

**DYNAMICS OF POTASSIUM IN SOILS OF SELECTED  
AGRO-CLIMATIC ZONES OF KARNATAKA**

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**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY  
UNIVERSITY OF AGRICULTURAL SCIENCES  
BANGALORE  
2003**

**DYNAMICS OF POTASSIUM IN SOILS OF SELECTED  
AGRO-CLIMATIC ZONES OF KARNATAKA**

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Thesis submitted to the  
**UNIVERSITY OF AGRICULTURAL SCIENCES  
BANGALORE**

in partial fulfillment of the requirements  
for the award of the Degree of

**Doctor of Philosophy**

**IN**

**SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

**BANGALORE**

**SEPTEMBER, 2003**


*Affectionately Dedicated to*  
*My*  
*Beloved Parents, and*  
*CHAIRMAN*

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY  
UNIVERSITY OF AGRICULTURAL SCIENCES  
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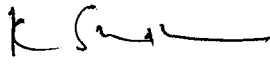
This is to certify that the thesis entitled “DYNAMICS OF POTASSIUM IN SOILS OF SELECTED AGRO-CLIMATIC ZONES OF KARNATAKA” submitted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Soil Science and Agricultural Chemistry to the University of Agricultural Sciences, Bangalore, is a record of research work carried out by JAGADEESH, B.R. during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of the award of any other degree, diploma, associateship, fellowship or other similar titles.

Bangalore  
September 30, 2003

  
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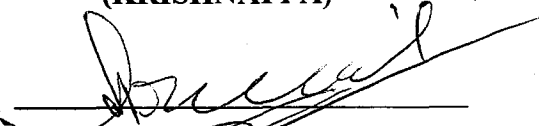
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## ACKNOWLEDGEMENT

*I express my deep sense of gratitude to the Chairman of my Advisory Committee, **Dr. K. Sudhir**, Professor of Soil Science, Department of Soil Science and Agricultural Chemistry, UAS, Bangalore, for his invaluable guidance, constructive criticisms and constant encouragement in this endeavour. He guided me in improving the quality of work and timely completion of the work.*

*I would also like to express my profound gratitude to **Dr. R. Siddaramappa**, Professor and Head, Department of Soil Science and Agricultural Chemistry and member of my Advisory Committee for his support and motivation throughout the course of my research work.*

*I am deeply indebted to **Mr. G.N. Gajanana**, Professor (DLAP), Department of Soil Science and Agricultural Chemistry and member of my Advisory Committee, for his valuable guidance and suggestions during the course of my study.*

*I am very grateful to **Dr. K.T. Krishnegowda**, Professor of Agronomy, Department of Agronomy, AICRP on millets, UAS, Bangalore, **Mr. Krishnappa**, Associate Professor, Department of Statistics, BS&H College, G.K.V.K., UAS, Bangalore, **Dr. S.L. Budihal**, Senior Scientist, NBSS & LUP, Hebbal, Bangalore, for offering critical comments and valuable suggestions, as members of my Advisory Committee.*

*I would like to extend my sincere thanks to **Dr. M.S. Badrinath**, Professor, Department of Soil Science and Agricultural Chemistry, **Mr. H.M. Chidanandappa**, Associate Professor, Department of Soil Science and Agricultural Chemistry and **Mr. T. Chikkaramappa**, Assistant Professor, Department of Soil Science and Agricultural Chemistry, UAS, GKVK, Bangalore, for their valuable suggestions and constant encouragement.*

*I extend my thanks to all the Staff Members of the Department of Soil Science and Agricultural Chemistry for the assistance extended to me during the period of my study.*


*I profusely thank the staff of NBSS and LUP, Nagpur, for the help rendered in timely completion of X-ray diffraction of clay samples and sending me the report. Thanks are also due to the staff, NBSS & LUP, Regional Centre, Bangalore, for permitting me to work in their laboratory and guiding me.*

*I am indebted my beloved father Shri. Rangaiah, mother Smt. Mallakka, sisters, brother and brothers in law, without whose blessings and encouragement, I would not have grown to this level.*

*My sincere thanks are due to Jayaprakash, Venkatesh, Srikanth, Chandrappa, Varalaxmi, Keerthi, Kitty, Chidu, Suma, Prashanth, Malli, Dhananjay, Rupa, Lokesh, Nagu, Shashi, Hema, Bhargavi and other friends for their direct and indirect help throughout the course of my study.*

*Lastly, I remain grateful to all those who have helped and encouraged me in one or the other way for the completion of my Ph. D. programme.*

**Bangalore**  
**September 30, 2003**

  
**(Jagadeesh, B.R.)**

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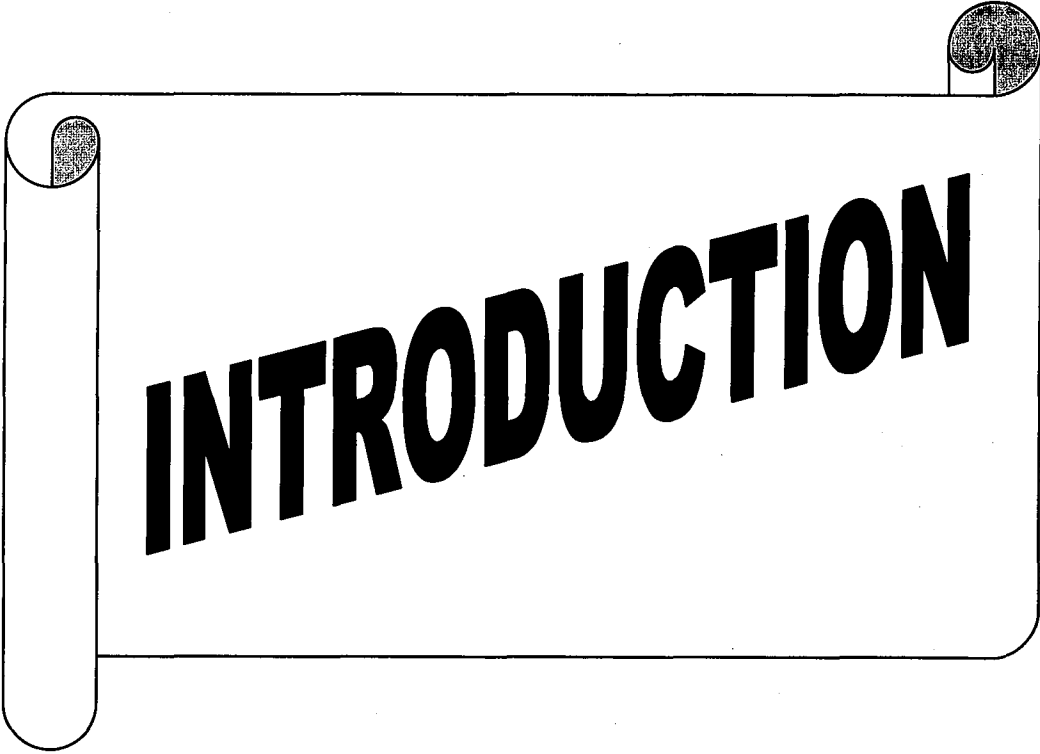
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## I. INTRODUCTION

The role of potassium (K) in plant is prodigious. Of the many plant nutrient-soil mineral relationships, those involving K are of major if not prime significance (Sparks and Haug, 1985). Over sixty enzymes require K for their activation. In addition to its major role in metabolic process and grain/seed formation, K improves the quality of agricultural produce, prevents lodging in cereal crops, imparts resistance to pests and diseases and tolerance to cold and frost.

Of the major nutrient elements, K is usually the most abundant in soils (Reitemeier, 1951). Igneous rocks of the earth's crust have higher K content than sedimentary rocks. Of the igneous rocks, granites and syenites contain 46 to 54, basalts 7, and peridotites 2.0 g K kg<sup>-1</sup>. Among the sedimentary rocks, clay shales contain 30, whereas limestones have an average of only 6.0 g K kg<sup>-1</sup> (Malavolta, 1985). Mineral soils generally contain K ranging between 0.04 and 3.00 per cent. Out of this total K content, 98 per cent is bound in the mineral form, whereas 2 per cent is in soil solution and exchangeable phases (Schroeder, 1979; Bertsch and Thomas, 1985).

The knowledge of potassium chemistry and supplying power of soil is essential to formulate sound fertilizer recommendations for potassium. Potassium is known to occur in a number of forms in soils viz., water soluble, exchangeable, non-exchangeable and lattice K. The forms of K in soil in the order of their availability to plants and microbes are solution, exchangeable, non-exchangeable and mineral forms (Martin and Sparks, 1985). The distribution of K differs from soil to soil and is a function of dominant clay minerals present. The different forms of K are known to exist in dynamic equilibrium with each other. When K is added to soil it would get fixed, which on intensive cropping is released. Thus, any decrease in soil solution K would be made up by the exchangeable K, which is maintained by the release of non-exchangeable K form to the exchangeable form. On the other hand, studies on K dynamics as affected by continuous cropping without K application indicated that measurement of exchangeable K alone may not give

a reliable estimate of K supplying capacity of soils and hence it is necessary to follow the changes occurring in non-exchangeable K also (Subba rao, 1984).

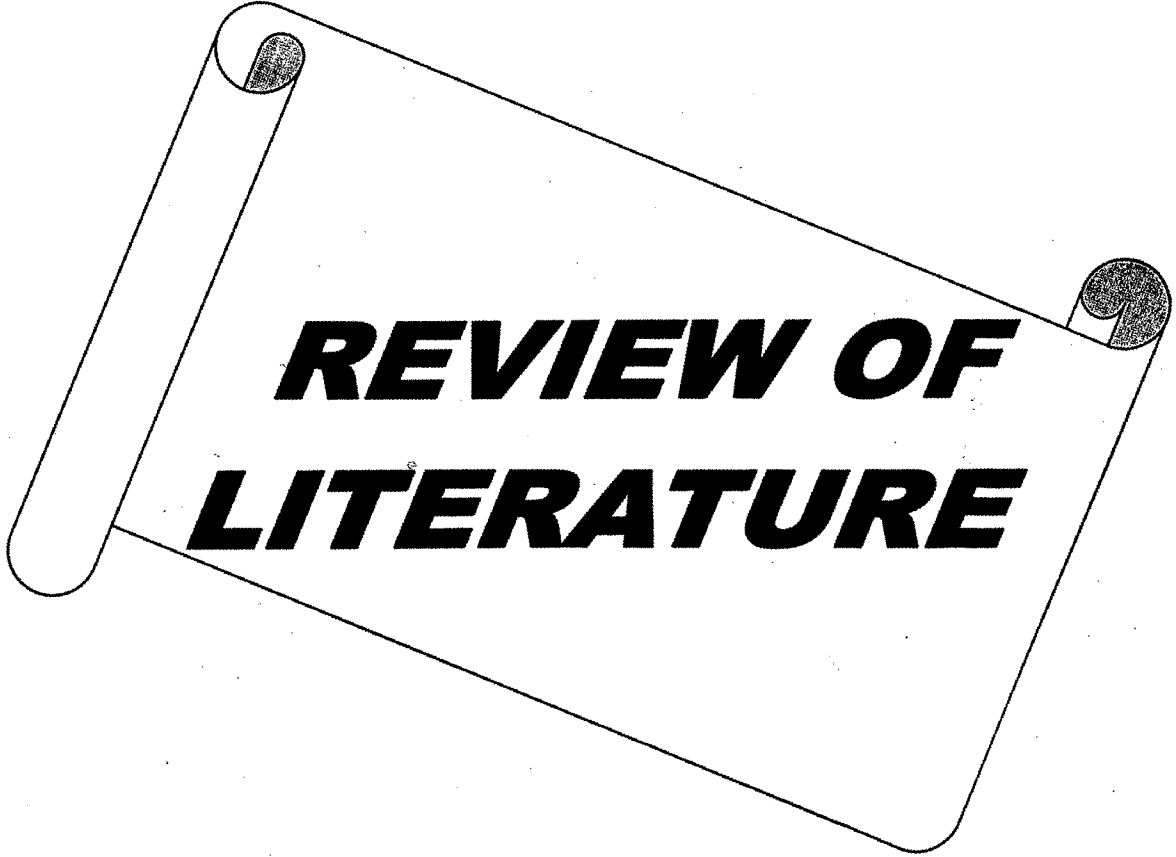
The K releasing capacity of the soils differ markedly with clay mineralogical make up, soil texture, moisture regimes and wetting and drying cycles. Low K status soils may not show response to fertilizer K, if the K releasing power is high. Thus K fixation and release characteristics dictates potassium availability under rainfed and irrigated agro ecosystems.

Extractable K measured by soil test procedure serves as an index of its availability to the plant at the time of estimation. The ability of a soil to supply K to a crop depends on its immediate availability and also on the ability of the soil to replenish against depletion, which is dependent on Quantity-Intensity relation of the labile K. The power of a given soil to supply any particular nutrient is characterized by total amount of nutrient present (Quantity) and the energy level (Intensity) at which it is held. The relationship between these two parameters may be determined by the Quantity-Intensity technique, which is based on thermodynamic principles and holds promise of being applicable to all soils (Beckett, 1964b). It is therefore important to know the magnitude of different Quantity –Intensity parameters of K so as to assure the K availability under different cropping system at different K status viz., low, medium and high.

Several research workers tried to extract the soil K considered to be available with the help of chemical reagents ranging from water to strong extractants leading to the dissolution of clay lattice and tried to correlate these K values with the crop yields. The K extracted by neutral normal ammonium acetate ( $\text{NH}_4\text{OAc}$ ) has been universally considered as available K. But recent findings reveal that using boiling normal nitric acid ( $1N \text{HNO}_3$ ) as extractant in some soils is helpful to redefine the limits for categorization of soil as low, medium and high K which may have greater likelihood of responding to fertilizer K (Brar and Sekhon, 1977). In many soils, there has been response to added K on soils considered to be high in so called “available K” whereas there have been cases where there is still lot of debate going on in respect of finding a suitable method as an

index of plant available K in the soils. For these purposes a thorough understanding of the behavior of K ie., its fixation and release patterns, activity in relation to other cations in the soil solution, its mineralogy in different types of soils is necessary. Hence, an in-depth study with respect to K dynamics in soils of selected agro-climatic zone of southern Karnataka was contemplated for a proper understanding of the behavior of this element. The objectives of investigation are:

1. To know the distribution of different forms of potassium in soils.
2. To understand the potassium fixation and release characteristics of soils under different agro-ecosystems.
3. To study the Quantity and Intensity parameters for potassium dynamics in the soils.
4. To elucidate information on the mineralogy of clay fraction of soils and
5. To evaluate the different extractants for assessing their suitability as K availability indices in soils.



***REVIEW OF  
LITERATURE***

## II. REVIEW OF LITERATURE

Potassium is a major plant nutrient in crop production. It is often absorbed by plants in amounts equal to or greater than nitrogen, which has drawn the attention of several workers to understand its behavior in different soils and study the crop response to applied K fertilizers. Lot of research works have been carried out to know its distribution and transformation in different soils, its fixation and release under different soil conditions and, the availability indices for K for predicting crop response to the application of K fertilizers under field conditions. The importance of potassium in practical agriculture is being increasingly recognised in India. A thorough understanding of potassium status in the soil could be possible only by measurement of several parameters (Grimme and Nemeth, 1978) that are related to its different forms in the soil solution and the solid phases of soil. Keeping these things in view, recent literatures related to the present investigation with emphasis on soils of different regions are reviewed under the following headings.

- 2.1 Forms and distribution of potassium in soils
- 2.2 Equilibrium among different forms of soil potassium
- 2.3 Potassium fixation capacity of soils
- 2.4 Potassium releasing power of soils
- 2.5 Quantity - Intensity parameters of potassium in soils
- 2.6 Mineralogy of clay fraction in relation to potassium
- 2.7 Evaluation of different extractants for assessing K availability in soils.

### 2.1 Forms of soil potassium

Martin and Sparks (1985) classified the different forms of K based on the location in the soil system.

Forms	Location
Water soluble	Soil solution
Exchangeable	Colloidal exchange sites- clay and organic matter
Non-exchangeable	Dioctahedral mica, Trioctahedral mica, Hydrous- mica, chlorite–vermiculite intergrades, interstratified mica- smectites.
Mineral	Trioctahedral mica, Dioctahedral mica , K-feldspars

### 2.1.1 Water soluble potassium

Potassium which is present in soil solution under normal field moisture conditions and relatively unbound by cation exchange forces is termed as water soluble potassium (Reitemeir, 1951).

Water soluble K in mineral soils is about one per cent of exchangeable K. Water soluble K in Indian soils under average conditions ranged from 7.8 to 39 ppm (Agarwal, 1965).

Ranganathan (1977) reported that the amount of water soluble fraction of K in the major soil groups followed the order alluvial > black > red > laterite in soils of Tamil Nadu. Water soluble form of soil K is highly mobile which is not sufficient to meet the normal K requirement of the crops. This form is taken up directly by plants and microbes and is also subjected for leaching (Sparks, 1980).

Adhikari and Ghosh (1991) observed that fine textured soils with relatively higher organic matter content had the highest water soluble K compared to coarse textured soils with low organic matter content. Higher water soluble K contents were present in saline sodic soils of Punjab (Dhillon *et al.*, 1985). Similar results were also reported by Pradeep Kumar *et al.* (1995).

Raskar and Pharande (1997) observed higher content of water soluble K in the surface layer of some Alfisols and reported that the high status of K was due to intense pedochemical weathering, higher organic carbon content and release of labile K from organic residues.

Manjunatha (2000) reported that the mean water soluble K content of soils of different Tobacco growing areas in Karnataka were in the order, Ramanathpur > Shimoga > Periapatna > Hunsur > H.D. Kote.

### 2.1.2 Exchangeable potassium

Potassium extracted by neutral normal ammonium acetate solution ( $NV NH_4OAc$ ) has been universally considered as available K, which includes both water soluble and exchangeable forms of soil K. More than 90 per cent of the available K in soil exists in exchangeable form, which often constitutes about one per cent of the total K in fertile loam soil (Attoe and Trough, 1945) and increased with the fineness of the soil texture (Singh and Datta, 1986; Sharma and Dubey, 1988).

Kansal and Sekhon (1976) reported that the exchangeable and potentially available K of soil increased with increase in clay and fine silt content. This form is used in classifying the soils as low, medium and high K status soils. Soil solution K was regarded as a function of exchangeable K present in illitic and kaolinitic soils (Brar *et al.*, 1986).

Sharpley (1989) observed close relationship between water soluble K and exchangeable K and in turn related it to  $1N HNO_3$  extractable K and concluded that exchangeable and  $HNO_3$  extractable K gave better indication of the potential K supplying power of a soil and also the initial K pool sizes.

Cervantes and Hanson (1991) opined that exchangeable K would estimate the easily available K, but failed to estimate the long-term capacity of the soil to release K.

Kumari and Aiyer (1993) from their field studies pointed out that  $\text{NH}_4\text{OAc}$  extractable K was the best method for determining available K in lateritic / red loam soils of Kerala.

Zubillaga and Conti (1994) stated that contribution of textural fractions on exchangeable K were 70-80 per cent, 8-18 per cent and 2-10 per cent for clay, silt and sand respectively indicating the influence of CEC of the minerals involved in addition to the amount of clay in the soil.

There was a decreasing trend in exchangeable K with continuous cropping and this decrease was found to be more pronounced during the first crop than later crops taken in succession. Crops started removing K from non-exchangeable fractions after a substantial part of exchangeable K was exhausted (Patiram and Prasad, 1983, Chakravarthi and Patnaik, 1990).

Exchangeable K in two soil series of South Kerala was positively correlated with water soluble, available, lattice bound and total potassium (Sudharmai Devi *et al.*, 1990). Das *et al.* (1993) observed positive correlation between exchangeable K and silt plus clay in some pedons of Rajasthan.

Venkatesh and Sathyanarayana (1994) found that the exchangeable K was positively correlated with clay, pH and CEC but negatively with sand and silt content in some Vertisols of North Karnataka.

Raskar and Pharande (1997) observed higher exchangeable K in surface layer than that of subsurface layers due to higher crop residues yielding higher humus content, K fertilizer application in the surface layer and variation in clay content.

Manjunatha (2000) noticed that the content of exchangeable potassium in surface soil varied from 30 to 135  $\text{mg kg}^{-1}$ . Exchangeable K represented on an average 0.67 per

ent of total potassium content of all the samples. This fraction showed significant and positive correlation with available potassium ( $r=0.860^{**}$ ).

Exchangeable K is the portion of the soil K that is electro statistically bound as an outer sphere complex to the surfaces of clay minerals and humic substances. It is readily exchanged with other cations and also is readily available to plants (Sparks, 2002).

### **2.1.3 Non-exchangeable potassium**

The soil K excluding soluble and exchangeable forms from that extracted with  $1N$   $HNO_3$  represents non-exchangeable K. It is distinct from mineral K in that it is not bonded covalently within the crystal structure of soil mineral particles. It is held between adjacent tetrahedral layers of dioctahedral and trioctahedral micas, vermiculites and inter-grade clay minerals (Rich, 1972). Non-exchangeable K ions are strongly held by the negatively charged inter layer surface sites (Kittrick, 1966). Therefore the ions are physically trapped to varying degrees, thus making the rate of K release a limiting factor in K nutrition of crops (Martin and Sparks, 1983).

Singh and Brar (1977) observed that as high as 80 per cent of available K is being contributed by non exchangeable form of K and this high contribution from non-exchangeable pool could be one of the possible reasons for poor correlation of exchangeable K to plant response (Singh *et al.*, 1983). A positive correlation between K removal by crops and non-exchangeable K released form the soil was also reported by Ganeshmurthy and Biswas (1985).

Patiram and Prasad (1983) noticed that the release of non-exchangeable K has been used to evaluate the long term K supplying power of soil. There existed a close relationship between total K uptake and the uptake of non-exchangeable K by crops under exhaustive cropping studies (Richards and Bates, 1988).

Non-exchangeable K could give better indication of the potential buffering capacity of a soil, which helps in determining initial K pool size from the readily available K pool. Soil taxonomy, clay mineralogy and chemical properties for modeling the cycling and plant uptake of soil K (Sharpley, 1989). Soil texture had a greater influence on available and reserve K (non-exchangeable K) in soil series of eastern India (Subba Rao and Sekhon, 1987). Talukdhar and Khera (1991) reported that sub soil contributed substantial amount of K from its non-exchangeable K pool towards crop uptake.

Raskar and Pharande (1997) noticed that the average values of non-exchangeable K in surface soil was higher in Vertisols than in Alfisol series due to the presence of inter layers in clay minerals in Vertisols and its release was not affected due to limited leaching soil environment under semi arid climate as compared to Alfisol soil series.

Singh *et al.* (2001) opined that the contribution of exchangeable and non-exchangeable K was found to be almost similar towards meeting K requirement of most crops. The release of non-exchangeable K was non significantly correlated with a number of physico chemical properties namely pH, EC, OC, CaCO<sub>3</sub>, sand, silt and clay, but was positively correlated with cumulative dry matter yield ( $r=0.591^{**}$ ) and cumulative K uptake ( $r=0.784^{**}$ ).

#### **2.1.4 Lattice potassium**

Lattice K in general is assumed to be slowly available to plants. However, its availability is dependent on the level of K in solution, exchangeable and non-exchangeable phases and the degree of weathering of feldspars and micas (Sparks and Haug, 1985). The direction of O-H bond as well as the tetrahedral rotation and tilting may favor rapid release of potassium from tri octahedral micas such as muscovite (Rich, 1968).

The lithosphere contains an average of 2.8 per cent, K while soil contains 1.7 per cent K (Reitemeier, 1951). Potash feldspars and micas are the mineral sources of K in the soil. Biotite mica is able to supply more K than muscovite mica, which is an important factor in determining the K supplying power of soils (Jia-Xian, 1989).

Lattice K can constitute about 79.00 to 90.00 per cent of soil K (Sharma and Dubey, 1988). The positive correlation between lattice K and clay was evident because, this form of K is an integral part of clay. The significant and positive correlation between lattice K and soil pH was because at higher pH values the base saturation will be more which may tend the level of total K to be higher (Sudharmai Devi *et al.*, 1990). The release of mica inter layer K in the alluvial and in the high K smectitic soil supplied sufficient K to plants even under intensive cropping (Bardolui *et al.*, 1992).

Raskar and Pharande (1997) reported that Alfisol soil series of Maharashtra showed higher content of lattice K than Vertisols. However, depth wise decrease in lattice K content was noticed in both Alfisol and Vertisol soil series.

Kuldeep Singh *et al.* (2001) reported that exchangeable, non-exchangeable, lattice and total K fractions were significantly correlated with clay indicating it's being the reservoir of K. Lattice K showed poor relationship with exchangeable K. This would imply the poor replenishment of exchangeable K from lattice K.

### **2.1.5 Total potassium**

It refers to the sum total of the forms of potassium present in the soil. The content of total K varies with presence of K bearing minerals like feldspars, micas and illite (Prasad *et al.*, 1967). The total availability of K is dependent on the extent of weathering of a mineral (Chahal *et al.*, 1976). Though it gives us an idea of the content of soil potassium, yet, all of it is not readily available to plants. It constitutes 97 to 98 per cent of the total soil K (Attoe and Trough, 1945).

Most of total K in soil was in the minerals such as feldspars, muscovites and biotites (Sparks, 1980; Sparks and Haung, 1985 and Wilson, 1992) and it is contained in the sand fraction of the soil (Sparks, 1980; Sandusky *et al.*, 1987 and Robert, 1992). Among the clay minerals, illite has substantial amount of potassium. The relative availability of K from K bearing minerals was in the order biotite > muscovite > orthoclase > microcline. The release of K from potassium silicate minerals occurring in soils decreased markedly with time (Rich, 1968).

A significant positive correlation between total K, sand, silt and clay in some Vertisols of North Karnataka was observed by Venkatesh and Sathyanarayana (1994). Mishra *et al.* (1995) reported a significant positive correlation between total K and lattice K while, negative with exchangeable K in some mica rich soils of Bihar. Total K was significantly correlated with clay in normal soils of Uttar Pradesh (Singh and Agarwal, 1995).

Ghosh and Mukhopadhyay (1997) reported that the total and non-exchangeable K were positively correlated with per cent silt and clay and negatively with sand; indicating that the finer particles contained higher amounts of potassium as compared to coarse fractions.

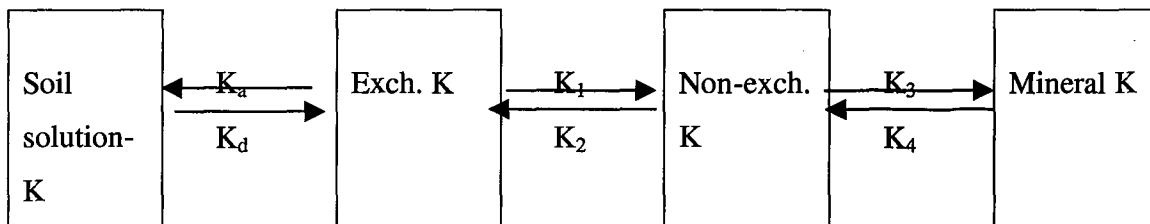
The total K content in Alfisol soil series was very low (< 1 per cent) which might be due to the low content of K bearing minerals in the basaltic alluvium of Maharashtra (Raskar and Pharande, 1997).

Manjunatha (2000) observed that the total potassium content of the surface soils of tobacco growing regions of Karnataka varied between 0.2 and 2.2 per cent. The mean total potassium content of different tobacco platforms were in the order of Periapatna >Hunsur >Ramanathapur >H.D. Kote >Shimoga. Total potassium recorded significant positive correlation with mineral potassium ( $r=0.9900^{**}$ ). Much of the total K in soils of Delaware is contained in the sand fraction (Sparks, 2002).

## 2.2 Dynamic equilibrium among different forms of soil potassium

A dynamic equilibrium exists between solution K, exchangeable K, non-exchangeable K and mineral or lattice K. The various forms of soil potassium are inter related and comprise a system in which an increase in one form occurs at the expense of one or more of the other forms.

Dynamic equilibrium between various forms of K as reported by Sparks (1980):



$K_a$  = Adsorption rate coefficient

$K_d$  = Desorption rate coefficient

$K_1$  = Fixation rate coefficient

$K_2$  = Release rate coefficient

$K_3$  = Crystallization rate coefficient

$K_4$  = Weathering and dissolution

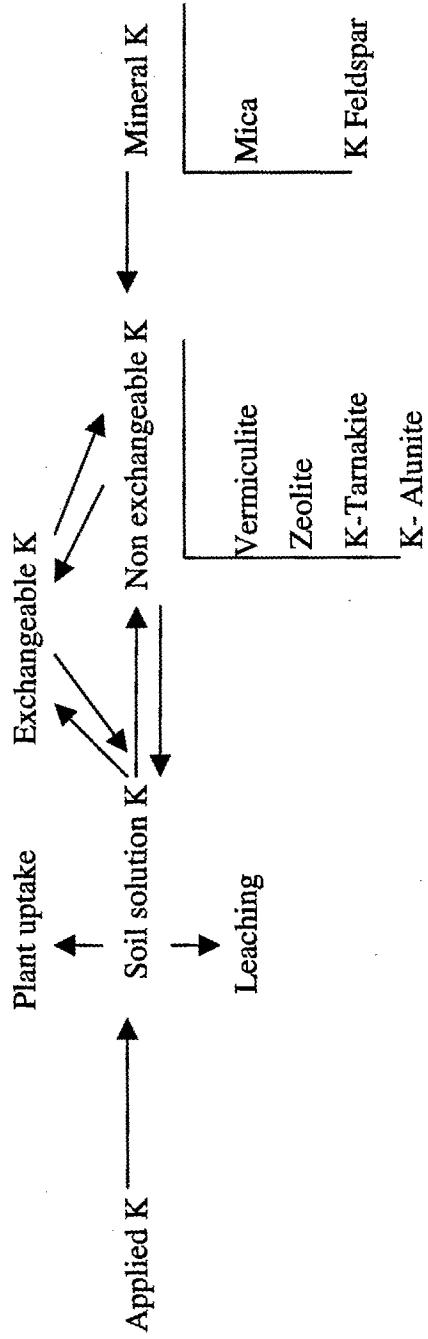


Fig.1 Dynamic equilibrium among forms of potassium after Sparks and Huang (1985)

Chatterjee and Rathore (1976) reported that the speed with which the equilibria is established depends on factors, such as expansion and contraction caused by wetting and drying, freezing and thawing cycles, the nature of mineral lattice eg. surface charge density, location of the charges and extent of the surface, the nature of the counter ions in the solution, the thickness of water films on adsorbing surface and the concentration of potassium ions relative to other cations in the equilibrium solution. Similar reports on dynamic equilibrium among forms of K were also expressed by several research workers (Ramanathan, 1975; Goulding, 1987; Tewatia *et al.*, 1989 and Sirajul Islam *et al.*, 1994).

Sharma (1976) opined that the availability of K to the plants depended on dynamic equilibrium existing among the non-exchangeable, exchangeable and water-soluble forms of potassium. Also, soil with higher amounts of reserve K had higher amount of exchangeable K (Choudhari and Pareek, 1976).

