.3333 cmol(+) kg⁻¹ soil for the surface. The minimum amount was obtained for L₂S₁ while maximum was obtained for L₁S₂. In the subsurface it ranges from 0.1154 cmol(+) kg⁻¹ soil to 0.3782 cmol(+) kg⁻¹ soil. The minimum content was recorded by L₇S₂ and L₁₅S₁ while maximum was obtained for L₁₂S₂. The average value of K extracted by this extractant was 0.1938 cmol(+) kg⁻¹ soil for the surface and 0.2029 cmol(+) kg⁻¹ soil for the subsurface.

The results showed that the quantity of potassium solubilised by the different extractants decreased in the following order: 1N HNO₃ > 1N NH₄OAc > Mathew's triacid > 0.01 M CaCl₂, both in the surface and in the subsurface. The order of K extracting capacity of the extractants as found in the present study is in conformity with the findings of Bolan and Ramulu (1980); Nath and Purkaystha (1988).

The boiling HNO₃ soluble K recorded the highest value among all the extractants because in addition to exchangeable K some of the non exchangeable K

is also brought into solution by the breakdown of primary and secondary minerals (Ram and Prasad, 1983). The average value for ammonium acetate K was higher than that extracted with Mathew's triacid and 0.01 M CaCl₂. This shows that ammonium ions is having the maximum replacing capacity for the absorbed potassium in the soil complex due to its smaller ionic size. Among the extractants boiling HNO₃ extracted maximum K for all the locations followed by neutral 1N NH₄OAc and Mathew's triacid.

4.4.5 Biological method for determining available potassium

Laboratory techniques can give a fair idea of the relative availability of different fractions of soil potassium. However, the biological technique gives the best assessment of the available potassium in soil.

Among the biological methods Neubauer technique allows for a rapid measurement of the nutrient supplying capacity of a large number of soils. Neubauer experiment was under taken to examine the short term absorption of potassium by rice and to correlate it with conventional estimates of K availability. The mean dry matter yield and the K uptake by rice plants were presented in Table 26.

The mean dry matter yield ranged from 1.421 g/pot in L₂S₂ to 1.644 g/pot in L₁₀S₁ in the surface layer. In the subsurface the minimum value of 1.458 g/pot was recorded by L₆S₁ and maximum value of 1.85 g/pot was recorded by L₁₃S₁. The higher dry matter production of certain samples may be attributed to larger amounts of ammonium acetate and HNO₃ extractable potassium in these soils (Sharma and Sekhon, 1992). The mean K uptake by the rice plants varied from

Table 26. Mean dry weight and uptake of K by rice grown in the surface and subsurface soils

Location	Surface		Subsurface	
	Dry wt. (g) soil	K uptake mg/100 g	Dry wt. (g) soil	K uptake mg/100 g
L ₁ S ₁	1.480	8.46	1.490	8.92
S ₂	1.609	9.57	1.613	9.90
L ₂ S ₁	1.432	7.65	1.589	7.70
S ₂	1.421	7.88	1.514	7.65
L ₃ S ₁	1.483	9.34	1.567	7.99
S ₂	1.547	9.12	1.655	9.09
L ₄ S ₁	1.563	8.85	1.536	8.25
S ₂	1.509	8.24	1.542	8.56
L ₅ S ₁	1.614	9.35	1.593	9.52
S ₂	1.438	8.56	1.600	8.77
L ₆ S ₁	1.569	9.25	1.458	8.47
S ₂	1.561	8.24	1.481	8.17
L ₇ S ₁	1.579	8.62	1.622	8.30
S ₂	1.441	7.97	1.524	7.39
L ₈ S ₁	1.584	8.95	1.733	9.12
S ₂	1.636	8.35	1.493	8.53
L ₉ S ₁	1.577	8.68	1.678	9.72
S ₂	1.581	9.22	1.621	8.96
L ₁₀ S ₁	1.644	9.39	1.679	8.63
S ₂	1.459	10.69	1.584	9.48
L ₁₁ S ₁	1.451	9.21	1.638	8.86
S ₂	1.626	9.35	1.607	8.66
L ₁₂ S ₁	1.569	9.22	1.494	7.96
S ₂	1.640	8.94	1.641	9.39
L ₁₃ S ₁	1.485	9.93	1.850	10.13
S ₂	1.527	8.54	1.582	8.60
L ₁₄ S ₁	1.591	9.73	1.743	8.57
S ₂	1.422	8.46	1.668	8.53
L ₁₅ S ₁	1.595	9.04	1.474	7.23
S ₂	1.589	8.53	1.619	9.79

7.65 mg/100 g soil (L₂S₁) to 10.69 mg/100 g soil (L₁₀S₂) in surface. In the subsurface the maximum uptake of 10.13 mg/100 g soil was obtained for L₁₃S₁ and the minimum uptake of 7.23 mg/100 g soil was obtained for L₁₅S₁. Soils having the medium base saturation recorded higher value for the K uptake by the rice crop.

4.4.6 Relationship between K extracted by the extractants and K uptake by rice

The coefficient of simple linear correlation (r) between the K extracted by the different chemical extractants and K uptake by rice crop was given in Appendix IV.

Significant positive correlations were obtained by all extractants both in surface and subsurface with K uptake by rice plants. However highest correlation was observed for NH₄OAc extractable K both for the surface and subsurface samples. The correlation coefficient decreased in the order : 1N NH₄OAc > Mathew's triacid > 0.01 M CaCl₂ > 1N HNO₃, for surface. For the subsurface it was 1N NH₄OAc > Mathew's triacid > 1N HNO₃ > 0.01 M CaCl₂. This is in conformity with the results obtained by Singh and Ghosh (1982) and Islam *et al.* (1994).

Potassium extracted by each of these extractants was also correlated positively and significantly to each other. Highly significant correlation between some of the methods further suggests that these are equally effective testing procedures for the present group of soils under study and particular mention is made for suitability of the widely used ammonium acetate as the extractant for available potassium.

Summary

SUMMARY

In the present investigation, attempt has been made to evaluate the chemical nature, distribution, fixation and availability of potassium in the soils of *kole* lands. Soil samples were collected from 15 locations in Chathan *kole* - Puppilakkad *kole* area of Trichur district. Seven locations were identified in Chittilappilly village and four each in Adat and Chalakkal villages. Surface (0-20 cm) and subsurface (20-40 cm) soil samples were collected from two sites of each location and were analysed for all the physico-chemical characteristics related to potassium availability. A retention study was carried out by applying potassium in water soluble form and extracting the potassium after shaking it for different time. In order to find out the transformations of applied potassium, a laboratory incubation experiment was carried out in the surface soil for a period of three months. To find out the most suitable extractant for available potassium chemical extractants were tried and its correlation with K uptake by rice in Neubauer experiment was carried out.

The salient findings are summarised below.

1. Wide variation was noticed in the particle size distribution of the soils in the three villages. The coarse sand fraction showed wide range in Chittilappilly village and varied from 2.71 to 75.6 per cent in the surface. The clay content showed a high variation in Adat village and it ranged from 17.71 to 81.1 per cent in the surface and from 20.26 to 84.47 per cent in the subsurface. The soils were mostly grouped under the textural class clay and sandy clay loam.