Sudharmai Devi *et al.*, (1990) noticed a positive and significant correlation between available K and fixed K, which was attributed to the dynamic equilibrium existing between the water soluble, exchangeable and fixed forms of potassium. All the forms of soil potassium were inter-correlated, indicating the existence of dynamic equilibrium among them (Venkatesh and Satyanarayana, 1994; Ghosh and Mukhopadhyay, 1996).

Byju *et al.* (2002) studied the effect of different K levels on K fractions in soils. The results indicated that the soil K maintained a dynamic equilibrium among its various forms. Levels of solution K were affected by the equilibrium and kinetic reactions that occur between the forms of soil K, the soil moisture content, and the concentrations of bivalent cations in solution and on the exchangeable phases (Sparks, 2002).

### **2.3 Potassium fixation capacity of soils**

Potassium fixation refers to the conversion of added or unused K into a form, which is temporarily unavailable, or difficulty available. Potassium fixation by soils and

clay minerals has been studied extensively because of its importance in understanding the dynamics of K in agricultural soils. One of the major problems that limits the efficiency of potassium fertilizers applied to the soil is its fixation by various minerals present in soils. But, it is not a total loss, as the fixation of K retards the loss of K by leaching and excessive uptake by plants. The suggested mechanism of K fixation is by emplacement of K between basal clay surfaces where it fits into the hexagonal cavities formed by tetrahedral oxygen of 2:1 type of clay minerals (Shaviv *et al.*, 1985).

Diffraction studies indicated that fixation of potassium was accompanied by collapse of 14Å reflection to 10Å (Sidhu and Gilkes, 1977; Sidhu and Dhillon, 1985). Generally the fixation of applied potassium was highest in micaceous soils containing high amounts of clay (Dhillon *et al.*, 1989). Soils dominated by montmorillonite fix much higher quantities of potassium as compared to kaolinite dominant soils (Ng Siew Kee, 1966).

Ramanathan and Krishnamoorthy (1978) reported that the extent of K fixation in representative soils of South India ranged from 4 to 36 per cent of the added K and the magnitude of K fixation by soil was in the order: alluvial > black > red > laterite. They also observed that K fixation was very much dependent on finer fractions (clay and silt) of the soil irrespective of their individual characteristics as they provide more surface area and increased number of fixation sites (Barber, 1979).

Ranganathan and Satyanarayana (1980) studied the fixation of potassium in different soils of Karnataka and found that the fixation was more in sub surface layer (15-30cm) of red, black and laterite soils and it increased with depth in alluvial soils. The fixing capacity of the soils was in the following order: black > alluvial > red > laterite soils. The higher fixation in black and alluvial soils was attributed to the dominance of montmorillonite and illite, respectively and low fixation in red and laterite soils was because of kaolinite. Ningappa and Vasuki (1989) noticed low potassium fixation in some acid soils of Western Ghats of Karnataka. The low fixation of these soils was attributed to the 1:1 type of clay mineral and low pH values.

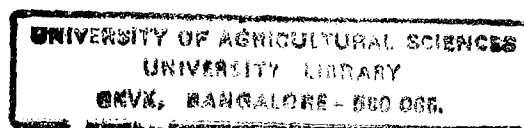
Fixation by Beidellite and vermiculite clays was found to be reduced by the simultaneous occurrence of other mineral species (Bajwa, 1981). He also noticed the influence of mineralogical variations in the soil clays on K fixation under the moist temperature regimes usually prevalent in tropical upland rice soils, Beidellite clay was the most severe fixer of added K (80%) followed by vermiculite (69%) clays. Fixation was not appreciable (<15%) in clays consisting of montmorillonite, X-ray amorphous materials, chlorites, hydrous mica, kaolinite and halloysite.

Singh *et al.* (1984) found that the soils having higher K fixation capacity had exchangeable Ca varying from 77 to 92 per cent of the exchange complex. The potassium fixing capacity of soils of Agra regions, Uttar Pradesh, varied from 8.8 to 35.5 mg/100g soil with a mean value of 21.3 mg/100g and the fixation was positively and significantly correlated with cation exchange capacity and clay content (Chandra prakash and Vinay Singh, 1985). Aravind and Muthuswamy (1989) from their study on K fixation under intensive cropping and fertilizer use concluded that continuous addition of fertilizer nitrogen alone or in combination with phosphorus to a vertisol subjected to intensive cropping for a number of years caused depletion of soil K resulting in increased fixation of the applied potash. Exhausting rice cropping increased the K fixing capacity for almost all the rice growing soils studied (Chakravarthi and Patnaik, 1990).

Aravind and Muthuswamy (1989) observed the K fixation capacity in surface and sub surface soil complex in a long-term field experiment on clay loam soil. There was an enhanced rate of K fixation in the treatments that had not received any K for the past 15 years. They also noticed that, K fixation was significantly higher in sub surface than in surface layer.

Boruah *et al.* (1991) reported that the amount of K fixed in the soil was in the order of Alfisol > Entisol > Inceptisol. The fixation increased with increasing rates of K application. But, percent of added K that was fixed decreased gradually. The amount of K fixed showed positive relationship with clay and silt fractions of soils, irrespective of soil orders. Except with Entisols, pH was correlated significantly with amount of K fixed

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while, in other soils K fixation related significantly with CEC of soils. Alluvial soils in general had high K fixation capacity as against laterite soils of Assam and the reason for high K fixation for alluvial soils was attributed to the presence of mica and vermiculite (Basumatary and Bardolui, 1992).

Talele *et al.* (1993) studied the potassium fixation capacity of soils representing nine agro-climatic zones of Maharashtra. The potassium fixation was significantly and positively correlated with soil pH, clay and silt plus clay content and negatively correlated with the sand and organic matter content of the soils. Under high rainfall, K fixation capacity was slightly decreased.

Masilmani *et al.* (1993) investigated the K fixation capacity of four major soil series viz., Vylogan (S<sub>1</sub>), Pattukottai (S<sub>2</sub>) Madukkur (S<sub>3</sub>) and Avudaiyarkovil (S<sub>4</sub>) of Pudukottai district in Tamil Nadu and reported that the K fixation values decreased in the order of 0.434 (S<sub>4</sub>), 0.388 (S<sub>1</sub>), 0.322 (S<sub>3</sub>) and 0.281 (S<sub>2</sub>) meq/100 g soil. The highest K fixation in soil series S<sub>1</sub> was attributed to higher amounts of clay, moderate CEC and, possibly presence of higher proportion of 2:1 type clay. While the least fixation in soil series (S<sub>2</sub>) was due to low amount of clay and low CEC. The fixation was positively influenced by pH, clay, clay plus silt and CEC of the soils.

Sannigrahi (1994) found that the soils of Nizamsagar catchment, had the potassium fixation capacity in the order: Entisols > Vertisols > Inceptisols. The potassium fixing capacity of soils of Uttar Pradesh varied widely in different soils depending upon the relative abundance and mineralogical make up of the clay fraction (Tiwari and Vandana Nigam, 1995).

The potassium fixation of surface soils under sugar cane based cropping system of North Karnataka ranged from 0.39 to 1.32 cmol (p<sup>+</sup>) kg<sup>-1</sup> (Hebsur, 1997). The highest fixation was observed in black soils from Gangavathi, which could be due to the dominance of chlorite in clay fractions. Mixed black and red soils had higher K fixing capacity due to the presence of vermiculite. They also observed significant positive

relationship between K fixation and clay content. Positive, but non- significant correlations of K fixation with pH, CEC, fine sand and exchangeable Ca plus Mg was also observed.

Amiri and Dorudi (1997) studied potassium fixation capacity in some soil series of Iran. The potassium fixing capacity ranged from 4 to 50% with a mean value of 37.3 per cent. K fixation capacity was higher in safroud and shalmanroud soil series. This would indicate that those soils contained micas or illite in addition to an abundance of smectite group minerals.

Srinivasa Rao *et al.* (2000) reported that fixation of added K increased with the rate of added K in all cases of soil mineralogy and depth. Surface soils of smectitic vertisols and vertic sub groups showed greater K fixation (26-32%) followed by illitic Inceptisols, Alfisols and Aridisols (23-29%) whereas lower fixation values were found for Kaolinitic Alfisols and Inceptisols (17-23%). The overlapping among the soils belonging to different mineralogical groups as regard to the extent of K fixation was ascribed to the composition of the associated minerals in silt and clay fractions of soils.

#### **2.4 Potassium release characteristics of the soils**

Potassium releasing power refers to the inherent capacity of the soil to supply K to growing plant from its natural source. As the quantity of exchangeable K in the immediate vicinity of the feeding tip of roots diminished, replenishment in this area takes place by release of potassium from non-exchangeable K form.

The chemically extractable potassium that may be present in a soil would not provide adequate meaningful information unless the rate of its release as well as the concentration in soil solution are included for actual assessment of the supply of K to the plants. Although the potassium releasing and supplying power of soil are often used as synonyms, the two terms have distinct implications. While the releasing power denotes

the gross availability in the soil system, the K supplying capacity of a soil is defined as the actual uptake of the nutrients by the plant (Nash, 1971).

In an empirical approach on the rate of release of non-exchangeable K with continuous acid extraction in order to know the long term K supplying power of soils, Haylock (1956) referred constant rate K (CR-K) as limited solubility K released at a constant rate, whereas step K as highly soluble K mostly released in the initial stages, when K is extracted with *1N* HNO<sub>3</sub>. He also used step-K values in classifying soils as follows: step-K values < 12 mg K 100g<sup>-1</sup> soil- K deficiency is expected; step K values between 12 and 19 mg 100g<sup>-1</sup> soil -response to added K is likely when removal of K is intense; step K values > 19 mg 100g<sup>-1</sup> soil- no response to applied potassium is expected.

Chandrashekar Rao and Prasad Rao (1981) reported that the CR-K and step-K varied from 0.104 to 0.780 and from 0.356 to 5.376 cmol (p<sup>+</sup>) kg<sup>-1</sup>, respectively in soils of Nagarjunsagar left bank canal area. Step K was more in the unfertilized than in the intensively fertilized plots with N and P as noticed by Patra and Khera (1982).

Subba Rao *et al.* (1984) revealed that, the cumulative release of K values indicated that the alluvial and black soils had greater K supplying power than red, laterite and sandy soils.

The capacity to supply K under continuous cropping was greater for smectitic than kaolinitic soils of similar exchangeable K contents and hence determination of both exchangeable and HNO<sub>3</sub> extractable K could give a better indication of the potential K supplying power of a soil (Sharpley, 1989).

Release of non-exchangeable K was more from alluvial and red soils than from lateritic and black soils (Chakravarthi and Patnaik, 1990). Maji and Chatterjee (1990) observed that the available K from non-exchangeable sources was higher from smectite dominant black soils as compared to that from illitic red soils.

Boruah *et al.* (1990) noticed that fine textured soils released more K than coarse textured soils. The same trend was observed for K release at each step of successive extraction. Further, the step K values had a significant positive relationship with exchangeable and non-exchangeable K contents of Entisols and Inceptisols.

Pal and Mukhopadhyay (1992) observed a positive correlation between cumulative K release and initial level of exchangeable and non-exchangeable K, which indicated that it was the K status which governed the K release characteristics of soils.

Deshmukh and Khera (1992) reported that the step K was significantly correlated with clay content, silt content, total K and CEC in eight alluvial soils of Delhi. Further, they indicated that the step K procedure was reliable for the prediction of plant utilizable K from these soils. Krishnakumari and Khera (1992) noticed that 70 per cent of the total step-K was released from an Inceptisol under intensive cropping in the first two extractions with boiling 1N HNO<sub>3</sub>.

Talukdar and Das (1994) observed that step K values of more than 1.5 cmol (p<sup>+</sup>) kg<sup>-1</sup> in soils of the orders, Alfisols, Inceptisols and Entisols, which indicated that all the soils had high K reserves that exceeded response level. Further, they stated that Entisols and Inceptisols were K deficient while, Alfisols were K-sufficient, when critical CR-K values of <0.2 cmol (p<sup>+</sup>) kg<sup>-1</sup> was considered for differentiation. It was also observed that Alfisols had higher CR-K than Inceptisol or Entisol.

Hariprakash Rao and Subramanian (1995) noticed that the CR-K values remained unaltered even after cropping irrespective of the level of K application in six typical soils belonging to Inceptisols, Vertisols and Alfisols.

Mehta *et al.* (1995) revealed that, the non-exchangeable K, in Entisols was released in two steps, an initial rapid release from edge sites followed by slow release from inter layer sites within the clay mineral. Debnath and Sanyal (1996) recorded a large reserve of step K in some Entisols, Alfisols and Inceptisols of West Bengal.

Srinivasa Rao *et al.* (1997b) observed non-exchangeable K, step K and CR-K values, which was attributed to the greater amounts of mica in the silt and clay fractions in some soils of Andhra Pradesh. In long-term fertilizer experiment on a typical Ustochrept, major portion of total extractable step K appeared in the first two extractions (Brijlal *et al.*, 1998). They also noticed almost similar values of step K in both the soil depths but CR-K values were slightly higher in surface than in sub surface soil.

Das *et al.* (1997) reported that the potassium release parameters like total extractable K, total step K and CR-K varied widely in different locations (watershed areas) of Phulbani district Orissa, indicating a wide variation in the K supplying capacity of these soils. Total extractable K and total step K were positively correlated with each other. Both the K release parameters were also positively correlated with non-exchangeable K, lattice K and total K indicating that non-exchangeable K may serve as a good index of the K-supplying capacity of these soils (Pal *et al.*, 2001).

Hirekurabar and Satyanarayana (2001) observed that the K release characteristics such as cumulative K release was positively and significantly correlated with clay ( $r=0.520^*$ ) and non exchangeable K ( $r=0.634^{**}$ ); step K was significantly and positively correlated with clay ( $r=0.432^*$ ) and non exchangeable K ( $r=0.807^{**}$ ); constant rate K was positively and significantly correlated with clay ( $r=0.593^{**}$ ) and non exchangeable K ( $r=0.900$ ) which indicated that the clay fraction and non exchangeable K served as good index of K supplying capacity of the soils.

Arabindadhar and Saroj Kumar Sanyal (2000) found that the cumulative release of non-exchangeable K by repeated extraction with boiling *IN* HNO<sub>3</sub> followed a semi logarithmic behaviour with increasing number of extractions, suggesting that the release of non-exchangeable K decreased with successive number of extractions. The reserves of step K content were in general related to the content of the clay fractions of the soils.

Pasricha and Bansal (2002) studied cumulative K release from some of the benchmark soil series of India and found that the soils dominant in kaolinite mineral released K at slower rate as compared to the illite soils.

#### 2.4.1 Desorption kinetics of potassium

Studies on K desorption were conducted (Srinivasa Rao *et al.*, 1995) using 0.01 M CaCl<sub>2</sub> solution as an extractant over time varying from 12hr to 360hr. The first order equation was fitted to describe the K desorption in these soils. The desorption rate coefficient ( $K_d$ ) did not differ appreciably among samples tested possibly because of similarity in their mineralogy.

Kaushik Majumdar *et al.* (1997) reported potassium release kinetics of a long-term fertilized soil. First order and parabolic diffusion equations were used to compare the release kinetics of the initial cultivated soil with that of soil after six and twelve years of cultivation with varying doses of N, P and K. Potassium release kinetics of the experimental plots were described adequately by the first order rate equations. Fertilization influenced desorption rate coefficients. The parabolic desorption equation delineated a diffusion controlled process, although a deviation from linearity was observed in all the treatments. This deviation was explained in terms of presence of organic matter and weathering in the soil.

Srinivasa Rao (1997) observed that parabolic diffusion was found to be the best to describe K release under exhaustive cropping followed by first order and Elovich equation. Zero-order equation was not found suitable to describe the K release data. Similar release rate constants were observed due to the similarity in their clay mineralogy. Higher release constants were found for soils with higher clay and illite content.

Srinivasa Rao *et al.*, (1998) studied exchangeable potassium desorption for 22 bench mark soil series of India employing four kinetic equations i e., first order, parabolic

diffusion, Elovich and zero order. The results demonstrated the usefulness of parabolic diffusion and first order equations for describing K desorption from these soils. Vertisols and vertic ustochrepts showed higher desorption rate constants (slope) of first order equation followed by Kaolinitic, Alfisols and Inceptisols, where as slope values of parabolic diffusion were higher for kaolinitic Alfisols and Inceptisols followed by illitic Inceptisols, Alfisols, Entisols and Aridisols.

Sharma and Swami (2000) studied K release kinetics using  $0.03N$  Sodium tetraphenyl boron (NaTPB) and  $0.01M$   $CaCl_2$  in some soil series of Rajasthan. They observed that kinetics of non-exchangeable K release for chomu and Pali series was best described by parabolic diffusion equation where as for Chambal series first order kinetics was found to be the best for  $0.03N$  NaTPB extractant. For  $0.01M$   $CaCl_2$ , Chambal series followed the first order kinetics where as kinetics of non-exchangeable K for chomu and pali series was best described by parabolic diffusion equation. Dhillon *et al.* (1989) observed first order kinetics as well as parabolic diffusion law valid while studying K release from some benchmark soils of India.

Mailappa (2000) obtained linear relationship with respect to K release kinetics when  $\log K_t/K_0$  was plotted against 't' in eleven soil samples. He found that desorption of K essentially followed the first order kinetic equation.

Sanjay Srivastava *et al.* (2002) reported that the parabolic diffusion equation described the reaction rates in  $CaCl_2$  solutions. Release rate constants (b) for non-exchangeable K showed the variation among treatments indicating that long term cropping with different rates of fertilizers and manures influenced the rate of K release from non-exchangeable fraction of soil. The b values were lowest in 100% NP and highest in 100% NPK + FYM treatment in the surface soil.

## 2.5 Quantity-Intensity relationship of potassium

Quantity-Intensity (Q/I) is a thermodynamic approach, which evaluates the K intensity factor in the soil. The capacity of a given soil to supply any particular nutrient is characterized by both the total amount of nutrient present and the energy level or intensity at which it is supplied.

In the past, the labile K in soils (exchangeable) has been described by a single measurement. In recent years attention has been shifted to a more comprehensive description i.e. to the curvilinear Q/I relationship, which relates changes ( $\pm\Delta K$ ) in the exchangeable K (Q) to the activity ratio i.e.  $a_K / \sqrt{a_{(Ca + Mg)}^{1/2}}$  [I]. In simple terms, the Q/I relationship relates changes in labile potassium in the soil to corresponding changes in effective potassium concentration in the equilibrium solution. The relationship between the exchangeable potassium content of a soil and the activity ratio of soil solution with which it is in an instantaneous equilibrium is a characteristic of a soil which is independent of soil: solution ratio or to the total electrolyte concentration of the solution.

The knowledge of equilibrium between exchangeable cations on the soil clays and their concentration in the equilibrium soil solution needs to be understood for many vital processes concerned with plant growth and development. The supplying power of soil for a given nutrient is governed by the total amount of the nutrient present (capacity) and the intensity with which, it is supplied to plants. In this connection, considerable efforts have been made to devise a method of combining both capacity and intensity factors into one function and use it to measure the K status of soils.

Schofield's (1947) concept has been in much use and is based on determining the bonding energies and other thermodynamic functions of soil water system. The concept states that "when cations in a dilute solution are in equilibrium with a large number of exchangeable cations, a change in the concentration of the solution will not disturb the equilibrium if the concentration of all the monovalent ions are changed in one ratio, those of divalent cations in the square of that ratio and those of all trivalent cations in the cube

of that ratio". This ratio is called as activity ratio (AR). The AR of a solution in equilibrium with the soil provides a satisfactory measure of the potential or intensity parameters. The Schofield ratio law provides a link between the Quantity (Q) and Intensity (I) of nutrients in the soil and very much describes the K status of the soil. This relationship has been used by Beckett (1964b) to describe K status of a soil in terms of Q/I parameters. With this in view, the importance of Q/I parameters [potassium equilibrium activity ratio ( $AR_e^k$ ), labile K ( $K_L$ ), potassium in specific sites ( $K_X$ ), potassium in nonspecific sites ( $K_o$ ), potential buffering capacity ( $PBC^k$ ) and free-energy change ( $-\Delta G^0$ ), in assessing K availability and their relation with K uptake by plants and soil conditions is reviewed and presented here under.

Mathews and Beckett (1962) reported that the  $AR_e^k$  were controlled by the amount or proportions of K in the fixed state. They also observed that the slope of Q/I curves was not related to CEC of the soil. However, they are closely related to the sum of exchangeable Ca, Mg and K. Beckett (1964a) observed that while pH values had negative relationship with  $AR_e^k$  values of soils it had positive relationship with  $PBC^k$ , since, the latter had a inverse relationship with  $AR_e^k$  (Zandstra and Mackenzie, 1968).

Acquaye and Maclean (1966) suggested that the  $AR_e^k$  and the quantity of K released [ $K_o$ ] together were much more indicative of total K uptake than any one of them alone. The  $K_o$  values which represent that part of the labile K located on planar surface is closely related to exchangeable K (Beckett *et al.*, 1966).

Le Roux and Sumner (1968) reported that Q/I relation studies gave prediction of K status of a soil through out the growing season of plants. It also illustrated how the labile pool of K influenced the amount of K taken up by the plants. They further stated that at low saturation of the exchange complex with K, the  $PBC^k$  increased due to increase in preference for K.

Acquaye (1973) opined that the higher value of  $K_o$  in association with higher organic matter content was a reflection of the contribution of organic matter to the labile

K after mineralisation. In contrast, the presence of high organic matter in soils reduced specific and non-specific sites for K and decreased the  $PBC^k$  of soils (Sen Gupta and Das, 1975). Further, they noticed that the higher  $PBC^k$  and lower  $AR_e^k$  values associated with the amount of clay represented major source of K released from the exchange sites. Sparks and Liebhardt (1981) reported that  $AR_e^k$  was increased in soils as the temperature increased and the  $PBC^k$  being related to the CEC, decreased with the increase in temperature.

Ramakrishnayya and Chatterjee (1976) revealed that low ionic activity ratio in respect of K in black soils dominated by smectite group of clay minerals compared to red soils indicated poor availability of K relative to other cations mainly Ca and Mg. In black soils  $PBC^k$  values were very high and were greater than  $100 \text{ me } 100\text{g}^{-1} / (\text{M/L})^{1/2}$  where as in red soils of Karnataka the values were very low [ $10 \text{ me } 100\text{g}^{-1} / (\text{M/L})^{1/2}$ ] indicating that red soils may respond to added K. Further they reported that, these variations were associated with clay content.

Chatterjee *et al.* (1983) measured Q/I relations and found that the  $PBC^k$  values were relatively low (1.33 to 1.48) in kaolinitic soils as compared to illite (35.0 to 254.5) dominated soils. Soils with predominance of smectites [ $6.9$  to  $13.56 \text{ me } 100\text{g}^{-1} / (\text{M/L})^{1/2}$ ] showed intermediate values. They concluded that Q/I relations were influenced not only by the nature and quantity of clay minerals present, but also by certain physico-chemical properties.

The exchangeable K,  $K_0$  and linear buffering capacity which is a measure of the rate of K release to the soil solution increased markedly with submergence (Pasricha, 1985). Evangelou *et al.* (1986) observed that K equilibrium concentration ratios (CR-K) and linear buffering capacity ( $LBC^k$ ) were greatly affected by soil organic matter. The labile potassium ( $K_L$ ),  $PBC^k$  and free energy change ( $-\Delta G^0$ ) were found to be more in montmorillonitic black soils as compared to illite dominated red soils but a reverse trend was observed in case of  $AR_e^k$  values (Maji and Chatterjee, 1990). The depletion of K

decreased  $AR_e^k$  and  $K_L$  but also decreased  $PBC^k$  (Ganeshmurthy and Biswas, 1984; Pal and Mahatim Singh, 1991).

A comprehensive study of Q/I parameters in Vertisol regions of India done by Sharma *et al.* (1992b) indicated that these soils recorded higher exchangeable K but maintained lower  $AR_e^k$ . They also mentioned that, the ammonium extractable K correlated significantly and positively with  $K_L$  and  $PBC^k$  of the soils. These results indicated that, Vertisols could maintain  $AR_e^k$  and supply K to crops for longer period of time; however, it will only be the case if K concentration in soil solution at equilibrium is sufficient to meet crop demand.

Significant positive correlation between different forms of K like water soluble K, exchangeable K,  $NH_4OAc$ -K and *IN*  $HNO_3$ -K and Q/I parameters like  $AR_e^k$ ,  $K_L$ ,  $K_0$  and K potential was reported by Das *et al.* (1993). Further, the coarse textured soils contained low values of quantity parameters ( $K_L$ ,  $K_x$ ,  $K_0$ ),  $PBC^k$  and K potential than medium and fine textured soils (Sharma and Mishra, 1989 and Roy and Ajay Kumar, 1993).

According to Nilima *et al.* (1994), in soils of Maharashtra, the  $AR_e^k$  was higher in surface than in sub surface soils, whereas  $PBC^k$  and free energy values increased with depth. This was attributed to their magnitude of exchange capacity. They also noticed that clay content and CEC of the soils were positively correlated with  $PBC^k$ .

Surekha and Subba Rao (1996) analysed Q/I parameters of potassium in Vertisols of Andhra Pradesh. They reported that all the soils except one showed low  $AR_e^k$  values and high  $PBC^k$  values indicating the higher potential to replenish K into soil solution for longer period. Multiple regression analysis showed significant contribution of soluble K towards  $AR_e^k$  and lattice K towards  $PBC^k$ .

Pal and Subba Rao (1997) observed that  $AR_e^k$  values were highest in surface soil than its sub surface counterparts. Significant correlations were found between  $PBC^k$  and clay content as well as CEC and between  $AR_e^k$  and per cent K saturation.

The Q/I parameters *viz.* Equilibrium activity ratio ( $AR_e^k$ ), potassium held at planar sites ( $K_o$ ), potassium held at specific sites ( $K_x$ ) and the labile pool of K ( $K_L$ ) showed significant and positive relationship with exchangeable and non exchangeable K. The change in free energy ( $-\Delta G$ ) was significantly related to forms of K (Nilima *et al.*, 1997).

Mausami Roy Chaudhary and Sanyal (1999) reported that the Q/I parameters, *viz.* equilibrium activity ratio ( $AR_e^k$ ), potential buffering capacity ( $PBC^k$ ) and labile potassium ( $\Delta K_o$ ) decreased with liming. Presence of large amount of aluminium in various forms restricted the unlimed soils from showing normal Gapon exchange behaviour. However, an approach towards the normal trend of variation of K against  $\Delta K$  exchange was observed as the liming rate increased.

Amrutsagar and Sonar (2000) observed that  $AR_e^k$  and  $\Delta K$  were increased with increasing rates of potassium application. This indicates that soil has higher  $K^+$  ion strength in comparison to  $Ca^{2+}$  and  $Mg^{2+}$  in soil solution so that the immediate availability of K will be more. Higher  $\Delta K$  values indicated higher exchange surface offering a selective or specific binding for potassium and not for Ca and Mg. Further lower  $PBC^k$  at higher potash application may be due to more depletion of K.

Niranjana *et al.* (2000) reported that there was positive correlation between  $AR_e^K$  and  $PBC^K$ , pH,  $CaCO_3$ , CEC, etc. Soil with higher clay content recorded higher  $K_x$  and  $PBC^K$  values. Mean values of  $\Delta G^0$  ( $-3.19$  k cal  $eq^{-1}$ ) of all the soil series in the present study were closer to the lower limit of optimum K availability.

Pannu *et al.* (2001) opined that the application of organic materials increased the potential buffering capacity ( $PBC^K$ ) and the intensity parameter ( $AR_e^K$ ) values of the soil. Amount of K adsorbed on the specific sites ( $K_x$ ) as well as on the non-specific sites ( $K_o$ ) was also increased with organic materials addition. Applications of wheat straw along with rice straw or green manure or rice straw plus green manure showed large effects in increasing the magnitude of Q/I parameters.

Sudhir *et al.* (2001) studied the Q/I parameters in long term fertilizer experiments at GKVK, Bangalore and observed that the soils in the plots with zero K application (100% NP, 100% N, and control) recorded significantly lower values for  $-\Delta K^0$ ,  $AR_e^k$  and  $PBC^k$  as compared to the soil in the plots treated continuously with K (100% NPK, 100% NPK + lime and 100% NPK + FYM). Naturally, the labile K content of soil was also relatively lower in the former case. Hence intensity factor was also weak in those soils. The  $-\Delta K^0$  and  $AR_e^k$  of the soil would be low when the K saturation of the exchange complex was also low and an increase in K saturation would lead to increase in the values for these parameters, but, a decrease in  $PBC^k$ . The reason for the  $PBC^k$  to remain lower could be attributed to lower pH and lower CEC of these soils. On the other hand the reason for the higher  $-\Delta K^0$ ,  $AR_e^k$  and  $PBC^k$  could be attributed to higher K saturation and higher CEC of the soil in those plots.

Byju *et al.* (2002) reported that the  $AR_e^k$  was closely correlated with yield response to K fertilizer than exchangeable K. The quantity factors such as labile K ( $K_L$ ), K on non-specific sites ( $K_o$ ) and K on specific sites ( $K_x$ ) recorded higher values with increasing K rates, indicating a greater K release into soil solution resulting in a larger pool of labile K. Similar results were also obtained by Rupa *et al.* (2001) and Samra and Anand Swarup (2002).

## 2.6 Mineralogy of clay fraction in relation to potassium

The potassium in soils owes its origin to the primary rock minerals: the K feldspars and the K micas, which undergo weathering on the surface of earth. The X-ray diffraction analysis is very useful for the identification of minerals in soil clays. The diffraction characteristic of each mineralochemical structure arises from the uniqueness of the atomic arrangement in it. This arrangement results in a unique array of diffraction peaks for each mineral called a diffraction pattern which is used as “finger print” to identify each mineral. The intensity of each diffraction peak is proportional to the number of diffraction planes, or more simply the concentration of each kind of mineral in a mixture if the several other factors are accounted for giving a semiquantitative estimate.

Diffraction analysis of soil clay consists of mounting of specimens followed by X-ray irradiation and qualitative and semi quantitative interpretation of the patterns. The diffraction study must be preceded by cation exchange saturation, solvation and / or heat treatment to enable differentiation of the various phyllosilicate groups or isomorphous series.

Potassium in soils is present as a structural constituent of the feldspar and micas, as exchangeable ion associated with the soil colloids and as potassium in solution. Plant uptake of K is related to the last two, which however, were derived from the potassium-bearing mineral by weathering (Sharma, 1976). Among the clay minerals present in soils, the micas, vermiculites, illites weathered micas and smectites had the property of exchanging K ions (Chatterjee and Rathore, 1976).

Sidhu (1983) reported that 65 per cent of the total K was in the form of micas (muscovite, biotite and illite) and, the remaining K was in feldspars (microcline and orthoclase) in three alfisols developed on alluvium in West Bengal. The feldspar K content in clay was the lowest when compared to sand and silt fractions and reverse trend was noticed with respect to mica in those soils. Sahu *et al.* (1983) observed a higher proportion of potash feldspar and mica in two red soils of Orissa, which are responsible for the dominance of illite in clay fraction.

Sometimes, red soils occur in association with laterite soils. The clay fraction of red soil was not exclusively kaolinite and contained illite and montmorillonite when podogenic process of high temperature and extensive leaching operated over long periods on geologically old parent materials (Agarwal and Bali, 1984). There was rapid and fairly complete attraction of weatherable minerals into secondary clays and oxides. Mineralogical studies on alluvial, red and lateritic soils of Burdwan districts of West Bengal by Ghosh and Ghosh (1984) suggested that the clay fraction of laterite and red soils was dominantly kaolinite and that of alluvial soil contained mica and smectites in almost equal proportion. Fairly high amount of smectites and interstratified minerals in laterite soils and 23 per cent vermiculite in the transitional red soils were the other

noteworthy features of these clays. No feldspar mineral was detected and only illite was the most abundant mineral in the clay fractions of three benchmark soils of Punjab (Sidhu and Dhillon, 1985).

X-ray diffraction for two red soils of peninsular India was done by Basavaraj (1989). Kaolinite was the dominant silicate mineral identified by 7.1Å and 3.6Å peaks. The 10Å peak of mica showed indication of weathering. The 3.25Å peak of feldspar was very clear while 4.34Å quartz peak was not sharp. vermiculite was noticed in small amount.

Tewatia *et al.* (1989) reported that the soil clays of some salt affected soils of Haryana were predominantly illitic, associated with kaolinite, mixed layer minerals, smectite and chlorites. Potassium in micaceous form dominated over feldspathic form in soil of five soil series of eastern India and clay fractions of all the series were richer in mica-K (Sharma *et al.*, 1992a).

Sanz-scovino *et al.* (1992) reported that hydroxy interlayered vermiculite was responsible for preserving K reserves against losses due to leaching and, in doing so, allowed the mineral itself to persist extremely against harsh weathering process.

Pal and Durge (1993) observed the difference in the release of K from clay fraction of six alluvial soils to clay mineralogy. The X-ray analysis indicated that semiarid clays (Haryana and Delhi), containing more biotite, released more K, whereas perhumid clays (Assam) containing more muscovite released least potassium. Rao *et al.* (1993) attributed that kaolinite dominated soils were low in K, smectite dominated soils medium and illite dominated soils were in high to very high categories. Potassium reserves in some soils of Southern India revealed that in general, mica-K predominated in finer fractions and feldspar K in coarser fractions (Sharma and Sekhon, 1993).

Dhillon and Dhillon (1994) carried out X-ray analysis in some benchmark soils of India and found that the dominant clay mineral in alluvial soil sample was illite, whereas,

smectite (of beidellite nature) was the most abundant clay mineral in sample of black soils, which also contained small amounts of micas. Most of the clay fractions in red soil samples consisted of kaolinite, micas and iron oxides (goethite and haematite). Rao *et al.* (1994) suggested that the presence of large quantities of illite in clays was responsible for the K replenishment rates under intensive cropping in eight soil series (Ustochrepts) from Delhi.

Study on clay mineralogy of some vertisol soil series developed on basalt/basaltic alluvium under different agroclimatic regions of Maharashtra studied by Pharande and Sonar (1997) revealed that smectite was the most dominant phyllosilicate in fine clays (> 90%) with small proportions (<10%) of kaolinite. Hebsur (1997) also noticed the dominance of smectite in the clay fraction of black soils of North Karnataka irrespective of their parent material.

Amiri and Dorudi (1997) studied the mineralogy of the East Gilan province and reported that those soils were dominated by montmorillonite with small amounts of illite and chlorite. This has been confirmed by the occurrence of strong sharp peaks at about 17.2Å in the ethylene glycol solvated specimen.

Totawat *et al.* (2001) reported that potassium availability from the soil to plants primarily depended on nature and abundance of K-bearing minerals in the soil. After quartz, feldspar is the dominant mineral in sandy soils of Rajasthan. Though, feldspar is considered to be a major source of K reserve, weathering and release of K<sup>+</sup> from it was a very slow process, contributing very little towards the soil pool of K, which could be utilized by the plants. Micas (muscovite and biotite) are considered as important sources of K in soil for plant growth since their weathering released K<sup>+</sup> in to the soil solution.

Pal and Srinivasa Rao (2002) studied the X-ray intensity ratio of peak heights of 001 and 002 basal reflections of mica for silt and clay respectively. The ratio is greater than unity in the silt and clay fractions of major soils of India.

## 2.7 Evaluation of different extractants for potassium availability

The most suitable extractants that bring into solution an amount of K proportional to the quantity removed during crop growth still remains elusive. Quite often, the major portion of the plant demand for potassium is met from the potentially available form (Non-exchangeable pool), as and when the readily available form in soil gets depleted. The estimation of  $\text{NH}_4\text{OAc}$  extractable K measures only the amount that may be available to growing crop but, it lacks the ability to predict the rate of release of K from the non-exchangeable sources to exchangeable and soluble form (Grimme, 1974).

In soils having low to medium  $\text{NH}_4\text{OAc}$ -K response to applied K was not observed, as those soils were dominated by micaceous clay minerals and the plants were able to obtain a good part of their potassium requirement from non exchangeable sources and hence  $\text{NH}_4\text{OAc}$  K was not a satisfactory index of K availability (Brar and Sekhon, 1977). Several soil testing procedures, both chemical and biological methods for K have therefore, been in vogue for determining its availability to plants and these hardly provide meaningful information unless the rate of release is included for actual assessment of the supply of K to plants.

Nanda (1977) suggested that *NV*  $\text{NH}_4\text{OAc}$  extractable K was not a good index of available K as found by yield of grain, total dry matter yield and total K uptake by plants in alluvial and laterite soils when rice was the test crop. Brar and Sekhon (1977), while working with micaceous soils of Punjab reported that boiling nitric acid which dissolved exchangeable and non exchangeable potassium was the most suitable extractant for micaceous soils.

A comprehensive study made with 40 representative soils of south India by Ramanathan (1978) revealed that *IN*  $\text{HNO}_3$  soluble K was the most suitable extractant to predict the uptake by IR-20 rice. Similar findings were also reported by Ramanathan and Krishnamoorthy (1981).

Chatterjee and Maji (1984) reported that in hilly regions (Uttar Pradesh), K extracted from the soils using  $0.1\text{ N}$  cold  $\text{H}_2\text{SO}_4$  and  $0.05\text{ N}$  NaTPB gave high positive significant correlation with dry matter yield. Potassium extracted with  $1\text{ N}$   $\text{NH}_4\text{OAc}$  and  $1.38\text{ N}$   $\text{H}_2\text{SO}_4$  could serve as indices of potassium availability in soils of North Bihar (Binod Kumar and Jha, 1987).

Jha (1993) opined that the conventional  $1\text{ N}$   $\text{NH}_4\text{OAc}$  extractant was largely valid as K availability index in alluvial soils of Bihar with  $1.38\text{ N}$   $\text{H}_2\text{SO}_4$  and Morgan's reagent being other alternative extractants. The K extracted by different extractants in swell shrink soils of Maharashtra was in the order:  $1\text{ N}$   $\text{NH}_4\text{OAc}$   $> 0.1\text{ N}$   $\text{HNO}_3$   $> 0.1\text{ N}$   $\text{H}_2\text{SO}_4$   $>$  saturation extractant. Best correlations were obtained with  $1\text{ N}$   $\text{NH}_4\text{OAc}$  and  $0.5\text{ N}$   $\text{HNO}_3$  with critical values of  $128\text{ kg ha}^{-1}$  and  $180\text{ kg ha}^{-1}$  respectively (Panda and Panda, 1993) in Rice.

Patil and Sonar (1993) found that method of extraction of K by  $0.5\text{ N}$   $\text{HNO}_3$  gave significant correlation with all the yield parameters of rice in soils belonging to Balisahi series. The correlation coefficient obtained (Kumari and Aiyer, 1993) between laboratory estimation of K and K uptake by Neubauer crop were in the following order:  $1\text{ N}$   $\text{NH}_4\text{OAc}$   $> 0.01\text{ M}$   $\text{CaCl}_2$   $> 0.5\text{ N}$   $\text{HCl}$   $>$  water  $> 6\text{ N}$   $\text{H}_2\text{SO}_4$   $>$  Morgans reagent  $> 1\text{ N}$   $\text{HNO}_3$ .

Debnath *et al.* (1994) evaluated six extractants for extraction of available K. Out of them,  $1\text{ N}$   $\text{NH}_4\text{OAc}$  showed the best correlation with the Neubauer values and hence was considered as the most suitable extractant for predicting the K availability in Tarai acid soils of West Bengal. Sirajul Islam *et al.* (1994) reported that  $\text{NH}_4\text{OAc}$  and boiling  $\text{HNO}_3$  extractable K had highest correlation co-efficients with dry matter yield and K uptake by the rice crop.

Verma *et al.* (1994) suggested that  $1\text{ N}$   $\text{HNO}_3$  method could be used for air-dried soil in predicting K availability and response of rice to K fertilization in traditionally rice growing soils of Himachal Pradesh.

Among the 14 extractants tried, boiling  $1N$   $HNO_3$ ,  $1N$   $NH_4OAc$ ,  $0.5N$  Acetic acid,  $0.5N$   $HNO_3$ ,  $6N$   $H_2SO_4$  and  $0.75N$   $HCl$  showed high degree of correlation with Bray's per cent yield and other parameters. Soil test values obtained with the  $1N$   $HNO_3$  and  $1N$   $NH_4OAc$  showed the best correlation with the crop response attributes studied. Therefore, critical limits of only those extractants were established which were 1275ppm and 120ppm respectively. The critical limit of K in rice plant at six week stage of the crop was 1.8 per cent (Ashok Tiwari and Mishra, 1995).

Subba Rao and Srinivasa Rao (1995) reported that of the several methods proposed to assess the non exchangeable K reserves and release characteristics, the method based on boiling  $HNO_3$ , dilute  $HCl$  and  $0.01M$   $CaCl_2$  were more popular in India than the other methods.

Srinivasa Rao and Takkar (1997) reported that mineral acids extracted higher amounts of K from soil, followed by dilute salt solutions, multinutrient extractants, organic acids and water. While  $1N$   $NH_4OAc$  -K could be used as a measure of plant available K, multinutrient extractants and dilute organic acids could also serve as equally good measures of available K in soils as revealed from their highly significant correlations with plant growth parameters.

The effect of chemical extractants studied by Upadhyay and Mishra (1997) on K released from muscovite and biotite followed the order: dilute  $H_2SO_4$  (1:2.5) >  $1N$   $HNO_3$  >  $0.1N$   $HCl$  >  $1N$   $NH_4OAc$  >  $0.01M$   $CaCl_2$  > distilled water. The amount of K released from muscovite with mild extractants was much higher than that from biotite, which was likely due to much higher surface charge of muscovite.

Surekha *et al.* (1997) evaluated K availability in soils with different chemical extractants. The amount of K extracted by the extractants was in the order: boiling  $HNO_3$  >  $0.1N$   $HNO_3$  >  $1N$   $NH_4OAc$  >  $0.1N$   $HCl$  =  $0.1N$   $H_2SO_4$  > 1:5 water extract > saturation extract. Significant positive correlations were found between various estimates of extractable K forms viz., water soluble, exchangeable, non exchangeable and lattice K.

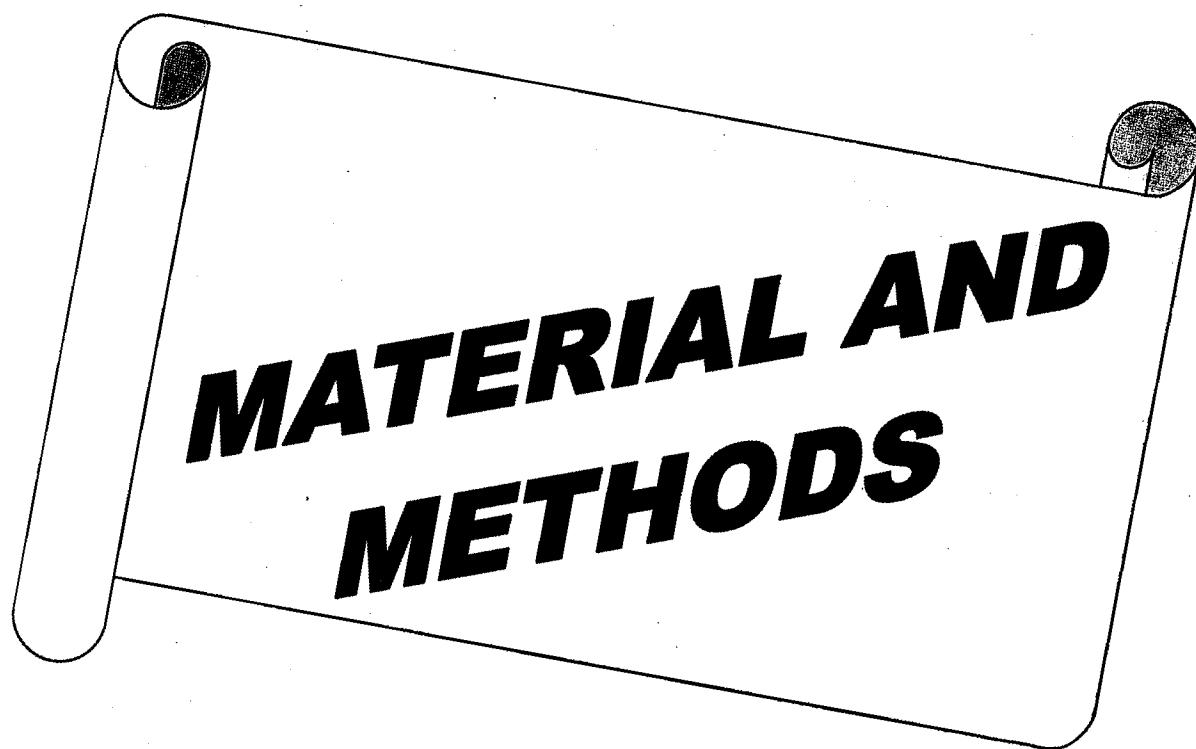
Linear multiple regression analysis between various estimates of extractable K and different K fractions estimated 11 to 99 per cent variation and,  $N NH_4OAc$  was found to be best index followed by boiling  $HNO_3$ .

Shankhayan and Singh (2001) reported that the amount of soil K extracted by  $0.01M CaCl_2$  gave the highest correlation coefficient ( $r=0.841$ ) and coefficient of determination ( $0.707$ ) with plant K up take at 55 days interval, indicating that this reagent was the best for determination of soil K available to the Maize plants.

Mailappa (2000) reported that boiling  $1N HNO_3$  extracted the highest amount of K from the soils, and concluded that the release of K from soils was mainly from the non-exchangeable pool. The amount of K extracted by various extractants from the soils was in the order:  $1N HNO_3 > 6N H_2SO_4 > 0.5N HCl > NH_4OAc-K > 0.01M CaCl_2$ . Boiling  $1N HNO_3$  soluble K was most closely related to plant uptake ( $r=0.93$ ). It is very clear from the above study that  $1N HNO_3$  soluble K was the most suitable extractant for predicting K needs by plants in kaolinite dominated acid soils containing low amount of available K and releasing considerable amount of non exchangeable- K during intensive cropping.

Bedi *et al.* (2002) analysed soils of Jammu region for choosing a suitable extractant for available K and found that the order of different extractants in terms of their capacity to extract available K was,  $0.01M CaCl_2 < \text{distilled water} < \text{Morgan's reagents} < 1N NH_4OAc < 1.38N H_2SO_4 < \text{boiling } 1N HNO_3$ . Correlation coefficient values among various extractants showed that  $1N NH_4OAc$  extractable K correlated significantly with K extracted by all other methods.

The review of literature on soil K dynamics, clearly indicates a derth in the research carried out on aspects like distribution of different forms of K, release pattern of K, desorption rates of K,  $Q/I$  relationship of K and evaluation of extractants for available K in soils of different zones in southern Karnataka. With this background comprehensive study on K dynamics including all those aspects was contemplated.



**MATERIAL AND  
METHODS**

### **III. MATERIAL AND METHODS**

In order to achieve the various objectives listed under introduction, investigations were carried out employing laboratory estimations and pot experiments. The details of experiments and methodology adopted are summarised below.

#### **3.1 Collection of soil samples**

Soil samples from fifty different locations including both surface (0-15 cm) and sub surface (15-30 cm) layers, were collected from all the agro-climatic zones of southern Karnataka (Fig.2) i.e. central dry zone (4), eastern dry zone (5), southern dry zone (6), southern transitional zone (7), hilly zone (9) and coastal zone (10). These soil samples were collected from both rainfed and irrigated agro-ecosystems representing various cropping systems. The locations, cropping pattern and other relevant information about the collected soil samples are given in table 1.

#### **3.2 Preparation of soil samples**

The soil samples collected were air-dried in shade, gently ground using wooden pestle and mortar and passed through 2-mm sieve. The sieved samples were preserved in stoppered plastic containers for further analysis.

#### **3.3 Methods of soil analysis**

The soil samples used for various investigations were analysed for mechanical separates and important chemical characteristics employing standard methods of analyses as detailed in table 2.

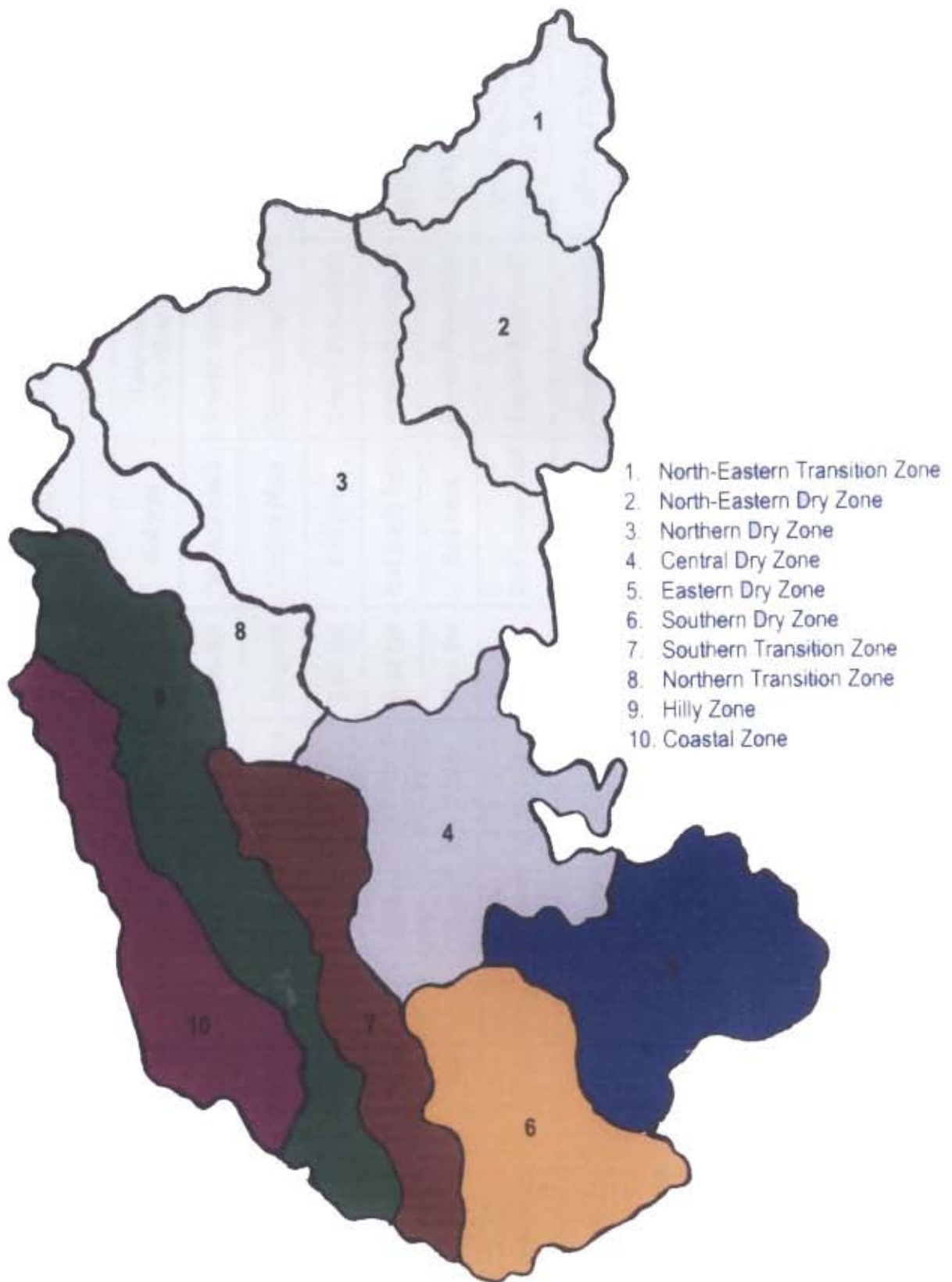


Fig.-2: Selected agro-climatic zones of Karnataka for the present investigation (shown in colours)

Table 1. Details of the soil samples collected from different agro climatic zones of Southern Karnataka

Central Dry Zone (4)									
Sl no	Village	Taluk	District	Cropping system	Rain fed/Irrigated	Soil type	Taxonomical classification	Fertilizer management	
1	Byadarahalli-1	Hiriyur	Chitradurga	Ragi-Ragi	Rain fed	Shallow black	<i>Chromic Haplusterts</i>	Only FYM @ 5-8 t ha <sup>-1</sup>	
2	Byadarahalli-2	Hiriyur	Chitradurga	Rice-Rice	Irrigated	Shallow black	<i>Chromic Haplusterts</i>	NPK@100-50-50 kg ha <sup>-1</sup> +FYM 5 t ha <sup>-1</sup> for each crop	
3	Halkur	Sira	Tumkur	Ragi + Redgram	Rain fed	Red loam	<i>Kandic Paleustalfs</i>	NPK @ 100-50-50 kg ha <sup>-1</sup> +FYM @ 5t ha <sup>-1</sup>	
4	Kallambella	Sira	Tumkur	Groundnut (monocrop)	Rain fed	Red sandy loam	<i>Kandic Paleustalfs</i>	NPK @ 40-20-20 kg ha <sup>-1</sup> +FYM 2t ha <sup>-1</sup> for each crop	
5	Tharur	Sira	Tumkur	Maize	Rain fed	Red loam	<i>Kandic Paleustalfs</i>	NPK @ 50-30-10 kg ha <sup>-1</sup>	
6	Karadikere	Thiptur	Tumkur	Rice-Rice	Irrigated	Red loamy sand	<i>Kandic Paleustalfs</i>	NPK@50-25-25 kg ha <sup>-1</sup> + FYM/GM/ @10t ha <sup>-1</sup> each crop	
7	Belgere	Thiptur	Tumkur	Red gram	Rain fed	Red loam	<i>Kandic Paleustalfs</i>	NPK @ 70-50-50 kg ha <sup>-1</sup>	
8	Bandihalli-1	Arasikere	Hassan	Areca+ Banana	Irrigated	Red sandy loam	<i>Rhodic Paleustalfs</i>	NPK @ 1.0-0.5-0 kg/tree + GM @ 5kg/tree	
9	Bandihalli-2	Arasikere	Hassan	Coconut	Irrigated	Red sandy loam	<i>Rhodic Paleustalfs</i>	NPK@ 1.0-0.6-1.2 kg /tree +FYM @ 5 kg/tree	
10	Bedadahalli	Kadur	Chikkamagalur	Arecanut (pure)	Irrigated	Red sandy loam	<i>Ustic Haplohumulis</i>	Only FYM@ 5 kg/tree	

(Continued....)

(Continued table 1)

Eastern Dry Zone (5)									
Sl no	Village	Taluk	District	Cropping system	Rain fed/Irrigated	Soil type	Taxonomical classification	Fertilizer management	
11	Upparalli-1	Malur	Kolar	Ragi-Ragi	Rain fed	Red sandy loam	<i>Udic Paleustalfs</i>	Only FYM @ 5t ha <sup>-1</sup> per crop	
12	Upparalli-2	Malur	Kolar	Red gram	Rain fed	Red sandy loam	<i>Udic Paleustalfs</i>	NPK @ 30-20-10 kg ha <sup>-1</sup> (No FYM)	
13	Muthenahatti-1	Malur	Kolar	Mango	Rain fed	Red sandy loam	<i>Kandic Paleustalfs</i>	Only FYM @ 5 kg/tree	
14	Muthenahatti-2	Malur	Kolar	Mulberry	Irrigated	Red sandy loam	<i>Kandic Paleustalfs</i>	NPK @ 140-50-25 kg ha <sup>-1</sup> + FYM @ 5t ha <sup>-1</sup>	
15	Tuvarahalli	Malur	Kolar	Ground nut	Rain fed	Red sandy loam	<i>Rhodic Paleustalfs</i>	NPK @ 20-30-0 kg ha <sup>-1</sup>	
16	Arur	Chikkballapur	Kolar	Vegetables	Irrigated	Sandy loam	<i>Kandic Paleustalfs</i>	NPK @ 75-50-75 kg ha <sup>-1</sup> +2.5 t ha <sup>-1</sup> FYM	
17	Vokkaleri	Hoskote	Bangalore (R)	Vegetables	Irrigated	Red sandy loam	<i>Typic Kandiuustalfs</i>	NPK @ 75-25-00 kg ha <sup>-1</sup>	
18	Bashettihalli	Doddaballapur	Bangalore (R)	Ground nut	Irrigated	Red sandy loam	<i>Kandic Paleustalfs</i>	Only FYM @ 10t ha <sup>-1</sup>	
19	Devanahalli	Devanahalli	Bangalore (R)	Mulberry	Irrigated	Red sandy loam	<i>Kandic Paleustalfs</i>	NPK @ 100-50-50 kg ha <sup>-1</sup> + 5 t ha <sup>-1</sup> FYM	
20	Kenchanapura	Magadi	Bangalore (R)	Banana (pure)	Irrigated	Red sandy loam	<i>Kandic Paleustalfs</i>	NPK @ 3-5-5 kg / tree	

(Continued...)

(Continued table 1)

Southern Dry Zone (6)									
Sl no	Village	Taluk	District	Cropping system	Rain fed/ Irrigated	Soil type	Taxonomical classification	Fertilizer management	
21	Madanahalli-1	Mysore	Mysore	Ragi-Ragi	Rain fed	Red sandy loam	<i>Rhodic Paleustalfs</i>	NPK @ 50-25-00 kg ha <sup>-1</sup> + FYM 5 t ha <sup>-1</sup>	
22	Madanahalli-2	Mysore	Mysore	Tobacco	Irrigated	Sandy loam	<i>Ultic Haplustalfs</i>	NPK @ 50-25-50 kg ha <sup>-1</sup> + 5 t ha <sup>-1</sup> FYM	
23	Gundlupet	Gundlupet	Mysore	Areca Garden	Irrigated	Sandy loam	<i>Ultic Haplustalfs</i>	NPK @ 1.5-1.0-0.5kg/tree and GM @ 5kg/tree	
24	V.C.Farm	Mandya	Mandya	Rice-Rice	Irrigated	Red sandy loam	<i>Typic Rhodustalfs</i>	NPK @ 100-50-50 kg ha <sup>-1</sup> + FYM @ 3t ha <sup>-1</sup> for each crop	
25	Mandya	Mandya	Mandya	Sugar cane	Irrigated	Red sandy loam	<i>Typic Rhodustalfs</i>	NPK @ 100-50-50 kg ha <sup>-1</sup> +FYM @5t ha <sup>-1</sup>	
26	Malavalli	Malavalli	Mandya	Rice-Rice	Irrigated	Red sandy loam	<i>Typic Rhodustalfs</i>	NPK @ 150-25-50 kg ha <sup>-1</sup>	
27	Maddur	Maddur	Mandya	Coconut Garden	Irrigated	Red sandy loam	<i>Typic Rhodustalfs</i>	Only FYM @ 5 kg/tree	
28	Pandavapura	Pandavapura	Mandya	Ragi- Groundnut	Rainfed	Red sandy loam	<i>Typic Rhodustalfs</i>	Only NPK @ 50-25-25 kg ha <sup>-1</sup> for each crop	
Southern Transition Zone (7)									
29	Navile-1	Shimoga	Shimoga	Groundnut (monocrop)	Rain fed	Red sandy loam	<i>Ultic Paleustalfs</i>	NPK @ 50-25-25 kg ha <sup>-1</sup>	
30	Navile-2	Shimoga	Shimoga	Tobacco (monocrop)	Rain fed	Red sandy loam	<i>Ultic Paleustalfs</i>	NPK @ 100-50-25 kg ha <sup>-1</sup> for each crop	

(Continued.....)