2. The physical constants were showing variations depending on the clay content and organic carbon.
3. All the soils were acidic in reaction and showed lower pH and electrical conductivity values in the subsurface.
4. In general the surface soils had high organic matter content except a few which showed a higher content in the subsurface.
5. The cation exchange capacity of the soils were low and it showed a range of 3.3 to 10.5 $\text{cmol}(+) \text{kg}^{-1}$ in surface and 3.8 to 12.8 $\text{cmol}(+) \text{kg}^{-1}$ in subsurface soils of Chittilappilly village.
6. The total reserves of nitrogen, phosphorus and potassium were relatively low.
7. The total potassium content showed a significant positive correlation with clay content, organic carbon and CEC.
8. Available nitrogen and phosphorus content showed wide variation from low to high values.
9. Available potassium content of the soils were generally low. It varied from 17.92 to 143.36 kg ha^{-1} in surface and from 20.16 to 125.44 kg ha^{-1} in the subsurface soils of chalakkal village.
10. Calcium and magnesium predominated among the exchangeable bases and exchangeable Ca decreased with depth while exchangeable Mg showed no such trend. Mostly, the soils were medium in percentage base saturation.

11. The potassium fixing capacity of the soils were low and it was less than 20 per cent. Potassium fixing capacity was positively correlated with clay, silt and CEC and negatively correlated with coarse sand and fine sand contents of the soil.
12. The water soluble potassium was low and constituted less than 1 per cent of the total potassium content.
13. The content of ammonium acetate extractable potassium varied from 0.0205 to 0.1333 $\text{cmol}(+) \text{kg}^{-1}$ in surface and from 0.0308 to 0.1282 $\text{cmol}(+) \text{kg}^{-1}$ in the subsurface soils of chittilappilly village. In Adat and Chalakkal villages it varied from 0.0718 to 0.1614 $\text{cmol}(+) \text{kg}^{-1}$ and 0.0667 to 0.1436 $\text{cmol}(+) \text{kg}^{-1}$ in surface soils and from 0.0615 to 0.1333 $\text{cmol}(+) \text{kg}^{-1}$ and 0.0231 to 0.1436 $\text{cmol}(+) \text{kg}^{-1}$ in the subsurface soil. On an average, it constituted 2.5 per cent of total K in the surface and 1.8 per cent in the subsurface.
14. HNO_3 soluble potassium constituted 5.6 per cent of total potassium in surface and 4.7 per cent in the subsurface.
15. Exchangeable K was significantly and positively correlated with clay content and cation exchange capacity of the soil and thus the distribution of exchangeable potassium is largely regulated by the fineness of texture of soil.
16. Nitric acid soluble potassium showed positive correlation with clay content and cation exchange capacity of the soil.

17. Water soluble, exchangeable and HNO_3 soluble potassium showed significant positive correlation with each other. Except the water soluble form, the other two are positively correlated with total potassium.
18. Potassium retention capacity of the soils depend on percentage of clay, cation exchange capacity and potassium saturation capacity of the soil. The retention of potassium was higher in the soils of Adat village.
19. From retention experiment it was found that in soils with low potassium saturation capacity, maximum amount of potassium will be retained with short period of shaking while it takes more time for soils with high potassium saturation.
20. From incubation experiment it was found that water soluble, exchangeable and HNO_3 soluble forms of potassium got increased at the end of three months. Wide fluctuations were noticed for these fractions during the incubation period.
21. In all the three villages up to 30th day of incubation both the water soluble and exchangeable K were increasing and there onwards no significant change was noticed for the next two fortnights with K application. However, the maximum release was noticed on 75th day of incubation for the water soluble fraction and on 90th day for the exchangeable form. The non exchangeable K was increasing up to 60th day of incubation and there afterwards it was decreasing. This fraction was maximum on 75th day of incubation in Chittilappilly and Adat villages and on 60th day for Chalakkal village.
22. NH_4OAc extracted higher amount of potassium from the soils compared to Mathew's extractant and $0.01M \text{CaCl}_2$.

23. 1N NH₄OAc-K, Mathew's extractant-K, 0.01M CaCl₂-K and 1N HNO₃-K gave significant positive correlation with K uptake by rice as test crop and the highest correlation was obtained with NH₄OAc-K.