(Continued table 1)

Sl no	Village	Taluk	District	Cropping system	Rain fed/Irrigated	Soil type	Taxonomical classification	Fertilizer management
31	Abbalagere	Shimoga	Shimoga	Rice-Rice	Irrigated	Red sandy loam	<i>Ultic Paleustalfs</i>	NPK @ 100-50-50 kg ha <sup>-1</sup> + FYM 8 t ha <sup>-1</sup> for each crop
32	Kommanalu	Shimoga	Shimoga	Vegetables	Rain fed	Red sandy loam	<i>Ultic Paleustalfs</i>	Only FYM @ 5 t ha <sup>-1</sup>
33	Holalur	Shimoga	Shimoga	Areca (pure)	Irrigated	Red sandy loam	<i>Ultic Paleustalfs</i>	NPK @ 2.0-1.0-0.75 kg per tree
34	Sithapur	Tharikere	Chikkamagalur	Rice-Rice	Irrigated	Red sandy loam	<i>Ultic Paleustalfs</i>	NPK @ 80-40-40 kg ha <sup>-1</sup> + FYM @ 3t ha <sup>-1</sup>
35	Belur	Belur	Hassan	Coconut plantation	Irrigated	Red sandy loam	<i>Rhodic Paleustalfs</i>	NPK @ 10-8-5 kg/tree/yr + 10 kg FYM per tree
36	Periyapatna	Periyapatna	Mysore	Tobacco	Irrigated	Sandy loam	<i>Ultic Haplustalfs</i>	NPK @ 70-35-30 kg ha <sup>-1</sup> + 5 t ha <sup>-1</sup> FYM
<b>Hilly Zone (9)</b>								
37	Thirthahalli	Thirthahalli	Shimoga	Rice-Rice	Rain fed	Lateritic	<i>Fluventic Ustropepts</i>	NPK @ 100-50-50 kg ha <sup>-1</sup> + FYM @ 10t ha <sup>-1</sup>
38	Sagar	Sagar	Shimoga	Areca (pure)	Irrigated	Red sandy loam	<i>Ultic Paleustalfs</i>	Only FYM @ 15 t ha <sup>-1</sup>
39	Balehonnur	Koppa	Chikkamagalur	Coffee	Rain fed	Red clay loam	<i>Ustic Kandihumults</i>	NPK @ 250-150-250 kg ha <sup>-1</sup>
40	Devarapalli	Madikeri	Coorg	Coffee	Rain fed	Red clay loam	<i>Kandic Paleustults</i>	NPK @ 200-100-200 kg ha <sup>-1</sup>
41	Appangala	Madikeri	Coorg	Cardamom + Coffee	Irrigated	Red clay loam	<i>Kandic Paleustults</i>	NPK @ 250-150-150 kg ha <sup>-1</sup> + GM 15t ha <sup>-1</sup>
42	Peraje	Madikeri	Coorg	Areca nut+ Coconut	Rain fed	Red clay loam	<i>Kandic Paleustults</i>	NPK @ 1.5-0.5-0.00 kg/tree

(Continued table 1)

Coastal Zone (10)									
Sl no	Village	Taluk	District	Cropping system	Rain fed/Irrigated	Soil type	Taxonomical classification	Fertilizer management	
43	Brahmavara-1	Udupi	Udupi	Rice-Rice	Irrigated	Red lateritic	<i>Typic Kandiuustults</i>	NPK @ 75-50-50 kg ha <sup>-1</sup> per crop	
44	Brahmavara-2	Udupi	Udupi	Cashew	Rain fed	Red lateritic	<i>Typic Kandiuustults</i>	NPK @ 0.5-0.5-0.5 kg/tree + FYM 5 kg/tree	
45	Sasthana	Udupi	Udupi	Ground nut (monocrop)	Irrigated	Red lateritic	<i>Typic Kandiuustults</i>	NPK @ 50-25-25 kg ha <sup>-1</sup> for each crop	
46	Kukunjebayalu	Karkala	Udupi	Rice-Rice	Irrigated	Red lateritic	<i>Typic Kandiuustults</i>	Only Nitrogen @ 100 kg ha <sup>-1</sup> for each crop	
47	Puttur	Puttur	Dakshina Kannada	Areca+ banana	Rain fed	Red lateritic	<i>Typic Kandiuustults</i>	Only FYM @ 25t ha <sup>-1</sup>	
48	Pangala	Udupi	Udupi	Coconut (pure)	Rain fed	Red lateritic	<i>Typic Kandiuustults</i>	NPK @ 1.75-0.5-0.5 kg/tree + GM @ 5kg/tree	
49	Kankanady	Mangalore	Dakshina Kannada	Rice-Rice	Irrigated	Coastal alluvial	<i>Typic Kandiuustults</i>	NPK @ 75-50-25 kg ha <sup>-1</sup> for each crop	
50	Bundka	Sulya	Dakshina Kannada	Rubber plantation	Rain fed	Coastal alluvial	<i>Aquic Ustifluvent</i>	NPK @ 2.0-1.0-00 kg / tree	

Table 2. Methods of soil and plant analyses

Sl. No	Parameter	Method adopted	Reference
1	Particle size analysis	International pipette method	Jackson (1973)
2	Soil reaction	Soil water suspension (1:2.5)	Jackson (1973)
3	Electrical conductivity	Soil water extract (1:2.5)	Jackson (1973)
4	Organic carbon	Wet oxidation	Walkley and Black (1934)
5	CEC	Ammonium saturation	Black (1965)
6	Exchangeable cations	NV Ammonium acetate extraction	Black (1965)
7	Available phosphorus	0.03 N $\text{NH}_4\text{F}$ & 0.025 N HCl extraction	Bray and Kurtz, 1945
8	Available potassium	NV Ammonium acetate extraction	Jackson (1973)
9	Forms of Potassium	Flame photometry	
9a	Water soluble-K	1:2 Soil Water suspension	Mac lean (1961)
9b	Exchangeable-K	NV Ammonium acetate extraction	Knudsen <i>et al.</i> (1982)
9c	Non exchangeable-K	Boiling with 1N Nitric acid extraction	Knudsen <i>et al.</i> (1982)
9d	Total-K	Hydrofluoric acid	Lim and Jackson (1982)
10	K- fixing capacity	Alternate wetting and drying method	Jackson (1973)
11	K-release characteristics	Successive extraction with 1N boiling $\text{HNO}_3$	Haylock (1956)
12	K-desorption study	0.01M Calcium chloride	Wood and De Turk (1940)
13	Quantity-Intensity relationship of K	Quantity-Intensity curve	Beckett (1964b)
14	Clay mineralogy	X-ray diffraction technique	Jackson (1976)
15	Plant-K	Tri-acid digestion	Piper (1960)

### 3.4 Determination of various forms of soil potassium

#### 3.4.1 Water-soluble potassium

Water-soluble potassium was determined in 1:2 soil water suspensions after shaking for two hours and allowing the suspension to stand for an additional 16 hours (Mac lean, 1961). The potassium in the extract was determined by flame photometer.

#### 3.4.2 Exchangeable potassium

Exchangeable potassium was determined by extracting with neutral *N* NH<sub>4</sub>OAc solution as outlined by Knudsen *et al.* (1982). Ten gram of soil sample was shaken with 25 ml of *NV* NH<sub>4</sub>OAc solution for ten minutes and then centrifuged. The clear supernatant liquid was decanted into 100ml volumetric flask. Three more additional extractions were made in the same manner and the combined extract was diluted to volume with NH<sub>4</sub>OAc. The K content in the extract was determined, by flame photometry. The water-soluble potassium content was subtracted from NH<sub>4</sub>OAc-K to get the exchangeable potassium content of the soil.

#### 3.4.3 Non exchangeable potassium

The boiling *1N* HNO<sub>3</sub> method as outlined by Knudsen *et al.* (1982) was followed for the determination of non-exchangeable K in the soil.

Two and half gram of finely ground soil was boiled gently with 25 ml of *1N* HNO<sub>3</sub> for 10 minutes. The content was filtered and the filtrate was collected in a 100ml volumetric flask. The soil was then washed four times with 15ml portions of *0.1N* HNO<sub>3</sub>. After making up volume and mixing, the potassium content in the extract was determined using flame photometer. The quantity of K obtained with the NH<sub>4</sub>OAc extract was subtracted to get the non-exchangeable potassium content in the soil.

#### **3.4.4 Total potassium**

Total potassium content was determined by digesting the samples with hydrofluoric acid in a closed vessel (Lim and Jackson, 1982). 200 mg of finely ground soil sample was transferred into 250 ml wide mouth polypropylene bottle. Two ml of aqua regia was added to disperse the samples. Later 10 ml of hydrofluoric acid was added by means of plastic pipette and after capping the bottle the contents were shaken to dissolve the sample for a period of 8 hours. The white residue remaining after the treatment was dissolved in 100ml of saturated  $H_3BO_3$  solution. The contents were diluted and final volume was made to 250 ml and subsequently used for analysis of total potassium by flame photometer.

#### **3.4.5 Lattice potassium**

The lattice potassium was computed as the difference between total potassium and the sum of water soluble, exchangeable and non-exchangeable K fractions.

### **3.5 Potassium fixation capacity of soils**

Only twenty five (surface layer) out of fifty samples were used for the study on K fixation capacity. These samples varied widely in their available K status.

The procedure suggested by Jackson (1973) was followed to determine potassium-fixing capacity of soils. 10ml KCl solution containing 10mg of K was added to 10 g of soil taken in a 250ml of conical flask. The soil-water suspension was evaporated to dryness on a steam bath. The dried soil sample was then treated with 5ml of KCl solution plus 5ml of distilled water and was evaporated to dryness. After that, the soil was treated with 2.5ml of KCl solution plus 7.5ml of water and the suspension was evaporated to dryness once again. Further, the soil was treated with 10ml of only distilled water and was dried on the steam plate. The last step of treating the soil with water and evaporating the suspension to dryness on the steam bath was repeated 3 times. Finally, K

in the dried sample was extracted with neutral  $N$   $NH_4OAc$  and was measure using flame photometer.

One more sample (10g) of the same soil was also taken separately in another conical flask and was treated with 10ml of  $KCl$  solution containing 10mg of  $K$  and the soil was immediately extracted with neutral  $N$   $NH_4OAc$  and the  $K$  content was determined. The difference expressed as  $cmol (p^+) kg^{-1}$  of soil was considered as the potassium fixing capacity of soil.

### 3.6 Potassium release characteristics of soils

The same twenty-five samples selected for fixation study were made use for studying  $K$  release characteristics.

The  $K$  release characteristics of soils were determined by employing successive extraction of soil with boiling  $1N$   $HNO_3$  after removing exchangeable  $K$  as per the method described by Haylock (1956).

#### 3.6.1 Cumulative $K$ release

One gram of soil was taken in a centrifuge tube and was treated with 10ml of  $1N$   $HNO_3$ . The contents were heated for 10 min on a hot water bath and centrifuged for 10 minutes at 2000 rpm. The  $K$  in the supernatant liquid was determined with the help of flame photometer. To the same soil, another 10ml of  $1N$   $HNO_3$  was added and the same procedure of boiling the sample, centrifugation and  $K$  estimation was followed. The above process was repeated till the amount of  $K$  released in successive extractions was constant. The cumulative  $K$  released was calculated by adding all the values of  $K$  extracted by successive extractions. Further, Haylock's step- $K$  and constant rate- $K$  (CR- $K$ ) were calculated.

### 3.6.2 Haylock's step-K

The amount of total step K was calculated as

Total step K = {(The amount of K extracted (cumulative) by boiling *1N* HNO<sub>3</sub> till constancy in K release is reached) – (The amount of CR-K x Total number of extractions)}

### 3.6.3 Constant Rate Potassium (CR-K)

After several repeated extractions of soil by boiling *1N* HNO<sub>3</sub>, the potassium extracted reached a constant value (as discussed in 3.6.1). This constant value of K is designated as CR-K.

### 3.6.4 Potassium desorption study

For desorption study, 2.5 gram soil sample was shaken with 25 ml of 0.01 M CaCl<sub>2</sub> extractant for 1 hr and equilibrated for 24 hours at 25<sup>0</sup>C. The soil suspension was centrifuged at 3000 rpm for 15 minutes and K in supernatant solution was estimated using flame photometer. The soil in the centrifuge tube was again extracted with a fresh lot of 25 ml electrolyte solution and the whole process was repeated upto a total of 14 extractions.

Cumulative K release was calculated by summation of the amounts extracted in individual extraction.

Potassium released (mg kg<sup>-1</sup>) with time (hours) and K desorption rate co-efficient of the reaction was calculated using first order kinetic equation as proposed by Shivasubramanian and Talibudeen (1972).

$$D(K_t/K_o)/d_t = K_d t \quad \text{----- (1)}$$

Where,  $K_0$  and  $K_t$  are the amounts of K on the exchange sites ( $\text{mg kg}^{-1}$ ) of the soils at zero time and the time of extraction (pertaining to the particular period), respectively and  $K_d$  is the absolute velocity constant or desorption rate co-efficient.

Equation (1) is a typical first order kinetic equation that, on integration with boundary conditions:

$$t = 0, \quad K_t/K_0 = 1 \quad \text{and} \quad t = \infty, \quad K_t/K_0 = 0$$

Gives,  $\ln (K_t/K_0) = K_d t$

If the rate of release of K follows pseudo first order kinetics, the  $\log (K_t/K_0)$  v/s time relationship should be linear and the regression co-efficient or slope ( $K_d/2.303$ ) gives the desorption rate co-efficient ( $K_d$ ). The regression equation was also calculated using the values of  $\log (K_t/K_0)$  and time.

### 3.7 Quantity-Intensity relationship of potassium in soils

Out of the total 50 soil samples collected for the study, the 25 surface samples chosen for fixation and release study were used for evaluating Q/I parameters. The potassium potential (Q/I) in soils was evaluated using the method suggested by Beckett (1964a and 1964b) with some modifications.

Two grams each of soil was taken in a series of 150 ml conical flasks and impregnated with 20 ml of 0.01 M  $\text{CaCl}_2$  solution containing graded concentrations of K (0, 0.2, 0.3, 0.4, 1, 2, 3 and 4 m mol  $\text{K l}^{-1}$ ). The soil suspension was shaken on a horizontal shaker for one hour. After allowing to stand over night, the suspension was filtered. Potassium in the filtrate was determined using flame photometer. Calcium plus magnesium were determined by versanate titration method (USSL, staff, 1954).

The quantity factor ( $\Delta K$  in units of  $\text{cmol (p}^+) \text{ kg}^{-1}$ ) was computed by the difference between initial and the final concentration of K in the equilibrium solution.

From the measured concentration of K and, Ca plus Mg, the activity ratios were calculated using the formula:

$$AR_k = a_k / a_{(Ca + Mg)}^{1/2}$$

Where  $a_k$  = activity of K in moles/L  
 $a_{(Ca + Mg)}$  = activity of Ca + Mg in moles/L

The activities of these ions were calculated using Debye-Huckel equations:

$$\text{Log } f_i = -A z_i^2 \sqrt{I}$$

Where

$f_i$  = activity co-efficient  
 $I$  = ionic strength  
 $Z_i$  = valency of ion  
 $A = 0.509$ , a constant at 24°C

Ionic strength (I) was calculated as

$$I = 0.5 \sum C_i Z_i^2$$

Where,  $C_i$  = concentration of the ion in mol L<sup>-1</sup>

The activity ratios ( $AR^k$ ) of all the equilibrium K concentration was plotted against  $\Delta K$  to obtain Q/I curve for a soil. The Q/I curves for all the 25 soils were plotted.

The extension of the lower curved part to the y-axis gives the total amount of K in labile pool ( $K_L$ ). X-intercept of the linear interpolated curve when K is zero, represents the equilibrium activity ratio of K ( $AR_e^k$ ). The y-intercept of the linear part represents the amount of K held on planar sites ( $K_o$ ). The difference between the upper linear part and lower curved part of the curve represents the K held on the specific sites ( $K_x$ ) at  $AR^k = 0$ .

The potassium buffering capacity was calculated by adopting the relationship.

$$PBC^k = \Delta K_0 / AR_e^k$$

Where

$PBC^k$  = Potential buffering capacity of K

$\Delta K_0$  = Labile K that is located at the planar sites

$AR_e^k$  = Equilibrium activity ratio of K

The free energy change ( $\Delta G^0$ ) was calculated from the relationship shown below (Beckett, 1972):

$$-\Delta G^0 = RT \ln (AR_e^k)$$

Where,

$\Delta G^0$  = free energy change (K cal eq<sup>-1</sup>)

R = Gas constant (1.987 cal/m mol)

T = Absolute temperature (<sup>0</sup> K)

$\ln AR_e^k = 2.303 \log_{10} (AR_e^k)$

Thus the most important parameters namely  $AR_e^k$ ,  $K_L$ ,  $K_o$ ,  $K_x$ ,  $PCB^k$  and  $-\Delta G^0$  were obtained to characterise the K status of soils from the Q/I isotherms.

### 3.8 Clay mineralogical studies

#### 3.8.1 Separation of clay

Only six out of 50 sub -surface soil samples collected for the present study were selected for the mineralogical studies. Prior to the actual clay separation, the soil samples (air dried, ground and passed through 2 mm sieve) were subjected to pre-treatment, which involved dissolution of soluble salts and carbonates using *INNaOAc* (buffered at pH 5.0), followed by removal of organic matter and free iron oxides by oxidation with 30

per cent  $\text{H}_2\text{O}_2$  and, treatment with sodium dithionate –citrate-bicarbonate solutions respectively. After that, the samples were boiled in 2 per cent  $\text{Na}_2\text{CO}_3$  solution for complete dispersion. The coarse sand fraction was separated by wet sieving, and the clay was separated from the soil suspension by gravity sedimentation technique (Jackson, 1976).

### **3.8.2 X-ray diffraction analysis**

For complete x-ray diffraction (XRD) analysis, the clay samples were given different treatments viz., (1)  $\text{Ca}^{2+}$ - saturation, (2).  $\text{Ca}^{2+}$ - saturation and ethylene glycol salvation, (3).  $\text{K}^+$ -saturation, (4).  $\text{K}^+$  - saturation and heating to  $110^\circ\text{C}$  (5).  $\text{K}^+$  - saturation and heating at  $300^\circ\text{C}$  and (6)  $\text{K}^+$  - saturation and heating to  $550^\circ\text{C}$  as described by Jackson (1976).

Parallel oriented clay samples were scanned @  $2^\circ 2\theta$  per minute using Phillips x-ray diffractometer PW 1390 with  $\text{Cu K}\alpha$  radiation source employing a voltage of 40 KV and current of 20 mA. Diffractograms were recorded for all the treated samples at NBSS and LUP Nagpur.

### **3.8.3 Identification of clay minerals**

The identification of different minerals was accomplished by comparing the x-ray diffraction pattern (d spacings) as described by Whitting (1965) and Tan (1996).

The diagnostic x-ray diffraction spacings after different treatments used for identification were as follows:

<b>d-spacings</b>		
<b>A<sup>0</sup></b>	<b>nm</b>	<b>Clay minerals</b>
		<b>Ca<sup>++</sup> - saturated air dried</b>
14-15	1.4-1.5	Smectite, Vermiculite, Chlorite
9.9-10.1	0.99-1.01	Mica (illite), Halloysite
7.15	0.715	Kaolinite, Chlorite (2 <sup>nd</sup> order maximum)
		<b>Ca<sup>++</sup> - saturated glycolated</b>
17-18	1.7-1.8	Smectite
14-15	1.4-1.5	Vermiculite, Chlorite
9.9-10.1	0.99-1.01	Mica (illite), Halloysite
7.15	0.715	Kaolinite, Chlorite (2 <sup>nd</sup> order maximum)
		<b>K<sup>+</sup> saturated air dried</b>
14-15	1.4-1.5	Chlorite, Vermiculite (with inter layered aluminium)
12.4-12.8	1.24-1.28	Smectite
9.9-10.1	0.99-1.01	Mica. (illite), Halloysite
7.15	0.715	Kaolinite, Chlorite (2 <sup>nd</sup> order maximum)
		<b>K<sup>+</sup>-saturated, heated (550<sup>0</sup>C)</b>
14	1.4	Chlorite
9.9-10.1	0.99-1.01	Mica, Vermiculite (contracted), smectite (Contracted)
7.15	0.715	Chlorite (2 <sup>nd</sup> order maximum) (Kaolinite peak disappear at 550 <sup>0</sup> C)

### 3.9 Evaluation of potassium availability indices

#### 3.9.1 Potassium extraction with various extractants

Potassium was extracted using various extractants differing in compositions, like, mineral acids and solutions of neutral salts to select a suitable chemical method as an index of K availability for soils of southern Karnataka. The soils used for this study varied widely in respects of K contents and the chemical properties. [The information about the locations of soil sampling for this study is furnished in the table shown below). A brief description of the methods used for extraction of available K from the soils are given below:

Sl. No	Extractant	Soil: Extractant	Shaking or reaction time	Reference
01	Ammonium acetate <i>NN</i>	1:5	5 min	Hanway and Heidel (1952)
02	Calcium chloride <i>0.01M</i>	1:10	30 min	Woodruff and McIntosh (1960)
03	Sulfuric acid <i>1N</i>	1:20	30 min	Hunter and Pratt (1957)
04	Nitric acid <i>1N</i>	1:10	10 min	Wood and De Turk (1940)
05	Sodium tetra phenyl boron (NaTPB), <i>0.03 M</i>	1:10	16hrs equilibration	Schulte and Corey (1965)

Bulk soil samples were collected from the selected locations (shown in the table) for pot experiment carried out in the green house at farm section of UAS, GKVK Bangalore.

Sl No	Village	Taluk	District	Agro climatic zone
1	Chokkanahalli	Tumkur	Tumkur	Central dry zone
2	Nittur	Gubbi	Tumkur	Central dry zone
3	Arasikere	Hassan	Hassan	Central dry zone
4	Tharikere	Chikmagaluru	Chikmagaluru	Southern transition zone
5	Navile	Shimoga	Shimoga	Southern transition zone
6	Kankanadi	Mangalore	Dakshina kannada	Coastal zone
7	Appangala	Madikeri	Coorg	Hilly zone
8	Madanahalli	Mysore	Mysore	Southern dry zone
9	Brahmavara	Udupi	Udupi	Coastal zone
10	GKVK 1	Bangalore	Bangalore	Eastern dry zone
11	GKVK 2	Bangalore	Bangalore	Eastern dry zone
12	Arur	Chikkaballapur	Kolar	Eastern dry zone
13	Bashettihalli	Doddaballapur	Bangalore(R)	Eastern dry zone
14	Thulasidoddi	Kanakapura	Bangalore(R)	Eastern dry zone

Ten kilograms of soil was taken in each pot for the experiment. In the case of each soil four K treatments were fixed i.e. 0, 25, 50 and 75 kg K<sub>2</sub>O ha<sup>-1</sup> and each treatment was replicated thrice. Farmyard manure, Urea and SSP were applied at adequate doses as sources of organic manure, N and P. Potassium was also applied as basal dressing as per the treatment schedule. Rice (var. IR-20), seedlings of 20 days old were transplanted @ 2 hills per pot and two seedlings per hill. The crop was irrigated regularly and appropriate plant protection measures were taken. The crop was top-dressed with nitrogen after 30 days of transplanting. It was harvested on the 60<sup>th</sup> day of planting. The plant material (above ground) was cleaned and dried, first under sun, followed by oven drying at 60<sup>o</sup>C for four days. The dry matter yield in each pot was recorded and, the

uptake of potassium by the crop in each pot was also determined after analysing the plant samples for K concentration.

Simple correlations were worked out between K extracted by different chemical extractants and per cent yield response (PYR) to evaluate the most suitable/best extractants for assessing K availability in the soils under investigation.

### 3.10 Statistical Analysis

The correlation coefficients were worked out and the results are reported at 5 and 1 per cent level of significance (Draper and Smith. 1966). The plant parameter value, per cent yield response (PYR) were determined using rice dry biomass production data in the following equation (Palaskar *et al.*, 1981).

$$\text{PYR} = [(\text{Treatment yield} - \text{Control yield}) / \text{Control yield}] \times 100$$



**EXPERIMENTAL  
RESULTS**

## **IV. EXPERIMENTAL RESULTS**

The results of the investigations on the potassium status and various other aspects of study viz., potassium fixation and release characteristics, forms of potassium, particle size distribution, Quantity-Intensity parameters of potassium and clay mineralogy, of soils under different cropping systems in different agro-climatic zones of southern Karnataka are presented in this chapter under the following headings.

4.1 Physico-chemical properties of soils

4.2 Available nutrient status of soils

4.3 Forms and distribution of potassium in soils

4.4 Potassium fixation capacity of soils

4.5 Potassium release characteristics of soils

4.6 Quantity and Intensity parameters of potassium

4.7 Clay mineralogy related to potassium

4.8 Evaluation of different extractants for estimating available potassium in soils.

### **4.1 Physico-chemical properties of soils**

Data on the physico-chemical properties of surface (0-15cm) and sub surface (15-30cm) soils of different agro climatic zones of Southern Karnataka are presented in tables 3 and 4.

#### **4.1.1 Physico-chemical properties of soils of Central Dry Zone**

Central dry zone consists of 17 taluks and covers a total geographical area of 19.99 lakh hectares. The net cultivated area of the zone is 9.93 lakh hectares. Soil type of the zone varies widely from red loam to shallow/ deep black clay. The annual rainfall of the zone ranges from 655 to 717mm. The major crops grown are rabi and kharif jowar, groundnut, tur and other pulses, small millets, sugarcane, paddy, ragi, maize and plantation crops.

The data on particle size distribution of soils revealed that the total sand content of soil ranged from 46.63 to 73.40 per cent in the surface layer and from 40.13 to 75.74 per cent in the subsurface layer. Silt content varied from 9.20 to 22.15 per cent in the surface layer and from 9.50 to 22.30 per cent in the sub surface layer. Clay content of soil ranged between 4.97 and 38.38 and, 5.00 and 42.82 per cent in the two layers respectively. Irrespective of soils the subsurface layer had more of clay content than the surface layer. The textural class showed that the soils of the zone were sandy clay loam to sandy loam. Soils of Byadarahalli, Belgere and Bandihalli villages belonged to the sandy clay loam texture whereas, soils of Halkur, Tharur and Bedadahalli belonged to the Sandy loam texture. There was not much difference in the soil pH between surface and subsurface layers, the values ranged from 5.33 to 8.30 in the surface layer and 5.00 to 8.30 in the sub surface layer. The lowest (5.33) and the highest (8.30) pH were recorded in Karadikere and Byadarahalli-2 respectively, the values being the same for both the depths. The electrical conductivity of surface layer of soils varied between 0.043  $\text{dSm}^{-1}$  (Kallambella) and 0.455  $\text{dSm}^{-1}$  (Byadarahalli-2) and that of subsurface layer of soils varied between 0.058  $\text{dSm}^{-1}$  (Kallambella) and 0.518  $\text{dSm}^{-1}$  (Byadarahalli-1). Organic carbon content of the soil was the highest (1.80%) in Karadikere and the lowest (0.62%) in Belgere in surface depth, and in the sub surface depth its content was the highest (1.50%) in Karadikere and the lowest (0.50%) in Halkur, Tharur and Kallambella. In general, most of the soils had lower OC content in the second depth as compared to the first depth. Cation Exchange Capacity of soils varied from 8.00 to 32.46  $\text{cmol (P}^+) \text{ kg}^{-1}$  in surface samples and from 8.86 to 45.82  $\text{cmol (P}^+) \text{ kg}^{-1}$  in subsurface samples. In the surface samples, the highest (32.46  $\text{cmol (P}^+) \text{ kg}^{-1}$ ) and the lowest (8.00  $\text{cmol (P}^+) \text{ kg}^{-1}$ ) values were recorded in soils of Byadarahalli-1 and Kallambella respectively.

#### **4.1.2 Physico-chemical properties of soils of Eastern Dry Zone**

Eastern dry zone has a total geographical area of 17.97 lakh hectares and it consists of 24 taluks. Net cultivated area is 8.48 lakh hectares. The annual rainfall of the zone ranges from 679 to 889 mm. The major soil type of the zone is red sandy loam and

Table 3. Mechanical analysis and textural classification of the soils

Sl No	Location	Central Dry Zone (4)					Texture	Clay (%)	Silt (%)	Sand (%)	Texture	
		Sand (%)	Silt (%)	Clay (%)	Texture	Sand (%)						
		← 0-15cm →						← 15-30cm →				
1	Byadarahalli-1	50.25	15.75	34.00	scl	48.50	15.2	36.25	scl			
2	Byadarahalli-2	46.63	14.08	38.38	scl	40.13	17.05	42.82	cl			
3	Halkur	72.80	20.20	7.00	sl	70.34	16.78	12.88	sl			
4	Kallambella	78.23	16.80	4.97	ls	75.74	19.26	5.00	ls			
5	Tharur	70.12	22.15	7.73	sl	68.28	20.14	11.58	sl			
6	Karadikere	73.40	9.20	17.40	sl	71.65	9.50	18.85	sl			
7	Belgere	50.80	20.60	28.60	scl	48.00	22.30	30.20	scl			
8	Bandihalli-1	63.18	13.23	23.59	scl	61.05	14.52	24.43	scl			
9	Bandihalli-2	60.12	10.12	27.76	scl	58.20	13.50	28.30	scl			
10	Bedadha halli	76.18	12.24	11.58	sl	70.25	14.20	15.55	sl			
	Average values	64.17	15.43	20.10		61.21	16.25	22.58				
<b>Eastern dry zone (5)</b>												
11	Upparalli-1	65.20	5.50	29.00	scl	62.50	7.34	30.16	scl			
12	Upparalli-2	65.80	5.8	28.40	scl	64.00	9.50	26.50	scl			
13	Muthenahatti-1	80.90	7.50	10.00	ls	74.91	9.83	15.26	sl			
14	Muthenahatti-2	72.10	10.50	17.40	sl	69.60	11.80	18.60	sl			
15	Tuvarahalli	68.10	6.80	25.10	sl	66.00	9.35	24.65	scl			
16	Arur	69.30	9.21	28.49	scl	65.20	12.32	22.48	scl			
17	Vokkaleri	63.80	18.20	18.00	sl	61.62	18.10	20.28	scl			
18	Bashettihalli	72.12	7.78	20.10	sl	69.60	8.10	22.30	scl			
19	Devanahalli	62.97	8.53	28.50	scl	62.05	12.30	25.65	scl			
20	Kenchanapura	65.12	10.20	24.68	scl	59.20	15.64	25.16	scl			
	Average values	69.54	9.00	23.00		65.46	11.43	23.10				

(Continued...)

(Continued table 3)

Sl No	Location	Southern dry zone (6)							
		Sand (%)	Silt (%)	Clay (%)	Texture	Sand (%)	Silt (%)	Clay (%)	Texture
		← 0-15cm →			← 15-30cm →				
21	Madanahalli-1	84.30	2.50	12.50	ls	80.12	4.76	15.12	sl
22	Madanahalli-2	79.20	7.08	13.72	sl	75.32	10.08	14.60	sl
23	Gundlupet	71.14	6.88	21.98	scl	70.55	5.46	23.99	scl
24	V.C.Farm	69.30	6.50	24.20	scl	64.50	10.15	25.35	scl
25	Mandya	68.45	6.75	24.80	scl	64.20	10.30	25.50	scl
26	Malavalli	75.62	6.10	18.28	sl	69.85	7.15	23.00	sl
27	Madur	80.12	5.46	14.42	sl	78.19	6.55	15.26	sl
28	Pandavapura	82.48	6.88	10.64	sl	74.81	8.35	16.84	sl
Average values		76.33	6.02	17.57		72.19	7.85	19.98	
Southern transition zone (7)									
29	Navile-1	76.80	12.40	10.60	sl	70.15	15.14	14.71	sl
30	Navile-2	71.17	12.14	16.69	sl	67.85	14.50	17.65	sl
31	Abbalagere	70.48	13.20	16.32	sl	67.00	15.50	17.30	sl
32	Kommanalu	74.30	14.14	11.56	sl	69.35	15.65	15.00	sl
33	Holarur	72.89	15.48	11.63	sl	65.44	19.46	15.10	sl
34	Sithapur	69.77	20.19	10.04	sl	58.68	23.27	18.10	sl
35	Belur	73.51	12.80	13.69	sl	68.48	15.52	16.00	sl
36	Periyapatna	75.30	12.50	12.20	sl	69.80	14.95	15.25	sl
Average values		72.98	14.10	10.74		67.10	16.75	16.14	
Hilly zone (9)									
37	Thirthahalli	70.20	4.40	25.40	scl	67.84	6.20	25.96	scl
38	Sagar	73.85	4.80	21.35	scl	71.18	6.80	22.02	scl
39	Balehonnur	80.10	4.90	15.00	sl	75.00	5.40	19.60	sl
40	Devarapalli	77.80	9.32	12.88	sl	73.57	10.68	15.75	sl
41	Appangala	56.86	16.94	26.20	scl	55.35	18.85	25.80	scl
42	Peraje	78.80	6.42	14.78	sl	72.43	8.37	19.20	sl
Average values		72.94	7.80	19.27		69.24	9.40	21.40	

(Continued.....)

(Continued table 3)

Coastal zone (10)									
Sl No	Location	← 0-15cm →			← 15-30cm →			Texture	Texture
		Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)		
43	Brahmavara-1	60.12	20.18	19.70	60.17	18.18	21.65	sl	scl
44	Brahmavara-2	58.79	22.11	19.10	55.00	23.50	21.50	sl	scl
45	Sasthana	73.24	10.28	16.48	68.32	12.80	18.88	scl	scl
46	Kukunjabaylu	67.50	4.25	28.25	67.39	6.75	25.86	scl	scl
47	Puttur	60.88	15.25	13.87	58.65	18.30	23.05	sl	scl
48	Pangala	68.00	5.28	26.72	62.58	10.10	27.32	scl	scl
49	Kankanady	72.70	12.00	15.30	68.37	13.23	18.40	sl	sl
50	Bundka	69.65	9.30	21.05	65.85	11.23	22.92	scl	scl
Average values		66.33	12.33	20.05	63.29	14.26	22.44		

scl=sandy clay loam; ls=loamy sand; sl=sandy loam; sc=sandy clay; cl=clay

the major crops grown are small millets, pulses, groundnut, paddy, ragi, maize, soybean, horticultural crops, vegetables and mulberry.

The total sand content of the soils ranged from 62.97 to 80.90 per cent in the surface layer and 59.20 to 74.91 per cent in the subsurface layer while, the silt content varied from 5.50 to 18.20 per cent in the surface and from 7.34 to 18.10 per cent in the subsurface layer. The clay content of soils varied between 10.00 and 29.00 per cent in surface layer and 15.26 and 30.16 per cent in subsurface layer. Nearly 80 percent of the soils in this zone were of sandy clay loam texture. The pH values ranged from 5.75 to 7.50 in the surface layer of soils and from 5.60 to 7.40 in the sub surface layer of soils. Muthenahatti-1 recorded the lowest values for both surface and subsurface horizons and Muthenahatti-2 recorded the highest values for both the depths. The Electrical conductivity of soils ranged from 0.085 to 0.290  $\text{dSm}^{-1}$  and, from 0.106 to 0.261  $\text{dSm}^{-1}$  in surface and subsurface depths respectively. The soils of Bashettihalli and Tuvarahalli recorded the lowest (0.085  $\text{dSm}^{-1}$ ) and the highest (0.290  $\text{dSm}^{-1}$ ) EC respectively. There was not much difference in the EC of soil between the two depths. Organic carbon content of soil was the highest in Muthenahatti-1 (0.80%) and the lowest in Muthenahatti-2 (0.50%) in the surface layer and it varied between 0.55 and 0.76% in the subsurface layer of soil. In the case of subsurface layer of soils, the lowest and highest values of OC have been recorded for the same soils. The CEC of soils ranged between 6.80 and 18.50  $\text{cmol (p}^+) \text{kg}^{-1}$  and 6.71 and 18.00  $\text{cmol (p}^+) \text{kg}^{-1}$  in surface and subsurface depths respectively. At both the depths, Muthenahatti-1 and Devanahalli recorded the lowest and the highest CEC values respectively.

#### **4.1.3 Physico-chemical properties of soils of Southern Dry Zone**

Southern dry zone consists of 18 taluks in three districts ie., Mandya, Mysore and Tumkur. The total geographical area of the zone is 15.56 lakh hectares, out of which the net cultivated area is 7.42 lakh hectares. The major type of soil is red sandy loam. The annual rainfall ranges from 800 to 900 mm. Major crops grown in this zone are kharif

jowar, pulses, small millets, groundnut, paddy, ragi, sugar cane, mulberry and plantation crops.

The results of soil analysis revealed that the clay content of soil was relatively higher in the subsurface layer in comparison to surface layer. The clay content ranged from 12.50 to 24.80 per cent in the first depth and from 14.60 to 25.50 per cent in the second depth. Silt content of soils of the zone varied from 2.50 to 7.08 per cent in surface layer and 4.76 to 10.30 per cent in sub surface layer. Total sand content of soil ranged from 68.45 to 84.30 per cent in surface depth and 64.20 to 80.12 per cent in subsurface depth. The soils of the zone belonged mainly to loamy sand and sandy clay loam textures. In respect of soil pH, the lowest (5.65) and the highest (6.55) values were recorded in the soils of V.C. Farm and Mandya respectively, at the 0-15cm depth. At the 15-30 cm depth, the lowest (5.80) and the highest (6.75) pH values were recorded by the same soils. Electrical conductivity of soils ranged from 0.115 to 0.190  $\text{dSm}^{-1}$  in the surface depth and from 0.078 to 0.198  $\text{dSm}^{-1}$  in the subsurface depth. Organic carbon content of soils varied from 0.92 to 1.72 and, 0.86 to 1.50% in the surface and the subsurface layers respectively. The highest organic carbon content was recorded in Mandya soil for both surface (1.72%) and subsurface (1.50%) horizons. The lowest (0.92% and 0.86%) OC values were recorded in soils of V.C.Farm (0-15cm) and Madanahalli-1 (15-30cm). With respect to CEC, the values for surface and subsurface layers ranged from 10.10 to 16.20 and 11.20 to 18.88  $\text{cmol}(\text{P}^+) \text{kg}^{-1}$  respectively. The soils of Madanahalli-2 and V.C.Farm registered the lowest and the highest CEC values for the first depth and soils of Madanahalli-1 and Mandya registered the lowest and highest CEC values for the second depth.

#### **4.1.4 Physico-chemical properties of soils of Southern Transition Zone**

Southern transition zone consists of 14 taluks and has a total geographical area of 16.60 lakh hectares. The net cultivated area is 6.75 lakh ha. The soil type in this zone is Lateritic and Red sandy loam. The zone receives an annual rainfall ranging from 700-

Table 4. Physico-chemical properties of soils

Sl No	Location	Central Dry Zone (4)									
		pH		EC (dSm <sup>-1</sup> )		OC (%)		CEC (cmol (p <sup>+</sup> ) kg <sup>-1</sup> )			
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm		
1	Byadarahalli-1	8.20	8.30	0.384	0.518	0.85	0.78	32.46	45.82		
2	Byadarahalli-2	8.30	8.28	0.455	0.411	0.82	0.80	28.75	30.25		
3	Halkur	6.45	6.50	0.113	0.177	0.68	0.50	12.00	12.18		
4	Kallambella	5.50	5.40	0.043	0.058	0.65	0.50	8.00	8.86		
5	Tharur	7.20	7.23	0.148	0.212	0.58	0.50	22.5	20.00		
6	Karadikere	5.33	5.00	0.078	0.085	1.80	1.50	18.16	22.48		
7	Belgere	6.70	6.84	0.240	0.247	0.62	0.55	10.88	10.00		
8	Bandihalli-1	7.20	7.50	0.304	0.347	0.98	0.95	13.20	11.50		
9	Bandihalli -2	6.71	6.85	0.310	0.305	1.12	0.85	28.12	28.18		
10	Bedada halli	7.15	7.20	0.283	0.204	1.26	1.20	23.13	22.25		
Average values		6.87	6.89	0.237	0.256	0.94	0.81	19.72	21.15		
Eastern Dry Zone (5)											
11	Upparalli-1	6.60	6.80	0.226	0.254	0.71	0.68	7.88	8.50		
12	Upparalli-2	7.05	6.89	0.113	0.117	0.78	0.75	17.50	18.26		
13	Muthenahatti-1	5.75	5.60	0.219	0.127	0.80	0.76	6.80	6.71		
14	Muthenahatti-2	7.50	7.40	0.219	0.219	0.50	0.55	8.75	8.00		
15	Tuvarahalli	5.90	5.83	0.290	0.198	0.60	0.48	13.56	14.20		
16	Arur	7.20	7.18	0.262	0.226	0.75	0.66	18.30	17.55		
17	Vokaleri	5.88	6.19	0.141	0.197	0.80	0.75	12.20	10.88		
18	Bashethalli	6.35	6.55	0.085	0.106	0.72	0.60	16.82	18.20		
19	Devanahalli	6.50	6.85	0.141	0.127	0.68	0.60	18.50	18.00		
20	Kenchanapura	6.62	6.60	0.177	0.268	0.89	0.75	17.60	18.50		
Average values		6.53	6.60	0.187	0.184	0.72	0.66	13.79	13.88		

(Continued....)

(Continued table 4)

Southern Dry Zone (6)											
Sl No	Location	pH		EC (dSm <sup>-1</sup> )		OC (%)		CEC (cmol (P <sup>+</sup> ) kg <sup>-1</sup> )		Average values	Average values
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm		
21	Madanahalli-1	6.25	6.30	0.115	0.198	0.97	0.86	11.20	11.20	11.20	11.20
22	Madanahalli-2	6.35	6.57	0.148	0.168	1.30	1.25	10.10	10.10	12.85	12.85
23	Gundlupet	5.72	5.90	0.153	0.164	1.50	1.40	12.85	12.85	13.35	13.35
24	V.C Farm	5.65	5.80	0.153	0.134	0.92	0.90	16.2	16.2	15.5	15.5
25	Mandya	6.55	6.75	0.198	0.078	1.72	1.50	15.25	15.25	18.88	18.88
26	Malavalli	6.40	6.50	0.189	0.128	1.20	1.12	14.44	14.44	15.80	15.80
27	Maddur	6.30	6.45	0.120	0.134	0.98	0.80	13.65	13.65	15.00	15.00
28	Pandavapura	5.80	6.15	0.145	0.176	1.62	1.25	14.50	14.50	16.26	16.26
Average values		6.12	6.30	0.152	0.147	1.27	1.13	13.52	13.52	14.85	14.85
Southern Transition Zone (7)											
29	Navile-1	5.25	5.08	0.198	0.141	0.80	0.68	6.70	6.70	7.12	7.12
30	Navile-2	7.43	7.68	0.388	0.291	0.90	0.80	13.30	13.30	15.25	15.25
31	Abbalagere	5.40	5.50	0.183	0.193	1.00	0.70	8.50	8.50	9.35	9.35
32	Kommanalu	5.56	5.68	0.218	0.250	1.08	0.75	9.80	9.80	10.70	10.70
33	Holalur	7.10	7.30	0.255	0.281	1.10	0.85	11.20	11.20	13.15	13.15
34	Sithapur	7.20	7.50	0.127	0.117	1.12	0.90	15.78	15.78	16.25	16.25
35	Belur	6.48	7.20	0.310	0.280	1.03	0.88	12.15	12.15	14.20	14.20
36	Periyapatna	6.10	6.80	0.309	0.275	1.00	0.73	10.00	10.00	12.85	12.85
Average values		6.31	6.60	0.248	0.228	1.00	0.78	10.92	10.92	12.35	12.35
Hilly Zone (9)											
37	Thirthahalli	4.85	5.20	0.191	0.186	2.80	2.30	15.90	15.90	17.72	17.72
38	Sagar	5.05	5.18	0.167	0.198	2.40	2.10	10.15	10.15	12.50	12.50
39	Balehonnur	5.15	5.19	0.205	0.171	2.32	2.05	12.00	12.00	13.35	13.35
40	Devarapalli	5.28	5.30	0.254	0.178	2.26	2.00	8.84	8.84	10.00	10.00
41	Appangala	5.20	5.28	0.057	0.131	2.20	1.80	8.10	8.10	10.00	10.00
42	Peraji	5.20	5.35	0.320	0.310	2.28	2.06	7.50	7.50	7.00	7.00
Average values		5.12	5.34	0.199	0.195	2.37	2.05	10.41	10.41	11.76	11.76

(Continued....)

(Continued table 4)

Coastal Zone (10)										
Sl No	Location	pH		EC (dSm <sup>-1</sup> )		OC (%)		CEC (cmol (P <sup>+</sup> ) kg <sup>-1</sup> )		Average values
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	
43	Brahmavara-1	5.02	5.15	0.120	0.191	2.18	1.86	6.28	6.00	
44	Brahmavara-2	5.30	5.20	0.240	0.191	1.28	0.88	11.10	8.60	
45	Sasthana	4.85	5.05	0.283	0.198	1.82	1.60	11.40	10.00	
46	Kukunjabaylu	5.05	5.12	0.065	0.127	2.06	2.00	10.20	9.50	
47	Puttur	5.45	5.56	0.077	0.071	3.18	3.06	9.34	8.88	
48	Pangala	5.05	5.20	0.198	0.162	3.12	2.45	15.80	11.56	
49	Kankanady	4.79	4.80	0.106	0.106	1.08	0.90	10.20	13.35	
50	Bundka	5.32	5.21	0.204	0.160	3.01	2.85	11.40	12.86	
Average values		5.10	5.16	0.161	0.150	2.21	1.95	10.71	10.09	

1050 mm. The major crops in this zone are pulses, groundnut, paddy, ragi, maize, plantation crops and tobacco.

The total sand content of soils varied from 69.77 to 76.80 per cent in the surface layer and from 58.68 to 70.15 per cent in the sub surface layer. The silt content of soils ranged from 12.14 to 20.19 per cent in surface layer and 14.50 to 23.27 per cent in sub surface layer and, the clay content varied from 10.04 to 16.69 and, 14.71 to 18.10 per cent in the respective layers. Texturally, soil is sandy loam in both the depths. Soil pH of surface layer varied from 5.25 to 7.43, the lowest and the highest values being noticed in Navili-1 and Navile-2. In the subsurface layer, the pH ranged from 5.08 to 7.50, the lowest and the highest values being noticed in Sithapur and Navile-1. Electrical conductivity of soils ranged from 0.127 to 0.388 and 0.117 to 0.291  $\text{dSm}^{-1}$  in surface and subsurface depths respectively. The highest values of 0.388 and 0.291  $\text{dSm}^{-1}$  and lowest values of 0.127 and 0.117  $\text{dSm}^{-1}$  were recorded respectively in soils of Navile-2 and Sithapur, in both surface and subsurface depths. In respect of organic carbon content of soils, the values varied from 0.80 to 1.12% in surface layer and 0.68 to 0.90% in subsurface layer. The highest and the lowest values for the first depth were recorded in Sithapur and Navile-1 respectively and for the second depth also, the highest and lowest values were recorded by same soils. The CEC of soils ranged from 6.70 to 15.78 and from 7.12 to 16.25  $\text{cmol (P}^+) \text{ kg}^{-1}$  in surface and subsurface layers respectively. The lowest values of CEC (6.70 and 7.12  $\text{cmol (P}^+) \text{ kg}^{-1}$ ) were recorded in the case of Navile-1 and the highest values of CEC (15.78 and 16.25  $\text{cmol (P}^+) \text{ kg}^{-1}$ ) were recorded in the case of Sithapur for both the depths of the soil.

#### **4.1.5 Physico-chemical properties of soils of Hilly Zone**

Hilly zone covers 22 taluks. The total geographical area is 22.89 lakh hectares, out of which 5.82 lakh hectares is cultivated. This zone records annual rainfall of 1300 to 3800 mm. The soil is mainly red clay loamy type. Major crops grown in this zone are paddy, pulses, maize, sugar cane, ragi, spices and plantation crops.

Sand content of the soils of this zone varied from 56.86 per cent to 80.10 per cent at 0-15 cm depth. In 15-30cm depth, the sand content of soils ranged from 55.35 to 75.00 per cent. The silt content of soils ranged from 4.40 to 16.94 and 5.40 to 18.84 percent in surface and subsurface depths respectively. The clay content, which was relatively more in the lower depth varied from 12.88 to 26.20 and 15.75 to 25.96 per cent in the first and the second depths respectively. In both the depths, the soil texture varied from sandy loam to sandy clay loam. In respect of soil pH of first depth, the lowest (4.85) and the highest (5.28) values were noticed respectively in Thirthahalli and Devarapalli while, in the subsurface layer, the lowest (5.19) and highest (5.35) values were observed respectively in soils of Balehonnur and Peraje. The Electrical conductivity of the soils ranged from 0.057 to 0.320  $\text{dSm}^{-1}$  in surface layer and from 0.131 to 0.310  $\text{dSm}^{-1}$  in subsurface layer. The highest values of Electrical conductivity for both the depths were noticed in Peraje whereas, the lowest value for the first depths was noticed in Appangala and the lowest value for the second depth was noticed in Balehonnur. Organic carbon content of the soil was the lowest in Appangala in both the depths, the values being 2.20 and 1.80 per cent in the first and second depths respectively. Similarly, the highest OC was noticed in soil from Thirthahalli, for both the depths. CEC of soils ranged from 7.50 to 15.90 and 7.00 to 17.75  $\text{cmol (P}^+) \text{ kg}^{-1}$  in upper and lower layers respectively. For both the depths, the lowest values were recorded by the soil from Peraje and the highest values were recorded by the soil from Thirthahalli.

#### **4.1.6 Physico-chemical properties of soils of Coastal Zone**

This zone consists of 13 taluks belonging to the districts of Uttara Kannada, Dakshina Kannada and Udupi. It covers a total geographical area of 9.84 lakh hectares. Net cultivated area of the zone is 2.27 lakh hectares. Soil types are red lateritic and coastal alluvial. The annual rainfall ranges from 3000 to 4700 mm. Paddy, groundnut, pulses, tuber crops, sugar cane and plantation are major crops grown in this zone.

Most of the soils in this zone are sandy loam and sandy clay loam in texture. The sand content in the surface layer ranged from 58.79 to 73.24 per cent and in the

subsurface layer, it ranged from 55.02 to 68.32 per cent. The silt content varied from 4.25 to 22.11 per cent in surface layer and 6.75 to 23.50 per cent in the subsurface layer. The amount of clay varied between 13.87 to 28.25 and 18.40 to 25.86 per cent in the two layers respectively. In the surface horizon, the soil from Kankanady recorded the lowest pH (4.79) and the soil from Puttur recorded the highest pH (5.45). In the subsurface horizon also, the same two soils recorded the lowest (4.80) and the highest (5.56) pH values. Electrical conductivity values of soils varied from 0.065 to 0.283  $\text{dSm}^{-1}$  in surface and from 0.071 and 0.198  $\text{dSm}^{-1}$  in subsurface layer. Organic carbon content of soil varied from 1.08 to 3.18 % in surface samples of soils and from 0.88 to 3.06 % in subsurface samples. At 0-15cm depth, the lowest soil OC value was noticed in Kankanady and the highest was noticed in Puttur. At 15-30 cm depth, OC was the lowest (0.88 %) in Brahmavara-2 and the highest (3.06 %) in Puttur. Soil CEC values varied from 6.28 to 15.80 and 6.00 to 13.35  $\text{cmol (p}^+) \text{ kg}^{-1}$  in surface and subsurface layers respectively.

## 4.2 Available nutrient status of soils

The available nutrient status of soils under different agro climatic zones is presented in table 5.

### 4.2.1 Available nutrient status of soils of Central Dry Zone

Available phosphorus content of soils ranged from 12.76 to 38.95  $\text{kg P ha}^{-1}$  in the surface layer, the highest and lowest P values being 38.95  $\text{kg ha}^{-1}$  (Bedadahalli) and 12.76  $\text{kg ha}^{-1}$  (Byadarahalli-2) respectively. In the subsurface layer of soil, the P values ranged from 12.25  $\text{kg ha}^{-1}$  to 36.57  $\text{kg ha}^{-1}$ , the lowest and highest values being noticed in the same soils. Available potassium content ranged from 92.96 to 343.55  $\text{kg K ha}^{-1}$  in the surface layer of soils and 85.52 to 305.77  $\text{kg K ha}^{-1}$  in the subsurface layer of soils. Tharur recorded the lowest K values for both surface and subsurface soils, and Byadarahalli-2 recorded the highest K values for both surface and subsurface soils. Exchangeable calcium content of surface layer of soil was the highest (12.20  $\text{cmol (p}^+)$ )

Table 5. Available nutrient status of the soils

Sl No	Location	Central Dry Zone (4)									
		Available P (kg ha <sup>-1</sup> )		Available K (kg ha <sup>-1</sup> )		Exch. Ca (cmol (p <sup>+</sup> ) kg <sup>-1</sup> )		Exch. Mg (cmol (p <sup>+</sup> ) kg <sup>-1</sup> )			
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm		
1	Byadarahalli-1	12.75	12.25	282.07	274.26	8.50	9.00	1.50	1.80		
2	Byadarahalli-2	12.75	12.25	344.55	305.77	12.20	10.10	0.80	1.20		
3	Halkur	27.10	24.86	241.70	197.08	3.00	3.50	1.30	0.40		
4	Kallambella	28.07	23.94	159.90	152.45	4.00	3.50	0.80	1.20		
5	Tharur	25.52	19.54	93.00	85.49	5.60	5.00	2.80	2.00		
6	Karadikere	23.72	23.33	256.00	218.20	9.50	4.80	1.40	1.20		
7	Belgere	37.25	29.17	306.44	294.42	7.30	6.00	1.30	1.50		
8	Bandihalli-1	13.32	19.54	97.08	85.48	4.10	4.00	5.00	3.20		
9	Bandihalli-2	19.10	18.97	264.05	242.20	10.80	5.30	5.20	3.10		
10	Bedada halli	38.85	36.58	183.00	185.92	6.80	3.10	1.80	0.30		
	Average values	23.56	22.04	223.00	204.10	7.20	5.00	2.20	1.60		
		Eastern Dry Zone (5)									
11	Upparalli-1	17.51	19.41	152.45	81.80	3.20	3.20	1.20	1.00		
12	Upparalli-2	13.33	14.88	129.50	118.90	8.80	7.60	2.50	2.00		
13	Muthenahatti-1	12.54	16.83	89.25	107.80	5.80	5.50	1.40	0.80		
14	Muthenahatti-2	13.33	12.37	222.80	213.24	3.50	4.20	0.20	0.60		
15	Tuvarahalli	26.38	25.02	152.45	135.57	8.20	5.50	2.50	3.20		
16	Arur	51.94	42.38	230.54	200.22	6.30	5.80	3.60	3.20		
17	Vokkaleri	11.88	16.90	74.37	89.00	5.20	3.80	2.00	1.80		
18	Bashettihalli	12.31	13.29	92.96	92.92	5.60	3.50	2.20	2.50		
19	Devanahalli	15.25	12.80	137.58	130.94	5.80	5.00	2.30	2.00		
20	Kenchanapura	14.68	19.54	107.88	78.17	4.90	4.50	1.10	0.70		
	Average values	18.91	19.34	138.94	125.00	5.70	5.00	1.90	1.80		

(Continued....)

(Continued table 5)

Southern Dry Zone (6)									
Sl No	Location	Available P (kg ha <sup>-1</sup> )		Available K (kg ha <sup>-1</sup> )		Exch. Ca (cmol (p <sup>+</sup> ) kg <sup>-1</sup> )		Exch. Mg (cmol (p <sup>+</sup> ) kg <sup>-1</sup> )	
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
21	Madanahalli-1	29.19	22.10	180.46	179.14	4.40	3.20	0.60	0.30
22	Madanahalli-2	15.91	17.30	161.21	140.07	5.60	5.50	2.50	1.20
23	Gundlupet	17.83	16.04	192.30	186.05	4.30	3.20	0.80	0.50
24	V.C.Farm	9.03	13.27	223.85	200.03	5.80	5.00	0.40	1.20
25	Mandya	18.85	18.86	208.20	209.85	4.20	3.50	1.00	1.40
26	Malavalli	16.80	15.40	118.70	130.14	5.50	3.60	1.50	0.70
27	Maddur	20.10	17.72	154.58	140.35	5.70	3.10	2.00	1.00
28	Pandavapura	18.30	17.80	158.44	145.62	5.00	2.00	1.00	0.80
Average values		18.24	17.31	175.35	166.41	5.10	3.60	1.20	0.90
Southern Transition Zone (7)									
29	Navile-1	33.54	28.00	232.38	214.47	4.50	3.80	2.30	2.00
30	Navile-2	25.74	18.12	216.63	183.00	4.30	2.20	0.90	0.20
31	Abbalagere	28.24	26.40	154.74	146.08	4.80	4.20	1.10	0.30
32	Kommanalu	31.10	27.34	160.73	157.25	5.10	3.50	2.20	1.00
33	Holalu	26.58	24.71	177.17	166.11	6.30	3.00	2.00	0.50
34	Sithapur	18.40	21.47	145.02	141.30	7.60	5.80	2.30	2.00
35	Belur	32.20	26.45	206.25	191.02	6.50	2.50	1.50	0.80
36	Periyapatna	32.67	27.48	247.96	212.48	5.30	2.80	2.20	1.30
Average values		28.56	24.94	193.28	176.38	5.60	3.50	1.80	1.00

(Continued.....)

(Continued table 5)

<b>Hilly Zone (9)</b>									
Sl No	Location	Available P (kg ha <sup>-1</sup> )		Available K (kg ha <sup>-1</sup> )		Exch. Ca (cmol (p <sup>+</sup> ) kg <sup>-1</sup> )		Exch. Mg (cmol (p <sup>+</sup> ) kg <sup>-1</sup> )	
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
37	Thirahalli	8.59	8.05	255.10	252.73	4.80	4.50	0.60	0.40
38	Sagar	12.61	8.88	216.96	176.92	3.60	2.00	0.80	0.30
39	Balehonnur	11.66	9.02	265.10	256.84	1.50	1.80	0.30	0.50
40	Devarapalli	14.10	11.57	244.60	216.16	5.00	4.20	3.00	2.10
41	Appangala	14.10	12.67	222.98	194.75	3.20	3.00	0.40	1.20
42	Peraji	11.36	9.02	100.40	96.28	3.80	3.50	0.50	0.20
Average values		12.20	9.87	217.52	198.90	3.70	3.10	0.90	0.80
<b>Coastal Zone (10)</b>									
43	Brahmavara-1	10.85	9.33	74.37	66.93	5.30	4.20	2.00	1.50
44	Brahmavara-2	11.56	9.02	70.53	134.00	6.20	4.00	1.30	1.10
45	Sasthana	12.11	7.99	74.84	104.16	4.20	4.00	0.60	1.30
46	Kukunjebaylu	14.00	15.00	104.11	118.98	2.90	3.70	2.00	1.30
47	Puttur	13.85	11.97	119.75	104.11	2.10	1.80	0.50	0.30
48	Pangala	4.85	3.20	193.35	174.44	4.10	2.80	0.20	0.50
49	Kankanady	5.72	4.40	118.98	104.11	3.10	1.60	0.20	0.20
50	Bundka	8.48	5.50	107.83	100.40	2.40	2.80	1.30	0.80
Average values		10.50	8.36	108.34	114.00	3.80	3.10	1.00	0.90

kg<sup>-1</sup>) in Byadarahalli-2 and the lowest (3.00 cmol (p<sup>+</sup>) kg<sup>-1</sup>) in Halkur, where as in the sub surface layer, it was the highest (10.10 cmol (p<sup>+</sup>) kg<sup>-1</sup>) in Byadarahalli-2 and the lowest (2.80 cmol (p<sup>+</sup>) Kg<sup>-1</sup>) in Karadikere .

#### 4.2.2 Available nutrient status of soils of Eastern Dry Zone

The lowest (11.88 kg P ha<sup>-1</sup>) and the highest (51.94 kg P ha<sup>-1</sup>) available P values were recorded by Vokkaleri and Arur respectively for 0-15cm depth of soil. Muthenahatti-2 recorded the lowest (12.37 kg ha<sup>-1</sup>), while Arur recorded the highest (42.38 kg ha<sup>-1</sup>) P content for 15-30cm depth of soil. The available potassium content of soils ranged from 74.37 to 230.54 kg K ha<sup>-1</sup> in the surface layer of soils and from 78.17 to 213.24 kg K ha<sup>-1</sup> in the subsurface layer of soils. The lowest content of soil available K was observed in Vokkaleri and the highest content of soil available K was observed in Arur at the first depth while, in the case of the second depth of soil, the lowest and the highest available K were observed in Kenchnapura and Muthenahatti-2. Exchangeable Ca and Mg contents in the surface layer of soils ranged from 3.50 to 8.80 and, 0.20 to 3.60 cmol (p<sup>+</sup>) kg<sup>-1</sup> respectively and in the subsurface layer of soils the contents of the same two elements ranged from 3.20 to 7.60 and, 0.60 to 3.20 cmol(p<sup>+</sup>) kg<sup>-1</sup> respectively.

#### 4.2.3 Available nutrient status of soils of Southern Dry Zone

The available phosphorus content of soils varied from 9.03 to 29.19 kg P ha<sup>-1</sup> in the surface layer and from 13.26 to 22.06 kg P ha<sup>-1</sup> in the subsurface layer. The highest phosphorus content was noticed in Madanahalli-1 and the lowest was in V.C. Farm for both the depths. Available potassium content in samples of surface layer of soils varied from 118.70 to 223.85 kg K ha<sup>-1</sup>, whereas in samples of subsurface layer of soils it varied from 122.50 to 209.85 kg K ha<sup>-1</sup>. Soils from Malavalli and V.C.Farm recorded the lowest and the highest values of available potassium for both surface and subsurface depths respectively. Exchangeable Ca and Mg contents of the top layer of soils varied from 4.20 to 5.80 cmol (p<sup>+</sup>) kg<sup>-1</sup> and 0.40 to 2.50 cmol (p<sup>+</sup>) kg<sup>-1</sup> respectively, and that of bottom

layer of soils varied from 3.20 to 5.50 cmol (p<sup>+</sup>) kg<sup>-1</sup> and 0.30 to 1.40 cmol (p<sup>+</sup>) kg<sup>-1</sup>, respectively.

#### 4.2.4 Available nutrient status of soils of Southern Transition Zone.

The available phosphorus content of soil varied from 18.40 to 33.54 kg P ha<sup>-1</sup> in the surface layer, the lowest (18.4 kg P ha<sup>-1</sup>) and the highest (33.54 kg P ha<sup>-1</sup>) values being observed in the case of Sithapur and Navile-1 respectively. Similarly subsurface layer of soils also varied in their available P contents, the values ranging from 18.12 to 28.00 kg P ha<sup>-1</sup>. The lowest and the highest values in the latter case were observed in Navile-2 and Navile-1 respectively. The available potassium content ranged from 145.72 to 237.40 kg K ha<sup>-1</sup> in the surface layer of soils, the lowest content of potassium being observed in Sithapur and the highest content being observed in Navile-1. The subsurface potassium content in the soils ranged from 141.30 to 214.47 kg K ha<sup>-1</sup>. Exchangeable Ca of soils varied from 4.30 to 7.60 cmol (p<sup>+</sup>) Kg<sup>-1</sup> in the surface layer of soils, and from 2.20 to 5.80 cmol (p<sup>+</sup>) kg<sup>-1</sup> in the subsurface layer of soils. Exchangeable Mg content in soils varied from 0.90 to 2.30 cmol (p<sup>+</sup>) kg<sup>-1</sup> in the first depth and from 0.20 to 2.00 cmol (p<sup>+</sup>) kg<sup>-1</sup> in the second depth.

#### 4.2.5 Available nutrient status of soils of Hilly Zone

The available phosphorus content of soil varied from 8.58 to 14.70 and 8.05 to 12.70 kg P ha<sup>-1</sup> in the surface and sub surface samples of soils respectively. The highest values were recorded in soils of Devarapalli and Appangala, for 0-15 and 15-30cm depths respectively. The lowest values were observed in the case of Thirthahalli soil at both the depths. The available potassium content was found to be the highest in Balehonnur soil at both the depths, the values being 265.10 kg K ha<sup>-1</sup> in the upper layer and 256.83 kg K ha<sup>-1</sup> in the lower layer. On the other hand soil from Peraje registered the lowest values viz. 99.60 kg K ha<sup>-1</sup> and 96.30 kg K ha<sup>-1</sup> respectively for the two depths. The exchangeable Ca and Mg contents of soils varied respectively from 1.50 to 5.00 and 0.30

to  $3.00 \text{ cmol (p}^+) \text{ kg}^{-1}$  in the surface layer and  $1.80$  to  $4.50$  and  $0.20$  to  $2.10 \text{ cmol (p}^+) \text{ kg}^{-1}$  in the sub surface layer.