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* Originals not seen

Appendices

APPENDIX-I

Correlation coefficient (r) of the different forms of potassium with soil properties in the surface

	Clay	Coarse sand	Fine sand	Silt	CEC	Organic carbon	pH	K fixing capacity	Total K	Water soluble	Exchan-geable K	HNO ₃ K
	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000											
2	-0.943**	1.000										
3	-0.613**	0.540**	1.000									
4	-0.128	-0.165	-0.187	1.000								
5	0.883**	-0.880**	-0.481**	0.002	1.000							
6	0.912**	0.870**	-0.434**	-0.162	0.877**	1.000						
7	-0.366*	0.378*	-0.066	0.137	-0.228	-0.367*	1.000					
8	0.126	-0.158	-0.175	0.161	0.177	0.142	0.404*	1.000				
9	0.659**	-0.627	-0.420*	-0.075	0.558**	0.519**	-0.179	-0.034	1.000			
10	0.155	-0.249	-0.170	0.256	0.005	0.006	0.020	-0.238	0.278	1.000		
11	0.698**	-0.717	-0.414*	0.084	0.671**	0.570**	0.277	0.004	0.627**	0.554**	1.000	
12	0.487**	0.556**	0.506**	0.317	0.448**	0.281	0.020	0.111	0.690**	0.513**	0.714**	1.000

* Significant at 5 % level

** Significant at 1 % level

APPENDIX-II

Coefficient of simple linear correlation (r) of the different forms of potassium with soil properties in the subsurface

	Clay	Coarse sand	Fine sand	Silt	CEC	Organic carbon	pH	K fixing capacity	Total K	Water soluble	Exchan-geable K	HNO ₃ K
	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000											
2	-0.909**	1.000										
3	-0.092	0.021	1.000									
4	0.103	-0.442*	0.348	1.000								
5	0.576**	-0.436*	-0.432*	-0.074	1.000							
6	0.476**	-0.406*	-0.076	-0.029	0.514**	1.000						
7	0.109	-0.004	-0.179	-0.183	-0.114	-0.148	1.000					
8	0.401*	-0.005	-0.189	-0.117	0.116	0.035	-0.050	1.000				
9	0.906**	-0.929**	-0.074	0.361*	0.532**	0.538**	-0.057	0.239	1.000			
10	0.067	-0.323	0.421*	0.459*	-0.208	0.145	-0.350	0.133	0.237	1.000		
11	0.658**	-0.768**	0.298	0.390*	0.371*	0.322	-0.005	0.263	0.725**	0.515**	1.000	
12	0.593**	-0.629**	0.284	0.161	0.307	0.239	0.009	0.260	0.622**	0.431*	0.912**	1.000

* Significant at 5 % level

** Significant at 1 % level

APPENDIX-III

Coefficient of simple linear correlation (r) between some soil properties
in surface and subsurface soils

Sl. No.	Soil characteristics		(r) values	
	X	Y	Surface	Subsurface
(a)	(b)	(c)	(d)	(e)
1.	Bulk density	Clay	-0.702**	-0.746**
2.	Particle density	Clay	-0.440*	-0.630**
3.	Water holding capacity	Clay	0.736**	0.813**
4.	Total N	Clay	0.788**	0.816**
5.	Total N	Cation exchange capacity	0.826**	0.427*
6.	Total N	Available N	0.480**	0.492**
7.	Total N	Organic carbon	0.762**	0.420**
8.	Total P	Organic carbon	0.672**	0.420*
9.	Available N	Organic carbon	0.471**	0.069
10.	Available P	pH	0.528**	0.439*
11.	Exchangeable Ca	Water soluble K	0.107	0.017
12.	Exchangeable Mg	Water soluble K	-0.054	0.027
13.	Exchangeable Na	Water soluble K	0.029	0.295
14.	Exchangeable Ca	Exchangeable K	0.666**	0.617
15.	Exchangeable Mg	Exchangeable K	0.155	0.329