#### 4.2.6 Available nutrient status of soils of Coastal Zone

Surface soil samples of coastal zone registered  $4.84$  to  $16.30 \text{ kg P ha}^{-1}$  with respect to their phosphorus contents, the highest ( $16.30 \text{ kg P ha}^{-1}$ ) and the lowest ( $4.84 \text{ kg P ha}^{-1}$ ) contents being noticed in Kukunjebayalu and Pangala respectively. The sub surface soil phosphorous content varied from  $3.20$  to  $15.50 \text{ kg P ha}^{-1}$ . The available potassium content of soils varied from  $70.63$  to  $193.35$  and,  $66.93$  to  $181.00 \text{ kg K ha}^{-1}$  in the first and the second layers of soils respectively. The highest value was recorded by Pangala and the lowest value was recoded by Brahmavara-1 irrespective of depths. The exchangeable Ca and Mg contents in the surface layer of soils varied from  $2.10$  to  $6.20$  and  $0.20$  to  $1.50 \text{ cmol (p}^+) \text{ kg}^{-1}$  respectively, and their respective values in the sub surface layer of soils varied from  $1.80$  to  $4.20$  and  $0.20$  to  $2.10 \text{ cmol (p}^+) \text{ kg}^{-1}$ .

#### 4.3 Forms of potassium:

The data on different forms of potassium in soils of different agro-climatic zones of Southern Karnataka are given in table 6.

##### 4.3.1 Central Dry Zone:

The content of water-soluble form of potassium in the surface layer of soils varied from  $6$  to  $16 \text{ mg K kg}^{-1}$ . In the first depth of soil, the highest ( $16 \text{ mg K kg}^{-1}$ ) and the lowest ( $6 \text{ mg K kg}^{-1}$ ) contents of water soluble potassium were noticed in Karadikere and Bedadahalli respectively, whereas in the second depth, the highest value of  $14 \text{ mg K kg}^{-1}$  was observed in Karadikere soil and the lowest value of  $4 \text{ mg K kg}^{-1}$  was noticed in soil of Bandihalli-1.

Table 6. Forms of potassium (mg K kg<sup>-1</sup>) in soils of different agro climatic zones

Sl No	Location	Central Dry Zone (4)											
		Water Soluble K		Exchangeable K		Non exch- K		Lattice K		Total K			
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm		
1	Byadarahalli-1	8	6	166	130	260	290	2446	2834	2800	3200		
2	Byadarahalli-2	8	5	180	135	280	320	3132	3540	3600	4000		
3	Halkur	12	10	102	94	140	150	1945	2146	2200	2400		
4	Kallambella	10	8	56	50	140	160	1794	2182	2000	2400		
5	Tharur	12	10	86	74	130	135	2172	2981	2400	3200		
6	Karadikere	16	14	126	112	160	160	1898	2114	2200	2400		
7	Belgere	12	8	90	75	170	195	2928	3322	3200	3600		
8	Bandihalli-1	8	4	74	74	120	130	2198	2592	2400	2800		
9	Bandihalli-2	10	6	80	74	110	135	1802	2185	2000	2400		
10	Bedada halli	6	6	44	40	120	135	1830	2619	2000	2800		
	Average values	10	8	92	80	163	181	2214	2652	2480	2920		
Eastern Dry Zone (5)													
11	Upparalli-1	6	4	40	30	125	130	1429	1836	1600	2000		
12	Upparalli-2	6	6	44	44	140	150	1610	1900	1800	2100		
13	Muthenahatti-1	4	4	38	34	155	180	1603	1782	1800	2000		
14	Muthenahatti-2	8	6	50	44	143	158	2199	2112	2400	2620		
15	Tuvarahalli	6	4	61	50	140	155	1792	1991	2000	2200		
16	Arur	10	8	114	96	150	160	1726	2536	2000	2800		
17	Vokkaleri	8	4	72	68	120	140	2400	2588	2600	2800		
18	Bashettihalli	6	8	68	56	150	175	2176	2561	2400	2800		
19	Devanahalli	6	4	84	72	135	155	1975	2369	2200	2600		
20	Kenchanapura	4	4	81	60	142	168	2573	2764	2800	3000		
	Average values	6	5	65	55	140	157	1948	2244	2160	2492		

(Continued.....)

(Continued table 6)

Southern Dry Zone (6)												
Sl No	Location	Water Soluble K		Exchangeable K		Non exch- K		Lattice K		Total K		
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	
21	Madanahalli-1	10	6	38	31	130	140	2422	2623	2600	2800	
22	Madanahalli-2	8	5	46	42	150	160	2192	2490	2400	2700	
23	Grundlupet	8	6	32	23	120	130	1800	2086	2000	2300	
24	V.C.Farm	12	8	88	72	160	185	2816	2624	2800	3000	
25	Mandya	4	4	52	41	125	130	2679	2605	2800	2900	
26	Malavalli	6	8	64	52	130	148	1800	1993	2000	2200	
27	Maddur	8	5	84	64	150	186	2058	2371	2300	2600	
28	Pandavapura	10	8	60	40	145	155	1985	2197	2200	2400	
Average values		8	6	58	46	139	154	2219	2374	2388	2612	
Southern Transition Zone (7)												
29	Navile-1	12	6	50	50	140	150	2198	2414	2400	2600	
30	Navile-2	12	10	42	30	120	130	2426	2630	2600	2800	
31	Abbalagere	8	6	50	45	110	125	2632	3024	2800	3200	
32	Kommanalu	6	6	55	50	130	140	2409	2804	2600	3000	
33	Holalu	6	4	80	68	140	145	2494	2883	2700	3100	
34	Sithapur	4	4	92	70	130	150	2284	2526	2500	2750	
35	Belur	6	6	49	42	135	158	2413	2604	2600	2800	
36	Periyapatna	12	10	94	68	130	150	1817	2272	2053	2500	
Average values		8	7	64	53	129	144	2334	2645	2532	2844	

(Continued.....)

(Continued table 6)

<b>Hilly Zone (9)</b>													
Sl No	Location	Water Soluble K		Exchangeable K		Non excl- K		Lattice K		Total K			
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm		
37	Thirthahalli	8	6	62	42	140	150	2182	2574	2400	2800		
38	Sagar	10	8	68	50	130	145	2188	2191	2400	2500		
39	Balehonnur	14	12	143	120	110	125	1933	2143	2200	2400		
40	Devarapalli	12	10	82	78	125	140	2341	2572	2560	2800		
41	Appangala	12	8	86	80	145	160	2057	2152	2300	2400		
42	Peraji	4	4	36	32	140	150	1920	2490	2100	2676		
Average values		10	8	80	67	132	145	2104	2354	2326	2596		
<b>Coastal Zone (10)</b>													
43	Brahmavara-1	8	8	48	36	110	130	2134	2426	2300	2600		
44	Brahmavara-2	8	4	48	38	120	140	1824	2618	2000	2800		
45	Sasthana	6	4	50	40	145	160	1999	2196	2200	2400		
46	Kukunjabaylu	8	8	48	46	150	155	1789	2191	2000	2400		
47	Puttur	8	6	44	42	125	135	2123	2217	2300	2400		
48	Pangala	8	4	74	61	145	155	1773	2167	2000	2400		
49	Kankanady	10	6	58	44	130	145	2202	2305	2400	2500		
50	Bundka	6	8	52	46	160	178	1982	2568	2200	2800		
Average values		8	6	53	44	136	150	1978	2336	2175	2538		

The exchangeable potassium content in the surface layer of soils ranged from 44 to 180 mg K kg<sup>-1</sup> with Bedadahalli and Byadarahalli-2 recording the lowest and the highest values. In the subsurface layer of soils, the exchangeable potassium content ranged from 40 to 135 mg K kg<sup>-1</sup>, the lowest and the highest values being recorded by Bedadahalli and Byadarahalli-2 respectively.

The non-exchangeable potassium content varied between 110 and 280 and, 130 and 320 mg K kg<sup>-1</sup> in surface and subsurface layers of soils respectively. The highest value of this form of potassium, both under surface and subsurface depth of soil was registered by Byadarahalli-2. On the other hand, the lowest values were registered by Bandihalli-2 and Bandihalli-1 respectively for the surface and subsurface depths of soils.

The lattice potassium content in the central dry zone varied from 1794 to 3132 mg K kg<sup>-1</sup> in the surface layer of soils and from 2114 to 3540 mg K kg<sup>-1</sup> in the subsurface layer of soils. The lowest content of lattice bound potassium in the surface layer of soil was recorded by Kallambella and the highest content was recorded by Byadarahalli-2. Similarly, the lowest and the highest amounts of lattice potassium in the subsurface layer were recorded by soils of Karadikere and Byadarahalli-2, respectively.

The total potassium content in soils of this zone varied from 2000 to 3600 mg K kg<sup>-1</sup> in the surface layer and 2000 to 4000 mg K kg<sup>-1</sup> in the subsurface layer of soils. In general the subsurface layer registered higher content of total potassium than the surface layer in all the soils.

#### **4.3.2 Eastern Dry Zone:**

The highest amount of water-soluble potassium (10 mg K kg<sup>-1</sup>) at 0-15 cm depth of soil was found in Arur and the lowest amount (4 mg K kg<sup>-1</sup>) was accounted in Muthenahatti-1. In the subsurface layer (15-30cm) of soil, the content of the same form of potassium ranged from 4 to 8 mg K kg<sup>-1</sup>.

Exchangeable potassium content in the surface layer of soils varied between 38 and 114 mg K kg<sup>-1</sup>. In the subsurface layer of soils, it varied between 38 and 96 mg K

$\text{kg}^{-1}$ . The highest values of 114 and 96  $\text{mg K kg}^{-1}$  respectively in surface and subsurface horizons were recorded by Arur and the lowest values of 30  $\text{mg K kg}^{-1}$  (0-15cm) and 30  $\text{mg K kg}^{-1}$  (15-30cm depth) were recorded by Muthenahatti-1 and Upparahalli-1 soils respectively.

In respect of non-exchangeable potassium, the lowest values, viz. 120  $\text{mg K kg}^{-1}$  and 130  $\text{mg K kg}^{-1}$  in the surface and the subsurface depths of soils were recorded by Vokkaleri and Upparahalli-1 respectively. The highest values viz. 155  $\text{mg K kg}^{-1}$  (surface) and 160  $\text{mg K kg}^{-1}$  (subsurface) were recorded by Muthenahatti -1 and Arur respectively.

The lowest (1429  $\text{mg K kg}^{-1}$ ) and the highest (2573  $\text{mg K kg}^{-1}$ ) contents of lattice potassium were observed respectively in Upparahalli-1 and Kenchanapura soils at 0-15 cm depth. At 15-30 cm, the lowest potassium content (1782  $\text{mg K kg}^{-1}$ ) was observed in Muthenahatti-1 and the highest potassium content (2764  $\text{mg K kg}^{-1}$ ) was observed in Kenchanapura.

The total potassium content in soils ranged from 1600 to 2800  $\text{mg K kg}^{-1}$  in the surface layer, whereas in the subsurface layer it ranged from 2000 to 3000  $\text{mg K kg}^{-1}$ .

#### 4.3.3 Southern Dry Zone:

In this zone, the water soluble form of potassium in the soils varied from 4 to 12  $\text{mg K kg}^{-1}$  in the surface layer of soils, the lowest amount being noticed in Mandya and the highest amount being noticed in Madanahalli-2. In the subsurface layer of soils, the lowest content (4  $\text{mg K kg}^{-1}$ ) was observed in Mandya and the highest content (8  $\text{mg K kg}^{-1}$ ) was observed in V.C.Farm, Malavalli and Pandavapura.

The exchangeable potassium contents varied from 32  $\text{mg K kg}^{-1}$  to 88  $\text{mg K kg}^{-1}$  in the surface layer of soils and from 23 to 72  $\text{mg K kg}^{-1}$  in the subsurface layer of soils. The lowest values were recorded by Gundlupet and the higher values were recorded by V.C.Farm.

The non-exchangeable form of potassium varied from 120 to 160 mg K kg<sup>-1</sup> in the surface samples of soils and from 130 to 185 mg K kg<sup>-1</sup> in the subsurface samples of soils. The highest potassium contents for both surface and subsurface samples of soils was found in V.C.Farm, whereas the lowest potassium contents for both the depths of soils was found in Gundlupet.

The surface soils contained lattice potassium in amounts ranging from 1800 to 2816 mg K kg<sup>-1</sup>, while subsurface soils contained the same form of potassium in amounts ranging from 1993 to 2624 mg K kg<sup>-1</sup>. The lowest value of lattice potassium in both surface and subsurface samples of soils was registered by Malavalli. The highest value of lattice potassium in both depths of soil was registered by V.C.Farm.

Generally the total potassium content of soils were higher in subsurface layer than in the surface layer of soils. The total potassium content of soils ranged from 2000 to 2800 and from 2200 to 3000 mg K kg<sup>-1</sup> in surface and subsurface layers respectively.

#### **4.3.4 Southern Transition Zone:**

The water soluble potassium content in the soils of this zone varied from 4 to 12 and 4 to 10 mg K kg<sup>-1</sup> in the surface and the subsurface layers respectively. The lowest value for water soluble potassium in both surface and subsurface soils was registered by Sithapur soil and the highest value for surface soil, was registered by Navile-1 and that of subsurface was registered by Periyapatna.

In the first layer (0-15cm), the lowest (42 mg K kg<sup>-1</sup>) and the highest (94 mg K kg<sup>-1</sup>) exchangeable potassium contents were observed respectively in the soils of Navile-2 and Periyapatna. In the second layer (15-30 cm), the lowest (30 mg K kg<sup>-1</sup>) and the highest (68 mg K kg<sup>-1</sup>) amounts of K were observed respectively in soils of Navile-2 and Periyapatna.

Non-exchangeable potassium in the surface and subsurface layers of soils of this zone varied from 110 to 140 and, 125 to 150 mg K kg<sup>-1</sup> respectively. The lowest and the highest values for the two depths of soils were recorded by Navile-2 and Kommanalu.

The lowest content of lattice bound potassium (1817 mg K kg<sup>-1</sup>) in the surface layer of soils was found in Periyapatna and the highest content (2632 mg K kg<sup>-1</sup>) was found in Abbalagere. The lattice Potassium in the subsurface layer of soils varied from 2272 to 3024 mg K kg<sup>-1</sup> with Periyapatna and Abbalagere recording the lowest and the highest value.

The total potassium content of soils ranged from 2053 to 2800 mg K kg<sup>-1</sup> in first depth and 2500 to 3200 mg K kg<sup>-1</sup> in the second depth.

#### 4.3.5 Hilly Zone:

Water-soluble potassium content in the surface samples of soils ranged from 4 and 14 mg K kg<sup>-1</sup>. The lowest value was recorded by Peraje and the highest value was by Balehonnur. In the subsurface samples of soils, the potassium content ranged from 4 to 12 mg K kg<sup>-1</sup> with Peraje and Balehaonnur soils recording the lowest and the highest value respectively.

The exchangeable potassium contents in the surface and the subsurface layer of soils varied from 36 to 143 mg K kg<sup>-1</sup> and 32 to 120 mg K kg<sup>-1</sup> respectively. At both the depths of soil, the lowest and the highest values for exchangeable potassium were recorded by soils from Peraje and Balehonnur, respectively.

The surface and subsurface depths of soils of hilly zone contained non-exchangeable potassium in the range, 110 to 145 mg K kg<sup>-1</sup> and, 125 to 160 mg K kg<sup>-1</sup> respectively. In the surface depth, the highest content was found in Appangala and the

lowest content was found in Balehonnur soil. In the subsurface depth, the highest and the lowest contents of potassium were found in the same soils.

Hilly zone soils varied widely with respect to lattice potassium content of the surface layer, the lowest amount ( $1920 \text{ mg K kg}^{-1}$ ) being found in Peraje and the highest amount ( $2188 \text{ mg K kg}^{-1}$ ) in Sagar. The lattice potassium content varied from 2143 to  $2574 \text{ mg K kg}^{-1}$  in sub surface soil with the highest and the lowest amounts being found in Balehonnur and Thirthahalli respectively.

In respect of total potassium, the lowest and the highest values were 2100 and  $2560 \text{ mg K kg}^{-1}$  in the surface layer of soils, and 2400 and  $2800 \text{ mg K kg}^{-1}$  in the sub surface layer respectively.

#### 4.3.6 Coastal Zone:

In the surface layer, the lowest water soluble potassium content ( $4 \text{ mg K kg}^{-1}$ ) was recorded by soils from Bundka and Sasthana and the highest potassium content ( $10 \text{ mg K kg}^{-1}$ ) was recorded by Kankanady. In the subsurface layer, water-soluble potassium content varied between 4 and  $8 \text{ mg K kg}^{-1}$  with soils from Brahmavara-2 and Bundka registering the lowest and the highest value.

The data in respect of exchangeable potassium in the soils of this zone showed the highest ( $74 \text{ mg K kg}^{-1}$  and  $61 \text{ mg K kg}^{-1}$ ) values in Pangala for the first and the second depths respectively. Similarly, the lowest values of 48 and  $360 \text{ mg K kg}^{-1}$  of exchangeable potassium was found in Brahmavara-1 for the surface and subsurface depths respectively.

The soil sample collected at Brahmavara-1 recorded the lowest (110 and  $130 \text{ mg K kg}^{-1}$ , respectively) non-exchangeable potassium content at both surface and subsurface depths. In surface depth, the highest amount of non-exchangeable potassium ( $160 \text{ mg K kg}^{-1}$ ) was found in Bundka, and in the subsurface depth of soils, the highest amount of this form of potassium ( $178 \text{ mg K kg}^{-1}$ ) was found in the same soil. The non-

exchangeable potassium ranged between 110 and 160 and 130 and 178  $\text{mg K kg}^{-1}$  in the surface and subsurface depths of soils respectively.

Soils of this zone recorded lowest values of 1773  $\text{mg K kg}^{-1}$  and 2167  $\text{mg K kg}^{-1}$  as lattice potassium in the surface and sub surface layers, respectively. The highest values of lattice potassium in the top (0-15cm) and the bottom (15-30cm) layers were 2186  $\text{mg K kg}^{-1}$  and 2589  $\text{mg K kg}^{-1}$  respectively. Kankanady recorded the highest value in the surface layer and Bundka recorded the highest value in subsurface layer of soils.

The soils of this zone varied widely with respect to total potassium content. In the surface layer, the lowest and the highest values recorded in respect of total potassium were 2000  $\text{mg K kg}^{-1}$  and 2400  $\text{mg K kg}^{-1}$  respectively, whereas in the subsurface layer, the lowest value recorded was 2400  $\text{mg K kg}^{-1}$  and highest value recorded was 2800  $\text{mg K kg}^{-1}$ .

#### 4.3.7 Correlation (r- values) between the forms of potassium and soil properties

Correlation (r-values) between the various forms of potassium and soil properties for 0-15 and 15-30cm soil depths are given in table 7 and 8.

Water-soluble potassium positively correlated with clay ( $r=0.3977^{**}$ ), pH ( $r=0.3161^*$ ), OC ( $r=0.3661^*$ ) and CEC ( $r=0.5972^{**}$ ), but was negatively correlated with silt content ( $r=-0.3054^*$ ) in soils of the surface layer, whereas in the subsurface layer, it positively correlated with pH ( $r=0.2786^*$ ).

There was positive and significant relationship between exchangeable K and, clay ( $r=0.3591^{**}$ ), OC ( $r=0.6494^{**}$ ), CEC ( $r=0.4683^{**}$ ) and water soluble K ( $r=0.8846^{**}$ ) in the surface layer of soil. In the subsurface layer of soil, exchangeable K was found to have significant and positive relationship with clay ( $r=0.4463^{**}$ ), OC ( $r=0.6441^{**}$ ), CEC ( $r=0.3849^{**}$ ) and water soluble K ( $r=0.6447^{**}$ ).

Table 7. Correlation between forms of potassium and soil properties for 0-15cm depth (r- values)

	Sand	Silt	Clay	pH	OC	CEC	WS-K	Exch-K	Nonexch-K	Lattice-K
Water soluble-K	0.2331	-0.3054*	0.2277	0.3161*	0.3661**	0.5972**				
Exchangeable-K	-0.0700	-0.1417	0.3591**	0.2105	0.6494**	0.4683**	0.8846**			
Non exchangeable-K	-0.2310	-0.4062**	0.3216*	0.0751	-0.2148	0.0607	0.1603	0.3126*		
Lattice-K	-0.5702**	-0.2546	0.2864*	0.1406	-0.1344	-0.1308	-0.1960	-0.2962*	0.1429	
Total-K	-0.5012**	-0.2694	0.2896*	0.4168**	-0.0759	-0.1303	-0.0983	-0.3307*	-0.1953	0.5121**

Table 8. Correlation between forms of potassium and soil properties for 15-30cm depth (r- values)

	Sand	Silt	Clay	pH	OC	CEC	WS-K	Exch-K	Non-exch-K	Lattice-K
Water soluble-K	0.2376	-0.3831**	0.2271	0.2786*	0.0868	0.1319				
Exchangeable-K	-0.2915*	-0.5144**	0.4463**	0.1762	0.6441**	0.3849**	0.6447**			
Non exchangeable-K	-0.1573	-0.3551*	0.5773**	0.1448	0.3213*	0.2050	0.3488*	0.3280*		
Lattice-K	-0.0988	-0.0204	0.3550*	0.0281	-0.2563	-0.2667	-0.2179	-0.1963	0.1329	
Total-K	-0.1772	-0.1183	0.1541	-0.0134	-0.2347	-0.2639	-0.1980	-0.3042*	0.1319	0.5726**

\*Significance at 0.05; \*\* Significance at 0.01

The non-exchangeable potassium fraction in the surface layer of soils was positively and significantly correlated with clay ( $r=0.3216^*$ ), exchangeable K ( $r=0.3126^*$ ) and negatively correlated with silt content ( $r=-0.4062^{**}$ ). In the subsurface depth, the non-exchangeable K was significantly and positively correlated with clay ( $r=0.5773^{**}$ ), OC ( $r=0.3213^*$ ), water soluble K ( $r=0.3488^*$ ) and exchangeable-K ( $r=0.3280^*$ ).

Significant and positive relationship was observed between lattice potassium and clay ( $r=0.2864^*$ ), but negative relationship with sand ( $r=-0.5702^{**}$ ), and exchangeable K ( $r=-0.2962^*$ ) in the surface layer of soils. In the subsurface layer also, significant and positive relationship was observed with clay ( $r=0.3550^*$ ).

The total potassium content was significantly and positively correlated with clay ( $r=0.2896^*$ ), pH ( $r=0.4168^*$ ) and lattice K ( $r=0.5121^{**}$ ) and was negatively correlated with sand ( $r=-0.5012^{**}$ ) and exchangeable-K ( $r=-0.3307^*$ ) in the surface depth of soil. Similar observation was recorded even for subsurface depth of soil.

#### 4.4 Potassium fixing capacity of soils

Twenty five surface samples out of fifty collected from different zones of southern Karnataka were selected to study potassium fixing capacity and the results are presented in table 9.

The potassium fixing capacity ranged from 0.09 to 1.44  $\text{cmol (p}^+) \text{ kg}^{-1}$ . Soil from Appangala (Hilly zone), with high  $\text{NH}_4\text{OAc-K}$  recorded the least amount of K-fixation ( $0.09 \text{ cmol (p}^+) \text{ kg}^{-1}$ ), whereas soil from Byadarahalli village recorded the highest amount of potassium fixation ( $1.44 \text{ cmol (p}^+) \text{ kg}^{-1}$ ). There was not a definite trend in the variations observed in respect of K- fixation by soils of different agro-climatic zones.

Table 9. Potassium fixing capacity of soils

SI No	Location	Taluk	Agro climatic zone	Cropping System	K-fixing capacity cmol (p <sup>+</sup> ) kg <sup>-1</sup>
1	Bashettihalli	Doddaballapur	Eastern dry zone	Ground nut (Irr)	0.32
2	Sasthana	Udupi	Coastal zone	Ground nut (Irr)	0.21
3	Brahmavara	Udupi	Coastal zone	Rice-Rice (Irr)	0.20
4	Karkala	Karkala	Coastal zone	Rice-Rice (Irr)	0.18
5	Tharur	Sira	Central dry zone	Jowar (Rain fed)	0.18
6	Vokkaleri	Hoskote	Eastern dry zone	Vegetables (Irr)	0.10
7	Brahmavara	Udupi	Coastal zone	Sugar cane (Irr)	0.18
8	Muthenahatti	Malur	Eastern dry zone	Mango plantation	0.12
9	Byadarahalli	Hiriyur	Central dry zone	Ragi (Rain fed)	1.23
10	Madanahalli	Mysore	Southern dry zone	Ragi (Rain fed)	0.53
11	Kallambella	Sira	Central dry zone	Groundnut (Rain fed)	0.36
12	Tharikere	Tharikere	Southern transitional zone	Rice-Rice (Irr)	0.61
13	Devanahalli	Devanahalli	Eastern dry zone	Mulberry (Irr)	0.41
14	Arur	Chikkaballapur	Eastern dry zone	Vegetables (Irr)	0.52
15	Navile	Shimoga	Southern transitional zone	Tobacco (Rain fed)	0.15
16	Mandya	Mandya	Southern dry zone	Sugarcane (Irr)	0.28
17	Appangala	Madikeri	Hilly zone	Cardamom (Rain fed)	0.09
18	Bandihalli	Arasikere	Central dry zone	Coconut (Irr)	0.38
19	Navile	Shimoga	Southern transitional zone	Groundnut (Rain fed)	0.16
20	Karadikere	Thiptur	Central dry zone	Rice-Rice (Irr)	0.22
21	Thirthahalli	Thirthahalli	Hilly zone	Rice-Rice (Irr)	0.32
22	Belgere	Thiptur	Central dry zone	Rdgram (Rain fed)	0.92
23	Devarapalli	Madikeri	Hilly zone	Coffee (Irr)	0.25
24	Balehonnur	Koppa	Hilly zone	Coffee (Irr)	0.23
25	Byadarahalli	Hiriyur	Central dry zone	Coconut (Irr)	1.44

Table 10. Correlation between Potassium fixing capacity and different soil properties

SI No	Soil characters vs Potassium fixing capacity ( KFC)	Correlation coefficients (r-values)
1	KFC with Sand	-0.1083
2	KFC with Clay	0.4226*
3	KFC with pH	0.5209**
4	KFC with OC	-0.1977
5	KFC with CEC	0.4620*
6	KFC with Ca	0.2917
7	KFC with Exch-K	0.2030
8	KFC with Non exch-K	0.5054**

\*Significance at 0.05    \*\* Significance at 0.01

#### **4.4.1 Correlation between potassium fixing capacity (KFC) and certain soil properties (r-values)**

Correlation between potassium fixing capacity of soils and certain soil properties is shown in table 10.

There was positive and significant relationship between potassium fixation capacity and pH ( $r=0.5209^{**}$ ), clay ( $r=0.4226^*$ ), CEC ( $r=0.4620^*$ ) and non-exchangeable-K ( $r=0.5054^*$ ), and negative relationship between K-fixing capacity and, sand ( $r=-0.1083$ ) and OC ( $r=-0.1977$ ) was observed but not significant.

#### **4.5 Potassium release Characteristics in soils**

The potassium release parameters were obtained only for the surface soil samples of different agro climatic zones of Southern Karnataka. The same 25 soil samples selected for the fixation were used for this study also. The results are presented in table 11.

##### **4.5.1 Cumulative potassium release**

The cumulative potassium release from different soils ranged from 368 to 977 mg K kg<sup>-1</sup>. The lowest and the highest cumulative K-release values were registered by soils of Balehonnur (hilly zone) and Byadarahally (central dry zone) respectively. The soils with higher contents of NH<sub>4</sub>OAc- K recorded relatively higher cumulative release of K than the soils with lower amounts of available K. The magnitude of K release from the soils at each extraction also depended upon the initial amount of NH<sub>4</sub>OAc-K in the soil with soils recording relatively higher quantities of NH<sub>4</sub>OAc K releasing higher amounts of K at each extraction than those recording lower quantities of NH<sub>4</sub>OAc-K. In general, potassium release from the soils was faster up to 5<sup>th</sup> extraction, gradually became slow, and reached constancy by the 11<sup>th</sup> or 12<sup>th</sup> extraction. This kind of a trend was observed in

Table 11. Release of potassium (mg kg<sup>-1</sup>) with boiling 1N HNO<sub>3</sub>, Step potassium and Constant rate potassium in soils

Sl No	Successive extraction (number) with 1N HNO <sub>3</sub>														Cumulative K release	Total step-K	C R-K
	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
1	135	96	84	51	40	34	28	25	25	15	8	5	5	-	486	5	
2	178	112	108	78	53	38	22	20	12	8	5	2	2	2	640	2	
3	182	90	71	45	42	30	26	21	10	5	2	2	1	1	514	1	
4	175	120	113	54	49	32	29	25	18	8	5	5	5	-	573	5	
5	140	108	54	44	32	28	28	17	10	4	1	1	-	-	467	1	
6	156	102	80	38	30	25	25	23	16	12	7	7	7	7	535	7	
7	144	110	101	86	54	38	27	25	17	8	5	2	2	-	593	2	
8	174	112	104	55	52	48	41	38	32	18	8	5	5	5	627	5	
9	205	155	142	135	75	62	53	40	25	20	20	15	15	15	977	15	
10	178	76	72	60	54	41	30	24	18	15	14	10	10	10	612	10	
11	168	110	75	65	51	45	33	29	22	12	7	4	4	-	625	4	
12	142	62	34	25	25	22	20	20	12	10	5	5	5	5	392	5	
13	184	82	40	38	34	31	26	18	15	15	10	6	6	6	427	6	
14	192	145	85	32	30	28	25	15	7	7	7	-	-	-	496	7	
15	180	112	106	56	48	32	30	27	20	17	8	8	-	-	548	8	
16	138	76	72	62	54	40	35	21	15	12	10	7	7	7	556	7	
17	145	125	85	40	26	18	10	7	6	3	3	3	-	-	481	3	
18	145	108	102	54	50	46	32	29	20	9	9	9	-	-	613	9	
19	125	115	110	82	76	57	41	28	20	13	8	4	4	4	687	4	
20	143	128	86	42	33	21	20	18	15	10	7	7	-	-	530	7	
21	132	92	45	35	22	22	18	16	10	6	6	6	6	-	416	6	
22	194	100	60	58	52	49	40	35	28	17	12	11	11	11	678	11	
23	138	74	32	30	25	25	19	19	15	10	5	5	-	-	397	5	
24	132	45	41	35	25	25	15	15	8	8	6	6	6	-	368	6	
25	218	164	120	85	80	45	36	20	20	14	14	10	10	10	846	10	

almost all the samples irrespective of the places from where they were collected or the variations in the soil types.

#### **.4.5.2 Total step potassium**

The total step potassium content in soils of different zones in southern Karnataka ranged from 290.00 to 767.00 mg K kg<sup>-1</sup> in the 0-15 cm depth. The lowest value was recorded by Balehonnur (Hilly zone) soil which has also recorded the highest amount of NH<sub>4</sub>OAC-K in the soils selected for this study and, the highest value was recorded by Byadarahalli soil (Central dry zone) which has recorded medium available K status.

#### **4.5.3 Constant rate potassium**

The constant rate potassium (CR-K) content of soils ranged from 1 to 15 mg K kg<sup>-1</sup> in the surface layer of soils collected from different zones in southern Karnataka. The lowest CR-K was recorded by soils of Brahmavara (Coastal zone) and Tharur (Central dry zone) which are low with respect to available K status and the highest CR-K value was recorded by Byadarahalli (Central dry zone) which is medium in available K status. Arur recorded the CR-K value (7 ppm) at the 9<sup>th</sup> extraction itself, whereas Byadarahalli (15 ppm), Madanahalli (10 ppm) and Belgere (11 ppm) recorded the CR-K at the 12<sup>th</sup> extraction.

#### **4.5.4 Kinetics of potassium desorption**

Results in respect of cumulative potassium desorption and kinetics of potassium release are presented in table 12 and 13 respectively.

Table 12. Cumulative Potassium desorbed ( $\text{mg kg}^{-1}$ ) in soils

SI No	Potassium ( $\text{mg kg}^{-1}$ ) desorption at different intervals of time (hours)																	Cumulative-K
	24	48	72	96	120	144	168	192	216	240	264	288	312	336				
1	62.6 (62.6)	30.2 (92.8)	28.8 (121.6)	24.0 (145.6)	22.1 (167.7)	20.8 (188.5)	18.2 (206.7)	14.6 (221.3)	12.5 (233.8)	11.4 (245.2)	10.3 (255.5)	9.8 (265.3)	9.4 (274.7)	9.2 (283.9)			283.9	
2	54.0 (54.0)	27.4 (81.4)	25.8 (107.3)	20.4 (127.6)	16.2 (143.8)	16.0 (159.8)	14.4 (174.2)	12.8 (187.0)	12.0 (199.0)	11.5 (210.5)	10.8 (221.3)	10.7 (232.0)	10.6 (242.6)	10.4 (253.0)			253.0	
3	38.9 (38.9)	25.8 (64.7)	24.5 (89.2)	16.0 (105.2)	15.0 (120.2)	11.0 (131.2)	10.0 (141.2)	9.0 (150.2)	8.0 (158.2)	6.0 (164.2)	5.3 (169.5)	5.0 (174.5)	4.8 (179.3)	4.5 (183.8)			183.8	
4	48.0 (48.0)	29.7 (77.7)	25.8 (103.5)	18.0 (121.5)	17.2 (138.7)	14.0 (152.7)	14.0 (166.7)	10.8 (177.5)	8.7 (186.2)	6.0 (202.2)	14.0 (216.2)	10.0 (226.2)	8.0 (234.2)	4.0 (238.2)			238.2	
5	79.2 (79.2)	40.2 (119.4)	30.2 (149.6)	30.0 (179.6)	30.0 (209.6)	28.0 (237.6)	24.2 (261.8)	20.0 (281.8)	18.8 (300.6)	16.8 (317.4)	14.2 (331.6)	7.6 (339.2)	5.8 (345.0)	5.2 (350.2)			350.2	
6	85.4 (85.4)	38.2 (123.6)	36.0 (159.6)	34.0 (193.6)	30.0 (223.6)	28.8 (252.4)	28.0 (280.4)	26.0 (306.4)	25.1 (331.5)	20.2 (351.7)	15.8 (367.5)	12.2 (379.7)	10.1 (389.8)	10.0 (399.8)			399.8	
7	40.2 (40.2)	28.8 (61.0)	20.5 (81.5)	18.4 (99.4)	16.4 (116.3)	15.1 (131.4)	10.2 (141.6)	8.9 (150.5)	8.7 (159.2)	8.2 (167.4)	6.8 (174.2)	4.8 (179)	4.2 (183.2)	4.1 (187.3)			187.3	
8	81.2 (81.2)	44.3 (125.5)	28.9 (154.4)	25.2 (179.6)	20.8 (200.4)	20.0 (220.4)	20.0 (240.4)	15.5 (255.9)	15.4 (271.4)	15.2 (286.5)	14.8 (301.3)	10.2 (311.5)	8.8 (320.3)	8.2 (328.5)			328.5	
9	118.5 (118.5)	58.3 (176.8)	38.2 (215.0)	26.5 (241.5)	21.2 (262.7)	18.7 (281.4)	14.5 (295.9)	12.8 (308.7)	10.7 (319.4)	9.1 (328.5)	8.5 (337.0)	7.0 (344.0)	6.5 (350.5)	5.8 (356.3)			356.3	
10	88.2 (88.2)	44.8 (133.0)	40.2 (173.2)	35.5 (208.7)	35.0 (243.7)	35.0 (278.7)	28.3 (307.0)	26.5 (333.5)	20.2 (353.7)	18.2 (371.9)	12.8 (384.7)	10.9 (395.6)	10.8 (406.4)	10.6 (417.0)			417.0	
11	62.3 (62.3)	30.1 (92.4)	25.4 (117.8)	25.2 (143.0)	20.8 (163.8)	20.4 (184.2)	20.2 (204.4)	18.2 (222.6)	16.8 (239.4)	15.1 (254.5)	14.0 (268.5)	12.8 (281.3)	10.9 (292.2)	10.0 (302.2)			302.2	
12	76.8 (76.8)	64.2 (141.0)	30.8 (171.8)	21.4 (193.2)	20.2 (213.4)	20.0 (233.4)	16.0 (249.4)	15.0 (264.4)	14.0 (278.4)	13.0 (291.4)	10.0 (301.4)	9.0 (310.4)	8.0 (318.4)	5.0 (323.4)			323.4	
13	69.2 (69.2)	46.8 (116.0)	28.2 (144.2)	25.3 (169.5)	23.1 (192.6)	21.4 (214.0)	18.3 (232.3)	17.5 (249.8)	14.8 (264.6)	12.0 (276.6)	11.5 (288.1)	11.3 (299.4)	11.0 (310.4)	11.0 (321.4)			321.4	
14	52.5 (52.5)	34.7 (87.2)	25.4 (112.6)	23.4 (136.0)	22.8 (158.8)	22.0 (180.8)	16.6 (197.4)	15.9 (213.3)	14.5 (227.8)	14.0 (241.8)	10.8 (252.6)	10.6 (263.2)	10.4 (273.6)	10.2 (283.8)			283.8	

(Continued.....)

(Continued Table 12)

15	91.3	58.2 (149.5)	46.3 (195.8)	24.8 (220.6)	20.2 (240.8)	18.9 (259.7)	16.0 (275.7)	14.1 (289.8)	13.0 (302.8)	12.5 (315.3)	10.2 (325.5)	9.3 (334.8)	8.2 (343.0)	8.0 (351.0)	351.0
16	87.6	47.4 (135.0)	42.3 (177.3)	40.8 (218.1)	30.3 (248.4)	24.4 (272.8)	20.5 (293.0)	20.0 (313.0)	16.4 (329.4)	14.0 (343.4)	10.8 (354.2)	9.8 (364.0)	8.0 (372.0)	7.0 (379.0)	379.0
17	54.4	43.8 (98.2)	29.2 (127.4)	26.9 (154.3)	20.8 (175.1)	18.0 (193.1)	10.2 (203.3)	10.0 (213.3)	9.5 (222.8)	8.0 (230.8)	4.8 (235.6)	4.4 (240.0)	4.3 (244.3)	4.0 (248.3)	248.3
18	57.8	28.3 (86.1)	24.0 (110.1)	16.0 (126.1)	15.7 (141.8)	14.3 (156.1)	12.2 (168.3)	11.2 (179.5)	8.7 (188.2)	7.6 (195.8)	5.9 (201.7)	5.6 (207.3)	5.2 (212.5)	5.0 (217.5)	217.5
19	86.1	54.6 (140.7)	20.1 (160.8)	18.4 (179.2)	16.3 (195.5)	15.0 (210.5)	13.3 (223.8)	11.8 (235.6)	9.4 (245.0)	7.7 (252.7)	6.4 (259.1)	5.1 (264.2)	4.9 (269.1)	4.7 (273.8)	273.8
20	49.3	28.7 (78.0)	24.2 (102.2)	18.0 (120.2)	16.0 (136.2)	15.8 (152.0)	14.2 (166.2)	12.0 (178.2)	10.7 (188.9)	8.3 (197.2)	6.8 (204.0)	5.9 (209.9)	5.8 (215.7)	5.7 (221.4)	221.4
21	87.4	31.3 (118.7)	20.3 (139.0)	10.6 (149.6)	8.4 (158.0)	6.4 (164.4)	5.5 (169.9)	5.0 (174.9)	4.6 (179.5)	4.2 (183.7)	3.6 (187.3)	3.5 (190.8)	3.5 (194.3)	3.0 (197.3)	197.3
22	80.4	40.1 (120.5)	20.4 (140.9)	19.8 (160.7)	18.2 (178.9)	17.7 (196.6)	14.4 (211.0)	12.8 (223.8)	11.2 (235.0)	10.2 (245.2)	9.8 (255.0)	9.6 (264.6)	9.5 (274.1)	9.3 (283.4)	283.4
23	88.0	33.8 (121.8)	26.5 (148.3)	17.0 (165.3)	14.3 (179.6)	12.5 (192.1)	11.5 (203.6)	8.0 (211.6)	6.7 (218.3)	6.0 (224.3)	5.6 (229.9)	5.0 (234.9)	4.3 (239.2)	3.8 (243.0)	243.0
24	64.3	24.0 (88.3)	12.0 (100.3)	8.5 (108.8)	5.2 (114.0)	5.0 (119.0)	5.0 (124.0)	4.8 (128.8)	4.5 (133.3)	4.5 (137.8)	4.5 (142.3)	4.5 (146.8)	4.3 (151.1)	3.0 (154.1)	154.1
25	120.1	86.4 (206.5)	40.2 (246.7)	35.0 (281.7)	33.5 (215.2)	20.0 (335.2)	18.0 (353.2)	14.5 (367.7)	12.0 (379.7)	10.0 (389.7)	8.2 (397.9)	7.4 (405.3)	7.3 (412.6)	7.2 (419.8)	419.8

Figures in parenthesis indicate amount of cumulative K desorbed from soils after particular period of time.

Table 13. Relation between time (x) and  $\log K_d/K_0(y)$ 

Sl no	Up to 120 hours			120-336 hours		
	Regression equation	R <sup>2</sup>	K <sub>d</sub> (h <sup>-1</sup> )	Regression equation	R <sup>2</sup>	K <sub>d</sub> (h <sup>-1</sup> )
1	Y = -0.146 - 0.0021 x	0.91	3.95X10 <sup>-3</sup>	Y = -0.210 - 0.0019 x	0.95	3.28X10 <sup>-3</sup>
2	Y = -0.132 - 0.0034 x	0.89	5.21X10 <sup>-3</sup>	Y = -0.141 - 0.0029 x	0.93	1.66X10 <sup>-3</sup>
3	Y = -0.129 - 0.0028 x	0.94	3.88X10 <sup>-3</sup>	Y = -0.219 - 0.0034 x	0.96	1.51X10 <sup>-3</sup>
4	Y = -0.212 - 0.0014 x	0.92	4.26X10 <sup>-3</sup>	Y = -0.312 - 0.0041 x	0.95	1.99X10 <sup>-3</sup>
5	Y = -0.311 - 0.0019 x	0.87	3.95X10 <sup>-3</sup>	Y = -0.216 - 0.005 x	0.91	2.26X10 <sup>-3</sup>
6	Y = -0.114 - 0.0036 x	0.93	3.79 X10 <sup>-3</sup>	Y = -0.514 - 0.0048 x	0.96	1.42X10 <sup>-3</sup>
7	Y = -0.118 - 0.0041 x	0.88	3.24X10 <sup>-3</sup>	Y = -0.418 - 0.0014 x	0.94	1.71X10 <sup>-3</sup>
8	Y = -0.210 - 0.0026 x	0.96	4.93X10 <sup>-3</sup>	Y = -0.624 - 0.0031 x	0.98	1.20X10 <sup>-3</sup>
9	Y = -0.312 - 0.003 x	0.84	6.23X10 <sup>-3</sup>	Y = -0.684 - 0.0049 x	0.93	3.68X10 <sup>-3</sup>
10	Y = -0.291 - 0.004 x	0.90	3.35X10 <sup>-3</sup>	Y = -0.32 - 0.0051 x	0.99	1.54X10 <sup>-3</sup>
11	Y = -0.216 - 0.004 x	0.98	4.30X10 <sup>-3</sup>	Y = -0.506 - 0.0018 x	0.93	9.47X10 <sup>-4</sup>
12	Y = -0.31 - 0.002 x	0.88	4.90X10 <sup>-3</sup>	Y = -0.414 - 0.0032 x	0.94	1.80X10 <sup>-3</sup>
13	Y = -0.40 - 0.006 x	0.81	4.46X10 <sup>-3</sup>	Y = -0.514 - 0.0019 x	0.89	9.60X10 <sup>-4</sup>
14	Y = -0.51 - 0.003 x	0.82	3.28X10 <sup>-3</sup>	Y = -0.41 - 0.0054 x	0.91	1.04X10 <sup>-3</sup>
15	Y = -0.41 - 0.0017 x	0.84	5.46X10 <sup>-3</sup>	Y = -0.321 - 0.0041 x	0.92	1.20X10 <sup>-3</sup>
16	Y = -0.216 - 0.004 x	0.87	4.35X10 <sup>-3</sup>	Y = -0.119 - 0.0024 x	0.91	1.89X10 <sup>-3</sup>
17	Y = -0.314 - 0.002 x	0.91	3.62X10 <sup>-3</sup>	Y = -0.481 - 0.003 x	0.94	2.13X10 <sup>-3</sup>
18	Y = -0.119 - 0.003 x	0.93	5.63X10 <sup>-3</sup>	Y = -0.517 - 0.002 x	0.96	1.48X10 <sup>-3</sup>
19	Y = -0.214 - 0.0021 x	0.94	6.31X10 <sup>-3</sup>	Y = -0.481 - 0.005 x	0.96	1.60X10 <sup>-3</sup>
20	Y = -0.118 - 0.004 x	0.84	4.50X10 <sup>-3</sup>	Y = -0.32 - 0.0019 x	0.91	1.33X10 <sup>-3</sup>
21	Y = -0.212 - 0.002 x	0.79	6.91X10 <sup>-3</sup>	Y = -0.41 - 0.002 x	0.89	2.27X10 <sup>-3</sup>
22	Y = -0.41 - 0.004 x	0.86	5.92X10 <sup>-3</sup>	Y = -0.41 - 0.004 x	0.92	3.60X10 <sup>-3</sup>
23	Y = -0.21 - 0.0031 x	0.89	6.67X10 <sup>-3</sup>	Y = -0.34 - 0.0021 x	0.94	1.71X10 <sup>-3</sup>
24	Y = -0.24 - 0.0021 x	0.93	5.53X10 <sup>-3</sup>	Y = -0.42 - 0.0031 x	0.95	1.91X10 <sup>-3</sup>
25	Y = -0.32 - 0.0031 x	0.91	6.90X10 <sup>-3</sup>	Y = -0.614 - 0.0019 x	0.94	5.46X10 <sup>-3</sup>

#### 4.5.4.1 Cumulative potassium desorption

Data on cumulative K desorption from various soils have been given in table 12. Potassium desorption essentially followed similar pattern in all the twenty five soil samples studied.

The soil from Balehonnur recorded the lowest cumulative potassium desorption value (154.1 mg K kg<sup>-1</sup>), while soil from Byadarahalli recorded the highest value (419.8 mg K kg<sup>-1</sup>). The cumulative desorption values ranged from 154.1 to 419.8 mg K kg<sup>-1</sup>. Cumulative K desorption did not show any specific relationship with available K content of soils.

#### 4.5.4.2 Potassium release kinetics

The linear regression equations and the desorption rate coefficients for the soil under study are given in table 13. It is very clear from the values shown in the table that potassium desorption rate co-efficients ( $k_d$ ) for exchangeable K release were much larger in the initial phase (up to 120 hours) and ranged from  $3.24 \times 10^{-3}$  (Brahmavara) to  $6.90 \times 10^{-3} \text{ h}^{-1}$  (Byadarahalli). The  $k_d$  values were found to be relatively higher for soils with relatively higher available K status than for soils with lower available K. The desorption co-efficient values ( $k_d$ ), for non-exchangeable K release (120 to 336 hours) ranged from  $9.47 \times 10^{-4} \text{ h}^{-1}$  (Kallambella) to  $5.46 \times 10^{-3} \text{ h}^{-1}$  (Byadarahalli). These  $k_d$  values for non-exchangeable K (120-336 hours) were lower in comparison to the  $k_d$  values observed for exchangeable K (up to 12 hours).

### 4.6 Quantity and Intensity (Q/I) parameters of potassium

The data on activity ratio ( $AR^k$ ) and the corresponding change in potassium ( $\pm \Delta K$ ) obtained during laboratory analytical studies on Q/I relationship for different soils (0-15cm) are shown in table 14.

Table 14. Activity Ratio of potassium ( $AR^k$ ) and corresponding change in Potassium ( $\pm\Delta K$ ) in surface soils.

Sl No	Location	Parameters	A	B	C	D	E	F	G	H
1	Bashettihalli	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.55	2.15	2.72	3.50	8.80	14.78	20.16	30.09
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.12	-0.07	-0.04	0.03	0.41	0.96	1.41	2.01
2	Sasthana	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.25	0.72	1.72	3.40	8.45	12.30	20.10	25.70
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.05	-0.02	0.03	0.12	0.20	0.35	0.52	0.55
3	Brahmavara	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.71	1.52	3.20	4.10	5.50	7.85	10.00	12.25
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.11	-0.09	-0.08	0.40	0.65	1.02	1.37	1.81
4	Karkala	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.73	0.98	1.95	3.15	6.75	8.93	12.95	18.26
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.18	-0.14	0.01	0.06	0.30	0.57	1.25	1.52
5	Tharur	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.68	2.65	4.80	5.55	11.04	19.20	26.20	30.02
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.08	-0.03	-0.01	0.12	0.28	0.36	0.64	0.88
6	Vokaleri	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.53	1.80	3.50	6.28	9.50	13.40	15.86	25.12
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.06	-0.04	-0.03	0.03	0.13	0.32	0.65	0.76
7	Brahmavara	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.98	1.25	2.07	3.51	7.81	10.86	15.34	18.40
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.19	-0.04	-0.02	0.15	0.96	1.25	1.35	2.10
8	Muthenahatti	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.21	0.58	2.80	3.11	8.86	11.16	18.55	25.50
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.15	-0.08	-0.04	0.02	0.08	0.18	0.28	0.42
9	Byadarahalli	$AR^k(M/L)^{0.5} \times 10^{-3}$	2.02	3.05	4.15	5.25	9.48	12.04	14.28	14.58
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.28	-0.22	-0.17	0.08	0.28	0.30	0.38	0.58
10	Madanahalli	$AR^k(M/L)^{0.5} \times 10^{-3}$	1.21	2.39	3.58	4.10	8.82	9.82	15.31	22.68
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.15	-0.13	-0.10	0.07	0.18	0.25	0.30	0.38
11	Kallambella	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.51	1.82	2.05	3.17	9.82	12.28	16.83	25.37
		$\pm\Delta K(cmol(p^+)kg^{-1})$	-0.08	-0.05	0.03	0.06	0.13	0.20	0.32	0.65

(Continued...)

(Continued table 14)

12	Tharikere	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.69	1.39	2.07	3.62	4.13	9.38	12.01	15.36
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.10	-0.01	0.08	0.21	0.36	0.85	1.28	2.08
13	Devanahalli	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.90	1.75	2.85	3.30	8.96	12.56	18.60	28.38
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.07	0.05	0.12	0.28	0.89	1.10	1.12	1.50
14	Aurur	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.50	0.88	1.13	1.15	3.05	5.83	7.12	12.82
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.08	0.10	0.16	0.46	1.12	1.80	2.60	2.70
15	Navile	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.75	2.02	2.56	3.80	9.82	13.35	20.17	29.03
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.18	-0.10	0.02	0.12	0.38	0.48	0.71	1.12
16	Mandya	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.78	1.83	2.41	4.10	7.71	10.06	15.69	26.20
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.11	0.08	0.28	0.42	0.62	1.02	1.42	1.88
17	Appangala	$AR^k(M/L)^{0.5} \times 10^{-3}$	2.21	2.61	4.21	5.82	6.32	10.51	14.51	18.79
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.40	-0.30	-0.21	-0.08	0.05	0.18	0.97	1.86
18	Bandihalli	$AR^k(M/L)^{0.5} \times 10^{-3}$	1.00	2.39	3.32	4.13	4.18	7.30	9.83	15.96
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.12	-0.08	-0.06	-0.04	0.24	0.45	0.77	0.81
19	Navile	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.47	0.73	2.00	2.88	7.10	11.41	15.15	23.25
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.29	-0.19	-0.10	0.18	0.34	0.52	0.70	1.29
20	Karadikere	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.64	0.88	1.26	2.26	6.28	7.48	12.15	32.12
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.05	0.04	0.06	0.08	0.35	0.42	0.78	1.26
21	Thirthahalli	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.32	0.52	1.72	3.88	7.09	12.56	20.25	30.92
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.05	-0.04	-0.02	0.04	0.18	0.20	0.32	0.58
22	Belgere	$AR^k(M/L)^{0.5} \times 10^{-3}$	2.85	3.39	4.10	5.15	9.82	15.13	18.68	23.38
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.13	-0.09	-0.07	0.07	0.22	0.63	0.99	1.08
23	Devarapalli	$AR^k(M/L)^{0.5} \times 10^{-3}$	4.12	5.06	6.73	8.65	8.87	9.52	10.18	18.33
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.63	-0.38	-0.24	-0.13	-0.08	0.03	0.58	0.78
24	Balehonnur	$AR^k(M/L)^{0.5} \times 10^{-3}$	2.07	3.15	4.21	5.47	6.32	9.42	12.41	13.28
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.36	-0.28	-0.20	-0.08	0.04	0.16	0.98	1.20
25	Byadarahalli	$AR^k(M/L)^{0.5} \times 10^{-3}$	0.78	1.64	3.08	4.10	5.44	7.84	10.26	15.69
		$\pm \Delta K(\text{cmol}(p^+) \text{kg}^{-1})$	-0.28	-0.18	-0.12	0.06	0.14	0.47	0.83	1.32

Note: A, B, C, D, E, F, G and H denote composition of solutions used for equilibrating the soils and they were 0.0, 1.0, 2.0, 3.0, 4.0, 1.0, 2.0, and 4.0 m mole  $l^{-1}$  KCl respectively in 0.01M  $CaCl_2$

The  $\Delta K$  (+) values in respect of Arur soil was found to be relatively higher in comparison to those of other soils at the surface depth indicating higher degree of unsaturation in that soil. It was least in the soil from Madanahalli. There was not a particular trend in the values in accordance with available K content of the soils. In general, there was desorption of K at lower K concentrations and adsorption at higher K concentrations. Only very few soils showed desorption even at  $0.4 \text{ mmol L}^{-1}$  KCl concentration.

Activity ratio ( $AR^k$ ) ranged between  $12.25 \times 10^{-3}$  and  $32.12 \times 10^{-3} (\text{M/L})^{0.5}$ . The lowest value  $\{12.25 \times 10^{-3} (\text{M/L})^{0.5}\}$  was recorded by Brahmavara which is low in K status and the highest value  $\{32.12 \times 10^{-3} (\text{M/L})^{0.5}\}$  was recorded by Karadikere which is high with respect to available K status. The data on various Q/I parameters are presented in table 15.

The labile K ( $K_L$ ) ranged from 0.10 to 0.90  $\text{cmol (p}^+) \text{ kg}^{-1}$ . The lowest quantity of labile K was found in Thirthahalli and the highest was found in Byadarahalli.

The  $K_0$ , which is held in planar sites of soil clay minerals was found to be the lowest ( $0.04 \text{ cmol (p}^+) \text{ kg}^{-1}$ ) in Karadikere and the highest ( $0.34 \text{ cmol (p}^+) \text{ kg}^{-1}$ ) in Devarapalli.

The difference between  $K_L$  and  $K_0$  is expressed as potassium ions on specific sites ( $K_X$ ) of soil clay minerals, which ranged from 0.05 to  $0.72 \text{ cmol (p}^+) \text{ kg}^{-1}$ . The highest value of  $K_X$  was observed in Byadarahalli ( $0.72 \text{ cmol (p}^+) \text{ kg}^{-1}$ ) and the lowest value ( $0.05 \text{ cmol (p}^+) \text{ kg}^{-1}$ ) was observed both in Kallambella and Thirthahalli.

The equilibrium activity ratio for soil potassium ( $AR_c^k$ ) ranged from 0.60 to  $9.2 \times 10^{-3} (\text{M/L})^{0.5}$ . The lowest activity was recorded in Karadikere soil  $\{0.60 \times 10^{-3} (\text{M/L})^{0.5}\}$  and the highest activity  $\{9.2 \times 10^{-3} (\text{M/L})^{0.5}\}$  was observed in Devarapalli. No definite trend in equilibrium potassium activity was observed among the different soils with respect to their available K content.

Table 15. Quantity –Intensity parameters of potassium in surface soils

SINo	AR <sup>k</sup> (M/L) <sup>0.5</sup> × 10 <sup>-3</sup>	-ΔG <sup>0</sup> k cal eq <sup>-1</sup>	K <sub>L</sub>		K <sub>0</sub> cmol (p <sup>+</sup> ) kg <sup>-1</sup>		K <sub>X</sub>	PBC <sup>k</sup> cmol (p <sup>+</sup> ) kg <sup>-1</sup> / (M/L) <sup>0.5</sup>
			K <sub>L</sub>	K <sub>L</sub>	K <sub>0</sub>	K <sub>0</sub>		
1	2.80	-3.52	0.30	0.21	0.09	80.00		
2	1.60	-3.85	0.14	0.05	0.09	32.14		
3	2.25	-3.65	0.38	0.18	0.38	66.66		
4	1.70	-3.81	0.34	0.24	0.10	55.45		
5	2.20	-3.66	0.17	0.08	0.09	30.00		
6	4.10	-3.28	0.27	0.15	0.12	35.71		
7	2.60	-3.55	0.30	0.16	0.14	62.50		
8	4.80	-3.19	0.21	0.10	0.11	20.80		
9	3.40	-3.20	0.44	0.33	0.11	125.55		
10	4.60	-3.22	0.33	0.19	0.14	45.55		
11	3.60	-3.36	0.15	0.10	0.05	25.00		
12	1.60	-3.85	0.40	0.19	0.21	111.10		
13	1.20	-4.02	0.24	0.18	0.06	35.71		
14	0.70	-4.34	0.48	0.28	0.20	114.00		
15	2.60	-3.56	0.28	0.12	0.16	44.11		
16	1.00	-4.13	0.26	0.10	0.16	100.00		
17	5.80	-3.08	0.80	0.61	0.19	117.65		
18	5.00	-3.16	0.20	0.14	0.06	26.31		
19	3.20	-3.43	0.40	0.22	0.18	71.42		
20	0.60	-4.43	0.16	0.04	0.12	65.21		
21	2.20	-3.66	0.10	0.05	0.05	21.74		
22	4.50	-3.23	0.40	0.26	0.14	55.55		
23	9.20	-2.80	0.60	0.34	0.26	80.38		
24	5.80	-3.08	0.70	0.50	0.20	86.96		
25	3.50	-3.38	0.90	0.18	0.72	146.34		

Potential buffering capacity ( $PBC^k$ ) of soils varied from 20.80 to 146.34  $\text{cmol (p}^+) \text{ kg}^{-1}/(\text{M/L})^{0.5}$ , the lowest (20.80  $\text{cmol (P}^+) \text{ kg}^{-1}/ (\text{M/L})^{0.5}$ ) and the highest {146.34  $\text{cmol (p}^+) \text{ kg}^{-1}/ (\text{M/L})^{0.5}$ } being recorded in soils of Muthenahatti and Byadarahalli, respectively.

The free energy change ( $-\Delta G^0$ ) calculated from the  $AR_e^k$  ( $-\Delta G^0 = RT \ln AR_e^k$ ) was found to vary between  $-4.43 \text{ Kcal eq}^{-1}$  and  $-2.80 \text{ Kcal eq}^{-1}$ . In most of the soils, particularly those contained available K in medium quantities,  $-\Delta G^0$  values ranged from  $-3.08$  to  $-3.85 \text{ Kcal eq}^{-1}$ .

#### 4.6.1 Correlation (r-values) between forms of K and Q/I parameters

Correlation values (r) between forms of K and Q/I parameters for K are presented in table 16.

The equilibrium activity ratio for potassium was positively and significantly correlated with  $K^0$  ( $r=0.7200^{**}$ ),  $K_L$  ( $r=0.6319^{**}$ ) and  $K_X$  ( $r=0.4047^*$ ). There was significant and negative correlation between  $AR_e^k$  and  $PBC^k$  ( $r=-0.3982^*$ ), and also between  $AR_e^K$  and  $-\Delta G^0$  ( $r=-0.3986^*$ ).

The labile K ( $K_L$ ) was significantly and positively correlated with  $K_0$  ( $r=0.9722^{**}$ ),  $K_X$  ( $r=0.5556^{**}$ ),  $PBC^k$  ( $r=0.3958^*$ ),  $-\Delta G^0$  ( $r=0.4840^*$ ), Exch K ( $r=0.3996^*$ ) and OC ( $r=0.3967^*$ ). There was positive and significant correlation between  $K_0$  and  $-\Delta G^0$  ( $r=0.5559^{**}$ ) as well as,  $K_X$  ( $r=0.3985^*$ ) and OC ( $r=0.3962$ ). Potassium on specific sites ( $K_X$ ) significantly and positively correlated with  $PBC^k$  ( $r=0.3971^*$ ), Exch-K ( $r=0.3990^*$ ) and CEC ( $r=0.3964^*$ ). The  $PBC^k$  and  $-\Delta G^0$  values were significantly and positively correlated ( $r=0.3966^*$ ) between them. There was also significant and positive correlation between  $PBC^k$  and non exchangeable-K ( $r=0.4063^*$ ), clay ( $r=0.5317^{**}$ ), and OC ( $r=0.3996^*$ ).

Table 16. Correlation coefficients (r - values ) between forms and Q/I parameters for different soils of Southern Karnataka

	$K_L$	$K_0$	$K_x$	PBC <sup>k</sup>	$-\Delta G^0$	Ex-K	Nonex-K	Sand	Clay	OC	CEC	Ex-Ca
AR <sup>k</sup>	0.6319**	0.7200**	0.4047*	-0.3982*	-0.3966*	0.2227	-0.2919	-0.0318	0.0254	0.1168	0.1148	-0.1549
$K_L$		0.9722**	0.5556**	0.3958*	0.4804*	0.3996*	-0.3242	-0.0338	0.0896	0.3967*	0.0833	-0.2750
$K_0$			0.3985*	0.3837	0.5559**	0.3174	-0.3512	-0.0902	0.1522	0.3962*	0.0419	-0.3136
$K_x$				0.3971*	0.0291	0.3990*	-0.0923	0.0988	-0.0259	0.2921	0.3964*	0.0316
PBC <sup>k</sup>					0.3966*	0.1399	0.4063*	0.0535	0.5317**	0.3996*	0.1674	0.0349

\*Significance at 0.05

\*\* Significance at 0.01

#### 4.7 Clay Mineralogy related to potassium

Results of the X-ray diffraction (XRD) of clay fractions of selected soils (15.30 cm) are presented in table 17 and the X-ray diffractograms are shown in Fig. 6a to 6f.