(a)	(b)	(c)	(d)	(e)
16.	Exchangeable Na	Exchangeable K	0.477**	0.553**
17.	Exchangeable Ca	HNO ₃ K	0.532**	0.533**
18.	Exchangeable Mg	HNO ₃ K	0.393*	0.313
17.	Exchangeable Na	HNO ₃ K	0.441*	0.592**
18.	Exchangeable Ca	Total K	0.493**	0.827**
19.	Exchangeable Mg	Total K	0.503**	0.658**
20.	Exchangeable Na	Total K	0.688**	0.681**

*Significant at 5% level

** Significant at 1% level

APPENDIX-IV

Coefficient of simple linear correlation (r) between the amount of K extracted by the various extractants and the K uptake by rice in Neubauer experiment

Surface

	1N NH ₄ OAc (1)	Mathew triacid (2)	0.01M CaCl ₂ (3)	1N HNO ₃ (4)	K uptake (5)
1	1.000				
2	0.961**	1.000			
3	0.958**	0.950**	1.000		
4	0.702**	0.650**	0.640**	1.000	
5	0.909**	0.897**	0.872**	0.640**	1.000

Subsurface

	1N NH ₄ OAc (1)	Mathew triacid (2)	0.01M CaCl ₂ (3)	1N HNO ₃ (4)	K uptake (5)
1	1.000				
2	0.949**	1.000			
3	0.852**	0.928**	1.000		
4	0.913**	0.879**	0.819**	1.000	
5	0.948**	0.908**	0.852**	0.846**	1.000

** Significant at 1% level

DYNAMICS OF POTASSIUM IN THE SOIL OF KOLE LANDS

BY

K. N. JYOTHIKUMARI

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture

KERALA AGRICULTURAL UNIVERSITY

Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR

KERALA, INDIA

1996

ABSTRACT

In the present investigation, attempt has been made to evaluate the chemical nature, distribution, fixation and availability of potassium in the soils of *kole* lands. Soil samples were collected from 15 locations in Chathan *kole* - Puppilakkad *kole* area, seven from Chittilappilly village and four each from Adat and Chalakkal villages. In each location, from two nearby plots both surface (0-20 cm) and subsurface (20-40 cm) soil samples were collected and were analysed for the physico-chemical characteristics related to potassium availability.

A retention study and a laboratory incubation experiment of three month duration was carried out in order to find out the level of retention and transformation of applied potassium. In order to find out the most suitable extractant for assessing the available potassium in these soils, different chemical extractants were tried and its correlation with K uptake by rice in Neubauer experiment was carried out.

The soils collected from the three villages showed wide variation in the particle size distribution and majority of them were grouped under the textural class clay and sandy clay loam. The single value constants were showing variations depending on the clay content and organic carbon.

Soils were generally acidic in reaction. Organic carbon content varied among the samples and for certain sites subsurface accounts higher value. The total reserves of nitrogen, phosphorus and potassium were relatively low. Total potassium showed significant positive correlation with clay content, organic carbon and cation exchange capacity.

Water soluble, exchangeable and HNO_3 soluble forms of potassium were low in these soils. These forms of potassium showed significant positive correlation with each other and also with total K except for water soluble fraction.

From the retention study it was found that in soils with high saturation capacity the retention capacity is low and hence longer duration of time is essential for maximum retention. From incubation experiment it was found that on application of potassium fertilizer, the different fractions viz., water soluble, ammonium acetate extractable and nitric acid soluble potassium got increased at the end of the incubation period although fluctuations were noticed in all the fractions during this period.

1N NH_4OAc extracted higher amount of potassium compared to Mathew's extractant and 0.01M CaCl_2 . The potassium extracted by these extractants and 1N HNO_3 -K were positively and significantly correlated with K uptake by rice in Neubauer experiment. Among all the four extractants maximum correlation was obtained for 1N NH_4OAc .