The major layer silicates of the subsurface clay fraction of soils were identified as kaolinite, smectite and illite. Vermiculite and gibbsite were seen only in minor quantities. Quartz and feldspar were the non-silicates present in traces.

Kaolinite in its better crystallized form was identified by its characteristic peak at 7.15 Å (001) and 3.57 Å (002). It was unaffected by K treatment but vanished at 550° C (K saturated and heated to 550° C). The presence of illite was characterized by a randomly interstratified smectite with mica and was identified by peaks at 10 Å (001) and 5 Å (002). The 10 Å peak was even identified on K saturation and heating to 300° C and 550° C. Minor amounts of vermiculite present in clay samples were identified by collapse of 14.1 Å (001) peak to 10 Å on heating the K-saturated clays to 300° C. Presence of smectite and gibbsite in minor amounts was clear from the fact that 14.1 Å (001) peak swelled to 17.1 Å after ethylene glycol treatment (smectite) and, 10 Å (001), 5 Å (002) peaks unaffected by heating to 550° C as well as 4.84 Å (gibbsite) in lateritic soil.

A very small but distinct peak at 4.26 Å (quartz) and 3.20 Å (feldspar) region indicated quartz that is not well crystallized which persisted even after heating to 550° C.

The types of clay minerals detected and their relative abundance in the soils as identified by height and distinctness of peaks are furnished in table 17. As could be seen from the XRDs, kaolinite was generally the dominant clay mineral in all the soils studied except the soil from Belgere (belonging to central dry zone), which contained illite as the dominant mineral. Minor amounts of illite as randomly interstratified with vermiculite, chlorite, smectite and gibbsite was found as associated clay minerals in all the clay samples except that of Thirthahalli. In the latter, it occurred in trace amounts. Very minor amounts/trace amounts of quartz and feldspar were detected in all the clay samples.

Table 17. Mineralogical composition of clay fraction ( $<2\mu\text{m}$ ) according to X-ray diffraction data

Sl No	Location	Major mineral	Minor mineral	Traces
1	Belgere	Illite (randomly interstratified smectite with mica)	Kaolinite (poorly ordered) and Quartz	Feldspars
2	Brahmavara	Kaolinite (moderately crystallized)	Illite (randomly interstratified vermiculite with chlorite and gibbsite)	Feldspars and Quartz
3	Shimoga	Kaolinite (poorly crystallized)	Illite (randomly interstratified with vermiculite smectite and gibbsite)	Feldspars and Quartz
4	Thirthahally	Kaolinite (moderately well crystallized)	Gibbsite and Quartz	Illite (randomly interstratified mica with vermiculite)
5	Mysore	Kaolinite (moderately crystallized)	Gibbsite with not so well crystallized Quartz	Illite (randomly interstratified mica with vermiculite and feldspar)
6	Malur	Kaolinite (poorly crystallized)	Quartz and Illite (interstratified with mica)	Feldspar

The results of the clay mineralogy study indicated that that the potassium bearing mineral was present only as associated mineral in all the soil samples studied except sample number 1.

#### **4.8 Evaluation of different extractants for estimating available potassium in soils**

Various soil test methods were compared through soil test-crop response parameters (correlation studies) in order to select suitable soil test extractants for estimating the available potassium status of soils growing rice as the test crop. Fourteen bulk soil samples collected from different locations of Southern Karnataka were used in the pot culture for evaluating the best extractant of available potassium. The data pertaining to available status of potassium yield parameters of rice and correlation between yield parameters and available potassium extracted by different extractants is presented in table 18, 19 and 20 respectively.

##### **4.8.1 Soil test values obtained by using different extractants**

Totally five different extractants were used for extracting available K from the soil samples, viz., *0.01M* CaCl<sub>2</sub>, *NN* NH<sub>4</sub>OAc, *1N* HCl, *1N* HNO<sub>3</sub>, and *0.03M* NaTPB. The amounts of K extracted by these reagents from the soils (table 18) ranged from 108.1 to 456.9, 125.42 to 457.00, 152.32 to 474.90, 250.92 to 564.50 and 215.02 to 537.60 kg K<sub>2</sub>O ha<sup>-1</sup> respectively.

The available potassium extracted by various extractants irrespective of the soils used for the study was in the following order: *1N* HNO<sub>3</sub> > *0.03M* NaTPB > *1N* HCl > *NN* NH<sub>4</sub>OAc > *0.01M* CaCl<sub>2</sub>.

Table 18. Soil test values for available potassium by different extractants in kg ha<sup>-1</sup>

Sl No	Location	0.01M CaCl <sub>2</sub>	N/N NH <sub>4</sub> OAc	1N HCl	1N HNO <sub>3</sub>	0.03M NaTPB
1	Chokkanahalli	177.4	188.2	224.0	250.9	234.0
2	Nittur	254.0	313.6	295.7	376.3	322.6
3	Arasikere	268.0	311.8	313.6	564.5	386.7
4	Tharikere	279.2	349.8	314.5	474.9	474.9
5	Navile	286.7	306.2	322.6	349.4	340.4
6	Kankanady	134.4	148.2	152.3	268.8	250.9
7	Appangala	456.9	457.0	474.9	553.5	537.6
8	Madanahalli	258.7	277.8	358.4	492.4	412.2
9	Brahmavara	132.1	161.3	188.2	295.7	215.0
10	GKVK 1	108.1	125.4	224.0	250.9	242.0
11	GKVK 2	241.9	377.2	360.0	457.0	421.1
12	Arur	224.0	279.6	379.3	492.8	367.4
13	Bashettihalli	188.2	289.9	307.5	419.7	349.4
14	Thulasidoddi	179.2	370.9	297.1	448.0	331.5

Table 19. Dry matter yield and K uptake by Rice crop

Sl No	Location	Relative yield	Per cent yield response	Dry matter yield (gms) in control	K-uptake (g/pot) in control
1	Chokkanahalli	64.37	70.32	25.48	20.67
2	Nittur	59.40	46.62	23.87	17.19
3	Arasikere	76.74	23.55	32.63	21.54
4	Tharikere	50.51	34.58	21.68	17.80
5	Navile	73.25	53.12	29.17	25.70
6	Kankanady	73.38	68.32	35.05	30.14
7	Appangala	79.90	25.00	33.80	39.00
8	Madanahalli	68.20	30.30	27.54	25.80
9	Brahmavara	65.30	55.34	25.56	24.03
10	GKVK 1	56.07	79.90	20.76	20.34
11	GKVK 2	76.92	36.26	42.00	30.20
12	Arur	81.52	30.30	27.80	21.50
13	Bashettihalli	75.61	40.04	27.13	28.00
14	Thulasidoddi	71.09	36.51	37.35	47.00

Table 20. Simple matrix correlation between different extractants for available potassium

Soil Extractants	Per cent yield Response	Mean Percentage	Yield in Control	K uptake in control	Soil test values of K (Kg/ha)	
					Mean	Range
<b>CaCl<sub>2</sub> (0.01M)</b>	-0.8663*	0.8850**	0.4897	0.2710	227.71	108.1-456.9
<b>HCl (1N)</b>	-0.9232**	0.9471**	0.5924	0.3789	300.84	152.32-474.9
<b>HNO<sub>3</sub> (1N)</b>	-0.9706**	0.9704**	0.6846	0.7978*	406.75	250.92-564.5
<b>NN<sub>4</sub>OAc</b>	-0.9543**	0.9605**	0.6578	0.7560*	282.60	125.42-457.0
<b>NaTPB (0.03M)</b>	-0.9274**	0.9378**	0.5916	0.7967*	348.97	215.02-537.6

\*Significance at 0.05

\*\* Significance at 0.01

#### 4.8.2 Plant growth indices for soil test evaluation

The growth indices considered in the soil test evaluation were mean per cent (relative) yield, per cent yield response (PYR) and K-uptake in control (Table 19). The mean per cent yield varied between 50.51 to 81.52, the PYR ranged from 23.55 to 70.97, and the K-uptake in control varied from 17.19 to 47.0 g/pot, for different soils.

#### 4.8.3 Correlation between soil test values and crop growth parameters

Correlation co-efficients (r-values) indicated that the amount of soil potassium extracted by all the five extractants correlated significantly with PYR and relative yield. Except for *0.01M* CaCl<sub>2</sub> and *1N* HCl, the soil test values for the remaining three extractants correlated significantly even with the K uptake by the crop. Among the different extractants *1N* HNO<sub>3</sub> recorded the highest “r” value for the relationship between the amount of K extracted and PYR (-0.9706\*\*), percent yield (0.9704\*\*) and K uptake (0.7978\*). This was followed by *1N* NH<sub>4</sub>OAc which in respect of the relationship between soil test values and the PYR, the relative yield and the K uptake. For the three crop parameters, their relationship with the soil test values according to the “r” values followed the order,

- PYR, *1N* HNO<sub>3</sub> > *1N* NH<sub>4</sub>OAc > *0.03M* NaTPB > *1N* HCl > *0.01M* CaCl<sub>2</sub>,
- Relative yield, *1N* HNO<sub>3</sub> > *1N* NH<sub>4</sub>OAc > *1N* HCl > *0.03M* NaTPB > *0.01M* CaCl<sub>2</sub>,
- K uptake in control, *1N* HNO<sub>3</sub> > *1N* NH<sub>4</sub>OAc > *0.03M* NaTPB > *1N* HCl > *0.01M* CaCl<sub>2</sub>.



***DISCUSSION***

## V. DISCUSSION

The results of the investigation on various aspects of potassium viz., forms and distribution, fixation and release characteristics, Quantity-Intensity parameters and clay mineralogy in different soils under different agro-ecosystems of Southern Karnataka as well as evaluation of soil testing methods for available potassium in soils are discussed in this chapter. The results pertaining to the above studies are discussed under following headings:

5.1 Physico-chemical properties and nutrient status of soils

5.2 Potassium fractions in different soils

5.3 Potassium fixation capacity of soils

5.4 Potassium release characteristics

5.5 Quantity-Intensity parameters of potassium

5.6 Clay mineralogy as related to potassium

5.7 Evaluation of different extractants for estimating available potassium in soils

### **5.1 Physico-chemical properties and nutrient status of soils of different agro-climatic zones in Southern Karnataka**

#### **5.1.1 Central Dry Zone**

The soils of this zone are formed under semi arid climatic condition. The texture of the soils varied from sandy loam to sandy clay loam (Table 3). The mechanical analysis indicated that even though the total sand content was high, soils contained appreciable amount of silt and clay. The clay content was more in the lower depth than in the upper layer, indicating movement of finer particles to lower layer by illuviation. Similar results were reported by Sahu et al (1983).

The soils are slightly acidic to slightly alkaline in reaction (Table 4). This would indicate that the soils were derived from parent rocks ranging widely from acidic to basic in nature. Lower layer recorded relatively higher pH values for most of the soils. The

variation in soil pH value may be due to differences in the total contents of exchangeable bases. The lower electrical conductivity values recorded in both the layers imply that the soils were well drained and hence the presence of soluble salts in harmless amounts. The presence of organic carbon in medium to high range indicates regular addition of organic manures to the cultivated soils of this zone. The CEC of soils, which was mainly a function of nature and amount of clay and organic matter content, was medium to high.

The available phosphorus content of the soils of this zone falls in the medium to high category according to the fertility ratings followed for P in Karnataka state. Available potassium content of soils which ranged from 92.96 to 342.82 kg K ha<sup>-1</sup> (Table 5) indicated a wide variation in the K status of soils, the reason for which might be attributed mainly to the differences in the amounts of K applied to different crops through fertilizers and organic manures rather than to the differences in soil materials. It has been reported in the literature that application of water soluble fertilizers in some cases would lead to a build up in available potassium contents depending upon the crop requirement of K (Chibba and Sekhon, 1985). The highest amount of available K noticed in the surface layer of soil as compared to the subsurface layer was due to the higher amount of organic matter present in the surface layer of soils (Sharma and Dubey, 1988).

### 5.1.2 Eastern Dry Zone

Most of the soils collected from this zone exhibited sandy loam texture (Table 3). The soils were dominant in sand with low silt and appreciable clay content. Clay content was more in lower layer and there was a concomitant decrease in sand content. These observations are in accordance with the results of Sahu et al. (1983) for red soils of Orissa.

The soils were slightly acidic to neutral in reaction (Table 4). This might be attributed to the development from acidic parent material viz., laterite and granite gneiss, which are deficient in basic minerals. These results are in corroboration with those of Ananthanarayana and Perur (1973). The soils being sandy, the content of soluble salts

was very low and hence recorded lower EC values. Organic carbon status of surface layer of soils in general, was medium and it was relatively lower in the lower depth. Cation exchange capacity of soils was medium and did not show any specific trend with depth. The available potassium content of soils of this zone was in medium category (Table 5). In the surface layer, the K content ranged from 74.37 to 230.54 kg K ha<sup>-1</sup>. The reasons for relatively higher contents of available K as noticed in some soils like Arur could be attributed to greater exposure of potassium bearing minerals to weathering conditions, as well as higher CEC and higher organic carbon status in those soils as compared to the soils with lower K contents. The available phosphorus content of soils was medium to high. Calcium and magnesium contents were also marginal in most of the soils. Calcium was the dominant cation on the soil exchange complex than magnesium.

### 5.1.3 Southern Dry Zone

The mechanical composition revealed that sand constituted the major textural fraction in all the soils (Table 3); hence the texture of soils ranged from sandy loam to sandy clay loam in both the depths. Clay content was relatively higher in the subsurface layer indicating the illuviation of clay from the upper to the lower layer.

Soil pH was slightly acidic, due mainly to their formation from acidic parent materials. The EC values, which were low, did not show any difference in the soluble salt contents between surface and subsurface layers of soils (Table 4). The reason for higher organic carbon content in the soil sample collected from Mandya was probably due to the continuous addition of organic manures in sufficiently large quantities to the soils, which were continuously under rice and sugarcane cultivation. The moderate CEC of soils was due to the presence of kaolinite with moderate amounts of illites in these soils.

The available phosphorus content of soils belonged to the medium to high category according to the ratings for available P for soils. The highest available potassium content observed in V.C. Farm at both the depths of soils was obviously due to continuous application of organic residues and K fertilizers. Higher amounts of clay in

the soil might have caused building up of available K in soils as reported by Chibba and Sekhon (1985).

#### **5.1.4 Southern Transition Zone**

The soils were mainly sandy loam in texture in both the depths. Soils contained relatively lower amounts of finer fragments viz. clay and silt (Table 3). Clay content of soil was relatively more in lower layer indicating the movement of clay from upper layer to lower layer.

The soils of this zone were slightly acidic to neutral in reaction and pH did not show much variation between lower and upper depths. This was obviously due to the development of soils from acidic rocks. The variation in the amounts of soluble salts in different soils of this region indicates their good drainage condition. Similarly, the medium to high organic carbon content of soils of this zone hints at the relationship between build up of organic carbon level and the climatic condition of the area, which is mainly semi-humid in this particular case. The CEC of soils, which was moderate, also indicates the presence of kaolinite along with illites in the soils (Table 4).

The presence of medium to high amount of available phosphorus and potassium in both surface and subsurface layers of soils, explains the good management of the soils by regular application of the phosphatic and potassic fertilizers as well as organic manures to the soils.

#### **5.1.5 Hilly Zone**

The soils of this zone are formed under the influence of heavy rainfall and thick vegetation. Hence, the soils are mostly sandy loam and sandy clay loam in texture (Table 3). Presence of sand in the surface layer as the most dominant fraction was due mainly to the removal of finer fractions of soils by illuviation or surface erosion under heavy rainfall condition (Singh, et al., 1991). The high amount of organic carbon content in the

soil was mainly due to the incorporation of more biomass to soil in the hilly forest track. Comparatively lower CEC values of soils at both the depths, indicates the dominance of kaolinites in the clay fractions. Available phosphorus content in soils of this zone is medium. Niranjana (1994) reported medium status of P under situations of proper fertilizer management in the soils of hilly zones. Potassium content was highest in soils under coffee plantation, for example, in soils of Balehonnur and Appangala at both the depths. This could be due to application of K fertilizers in larger amounts and concomitant leaching of calcium and magnesium from the upper horizons of soils under heavy rainfall conditions. This is in corroboration with the findings of Girisha (1993).

#### 5.1.6 Coastal Zone

The soils of this zone are sandy loam and sandy clay loam in texture. Soils were dominant in sand with appreciable amounts of clay particularly in the lower layers. These soils are intensively weathered and are formed under heavy rainfall and hot-humid conditions (Ananthanarayana and Perur, 1973). High organic carbon content noticed in almost all soil samples and in both depths was probably due to the thick vegetation of the area and formation of stable organo-mineral complexes in the soils dominant in polyvalent cations like  $Al^{3+}$  and  $Fe^{3+}$ . The reason for comparatively low CEC of the soils could be attributed to the presence of very high amounts of kaolinite and hydrous oxides of iron and aluminium (Rajashekara Rao, 1997).

Leaching of bases under high rainfall conditions and presence of high organic matter could be quoted as the reasons for the acidic reaction of these soils. Similarly, low electrical conductivity and, low amounts of exchangeable Ca and Mg in the soils are also the results of leaching of salts due to high rainfall.

Due to the presence of oxides and hydrous oxides of aluminium and iron and also the dominance of kaolinite, the soils in both the depths contained only low to moderate amounts of available phosphorous. Available potassium in soils of this zone ranged from low ( $70.98 \text{ kg K ha}^{-1}$ ) to medium ( $193.35 \text{ kg K ha}^{-1}$ ). The reason for higher contents of

available K in surface layer as compared to lower layer soils may be attributed to higher amount of organic matter present in the upper layer (Chibba and Sekhon, 1985).

## 5.2 Forms of potassium

### 5.2.1 Central Dry Zone

The reason for the relatively higher content of water-soluble potassium in the surface layer of these soils in comparison to the soils of hilly or coastal zones could be related to the less intensive leaching of these soils. The water-soluble K values were lower in the subsurface layer than in the surface layer of soils (Table 6). The reason for this may be attributed to higher organic carbon content in the surface layer, acting as a good source of labile K (Singh and Datta, 1986). It could also be explained by the fact that the amount of clay was relatively higher in the lower depths in comparison to the upper depths of soils and vice versa in the case of sand fraction of the soils (Sahu and Gupta, 1988). The content of exchangeable potassium in the upper horizon (Table 6) was also found to be relatively higher as compared to those of the lower horizon. This may be due to the relatively higher organic carbon content and cation exchange capacity of soils in the surface layer. Similar reason has been reported by Singh et al (1983). Unlike the water soluble and exchangeable forms of K, the content of non-exchangeable form of potassium was higher in the second depth (Table 6). The lower values of non-exchangeable potassium in the surface layer indicates the rapid conversion of fixed form of potassium to available form to compensate the removal of available K by crop uptake in the surface layer of soils (Ranganathan and Sathyanarayana, 1980). The variation among the soils in the non-exchangeable K content is due to difference in the clay contents of the soils (Singh et al., 1985). The contents of lattice and total K were also relatively higher at second depth of soils. This was mainly due to the difference in the intensity of weathering of soils in the two depths, the intensity being more in upper layer compared to the lower layers of soils. About 85 to 92 per cent of total K found in the

lattice bound form indicated that majority of the total potassium was present as structural constituent of minerals. The variation in lattice and total potassium content among soils is attributed to the clay content and extent of weathering of potassium minerals (Chahal et al., 1976).

### **5.2.2 Eastern Dry Zone**

As in the case of central dry zone, the content of water-soluble potassium was found to be higher in surface layer than in the subsurface layer of soils (Table 6). The possible reason for this could be the upward translocation of K from subsurface layers to the surface layer due to capillary rise of water in the soil and also the higher amount of OC in the surface layer of soils (Chandraprakash and Vinay Singh, 1985). Exchangeable potassium content of soils was less in the second depth when compared to that of the first depth. The higher values of exchangeable K in the Muthenahatti-3 and other soils is probably due to supply of K through fertilizers and exposure of more functional groups in the organic residues for K adsorption (Singh and Datta, 1986). Non-exchangeable potassium contents of the soils increased with increase in the depth of soils. This kind of an increase in its content with soil depth was due to increase in the clay content of the soils. The contents of both lattice K and total K showed an increasing trend with depth of soils. Lattice potassium formed 81 to 91 per cent of total potassium. The content of these two pools of K increased in the second layer due to increase in finer fractions of soil particles with depth; similar results were also reported by Subba Rao and Sekhon (1990).

### **5.2.3 Southern Dry Zone**

As in the case of the soils of the other two zones, the content of water soluble K in the soils of this zone also decreased with the depth of soil. In the case of soils with higher amounts of sand and higher organic matter content in the surface horizons as compared to subsurface horizons, the water-soluble K contents have been reported to be relatively higher in the former than the latter horizon (Chahal et al, 1976). Another reason for the higher water soluble K content in the surface layer of soils may be attributed to

the greater exposure of potassium bearing minerals to weathering conditions. In some cases, for example the soil from V.C.Farm, contained very high amount of water soluble K. This might be due to the regular application of water soluble K fertilizers and dominance of kaolinitic type of clay in the soil. Similarly, the reason for higher content of exchangeable potassium in the surface layer of soil of this zone also could be attributed to the application high doses of K fertilizers. Singh *et al*, (1983) have also reported a building up of K in soils under regular application of K fertilizers. In the case of soils of this zone also, there was relatively higher amount of non-exchangeable K in the lower depth of soils. In this case also the reason could be attributed to the presence of higher amount of clay in the second depth of soil. Grewal and Kanwar (1966) observed a linear relationship between the amount of non-exchangeable potassium and clay content of soils. The amount of total K which depended largely upon the clay content of soils (Mehrotra *et al.*, 1973) might be the cause for the amount of total potassium being higher in the lower depth of soils.

#### **5.2.4 Southern Transition Zone**

Since there were similarities with respect to soil texture as well as the mineralogical composition of soils of this region with those of the other zones, the trend in respect of distribution of different forms of K viz., water soluble\_, exchangeable\_, non exchangeable\_, lattice\_ and total K was found to be the same as those found in the soils of the other zones. The same reasons could be quoted for higher or lower amount of a specific form of K in the surface or subsurface layer of soils. The other reasons could be, upward translocation of potassium from subsurface layers through capillary water for relatively higher content of water soluble K in the surface layer (Gajbhiye, 1985), intensive weathering of minerals and release of labile K from organic residues for relatively higher content of exchangeable K in the surface layer (Ranganathan and Sathyanarayana, 1980), the presence of higher amounts of weathered micas and feldspars for relatively higher amounts of non-exchangeable K in the subsurface layer and the presence of higher amounts of potassium bearing minerals like orthoclase feldspar and

micas and their less exposure to weathering processes for the relatively higher amount of total K in the subsurface layer of soils. (Prasad *et al.*, 1967, Ramakrishna Parama, 1981).

### 5.2.5 Hilly Zone

Even though the soils of this zone were subjected to relatively more leaching than the soils of the semi arid and transition belts, there were instances of the presence of very high amount of water-soluble K as noticed in Balehonnur soil. This could be attributed to the continuous addition of high amount of K fertilizers and organic manures to the soil and the dominance of sesquioxides and kaolinite in the clay fraction of soils that contained large amounts of even the exchangeable form of K. Singh *et al* (1983) and Girisha (1993) have reported about the increase in water soluble K content of soils due to the application of K in heavy doses in the form of fertilizers and manures. The reason for higher amount of exchangeable potassium in Balehonnur soil may be attributed to the preferential adsorption of K compared to other bases by the soil colloids at higher solution concentrations. These results confirmed the work of Venkataratam (1977). Non-exchangeable K registered higher values at lower depth thus indicating a direct relationship with clay content of soils. The contents of lattice and total K that varied among different soils depended mainly on the amount and nature of clay and clay minerals present in the soil.

### 5.2.6 Coastal Zone

The reason for low water soluble K in the soils of this zone as compared to soils of other zones may be attributed to the presence of relatively higher amounts of kaolinite and sesquioxides having less exchange capacity and also heavy leaching loss of K from the surface layers. Niranjana (1994) reported similar observations for coastal soils of Dakshina Kannada district in Karnataka. The reason for higher amount of water soluble K in the surface layer of some soils of this zone could be attributed to upward translocation of K from subsurface layers brought about by capillary rise of water and higher amount of organic matter in the top soil (Girisha, 1993) and, more exposure of K

bearing minerals to weathering conditions (Chahal et al, 1976). The reason for higher content of exchangeable potassium in the upper layer of soils of this zone may be attributed particularly to the higher amounts of humified organic matter existing in the surface layer of soils. This observation is in corroboration with that of Singh et al. (1983). On the other hand, the reason for higher amount of non-exchangeable K in the subsurface layer may be explained by the fact that the lower layer contained relatively higher amount of clay than the upper layer of soils (Mehrotra et al, 1973). Lattice and total potassium contents were also found to be higher in the subsurface layer. This is probably due to the slightly higher content of clay /finer fraction in the subsurface horizon of soils as observed by Satyanarayana et al. (1985).

#### **5.2.7 Relationship of different forms of potassium with soil properties**

The significant and positive correlation found between water-soluble and exchangeable K in both surface and subsurface layer of (Table 7 and 8 respectively) soils belonging to different zones of southern Karnataka indicates the dynamic relationship existing between those two forms of K and the replenishment of water-soluble K by exchangeable K. Similar observations have been recorded by Singh et al. (1983), Krishna Kumari et al. (1984), Singh and Datta (1986), Sharpley (1989) and Roy et al.(1991). There was a positive relationship between water-soluble K and clay fraction of the soil. This is obviously due to an increase in the content of exchangeable K, which the soil owes to the large surface area of its clay size fraction. The beneficial effect of organic matter on K status of soil was evident from the positive and highly significant correlation between them. This is in confirmation with the results reported by Adhikari and Ghosh (1991).

There was also positive correlation between water-soluble K and pH and water soluble K and CEC of the soils. With increase in soil pH, the CEC of soil also increases, which in turn, increases the exchangeable K. Water soluble K and exchangeable forms of K are in a dynamic state of equilibrium in the soil system. Exchangeable K was positively and significantly correlated with the organic carbon content of soils. This may be due to

the large surface area offered by the organic colloids to hold potassium in exchangeable form.

A positive correlation between exchangeable K and clay and exchangeable K and CEC of soils was observed for both the depths (Table 7 and 8). The high CEC at high pH would have retained more K in the exchangeable form (Powell and Hutcheson, 1965).

The positive and highly significant correlation between exchangeable and non-exchangeable forms of K supports the claim that, there is a dynamic equilibrium between the two forms of K in the soil. Non-exchangeable form of K was also found to be positively and significantly correlated with clay content of soils. The greater amounts of K fixed in clay fraction of the soil can be attributed to the larger surface area, increase in fixation sites and increase in the content of micaceous minerals in the clay fraction (Mehrotra et al., 1973). Positive and highly significant correlation between the total and lattice K (Table 7 and 8) indicated that most of the soil K was in the lattice bound form. This is in agreement with the results of Sharma and Dubey (1988) and Parker et al. (1989), who reported that lattice K constituted 97 to 98 per cent of total K. The significant and positive correlation noticed between total K and clay fraction indicated that the finer fraction of soils contained large amounts of K bearing minerals. This was further supported by the negative relation observed between total K and sand fraction of the soils in the present study.

### **5.3 Potassium fixing capacity of soils**

The potassium fixing capacity of surface soils of different zones of Southern Karnataka (table 9) showed wide variations (0.09 to 1.44 cmol ( $p^+$ )  $kg^{-1}$ ) in their capacity to fix added K. This may be related to the K saturation of the exchange complex of the soils and the nature and amount of clay minerals, as evident from very low K fixation by soil from Appangala and high fixation by soil from Byadarahalli, the former having very high amount of exchangeable K and/or more of kaolinitic clays, and the latter having low amount of exchangeable K and relatively larger amounts of illitic clay minerals along with

kaolinites and also the total clay content was relatively higher in the latter soil. Dinesh (1995) and Ng Siew Kee (1966) have also reported similar results. Clay fixation was reported to be relatively higher in soils dominant in 2:1 type of clay minerals than in soils dominant in 1:1 clay minerals (Ramanathan and Krishnamoorthy, 1978).

### **5.3.1 Correlation co-efficients (r) between potassium fixing capacity and certain soil properties**

A perusal of the results (table 9) indicates that the fixation of K in the soil increased with increase in pH of the soil. The positive relationship between pH and K fixation by soils (table 10) confirms this observation. This is in agreement with the results of Sahu and Gupta (1988) and Ningappa and Vasuki (1989). Ramanathan and Krishnamoorthy (1978) quoted a possible explanation for this. When the concentration of  $H_3O^+$  ions having similar radii as  $K^+$  ion was decreased in the soil solution due to an increase in the soil pH,  $K^+$  ion would find it easy to occupy specific positions on the clay surfaces that cause their entrapment. Potassium fixation by soils registered positive relationship with finer fraction of soil (clay), while negative relationship with coarser fraction of soil (sand). The finer fractions have more K specific sites and specific surface area than coarser fraction, and hence would cause greater K fixation (Shaviv et al., 1985, Sahu and Gupta, 1988 and Ross et al., 1989). There was positive relationship between K fixation capacity and CEC of soils also. Increase in CEC of soils meant an increase in the exchangeable capacity of soils and the dominance of 2:1 types of clays permitting greater quantity of K to enter into the exchange complex and get trapped (Ningappa and Vasuki, 1989). The negative relation between K fixation capacity and OC observed in this study might be explained by the fact that organic matter, having very high cation exchange capacity, successfully compete with clay minerals in the adsorption of  $K^+$  in the exchangeable form and thus diverted a considerable portion of added K from getting entrapped in the inorganic exchange complex. (Joffe and Levine, 1947).

## 5.4 Potassium release characteristics of soils

There is a need to include part of non-exchangeable K in the available portion while assessing K availability to the crops. Subba Rao (1984) also suggested that there was a need for the use of methods of analysis which would extract K from the reserve pool in the soil, if the long term K supplying power of soil is to be assessed. The method suggested by Haylock (1956) simulates the potassium depletion pattern under intensive cropping.

### 5.4.1 Cumulative potassium release (CPR)

The CPR values estimated by successive extractions with boiling  $1N$   $HNO_3$  (Table 11) in surface soils varied between 368.00 and 977.00 mg K  $kg^{-1}$  in different soils. Much of the total cumulative K was released by the end of the fourth extraction, and the K release became very slow then onwards (Fig. 3). Atage (1974) has also reported about the removal of more than 80 percent of total cumulative K at the end of 3<sup>rd</sup> extraction in Nigerian soils. The results of the present study suggests that the soils, irrespective of their origin and nature and the amount of total or the different forms of K, released a substantial proportion of their cumulative K which probably included the major portion of the so-called non-exchangeable K- relatively easily upon depletion of the exchangeable K from the exchange complex. The reason for the removal of relatively larger quantities of cumulative K from Byadarahally soil may be attributed to the presence of altered micaceous minerals (illites) in relatively larger quantities in the clay fractions of soils. These soils also had relatively higher amounts of non-exchangeable K and clay. The results are in conformation with the findings of Bansal and Sekhon (1976). On the other hand, relatively lower amounts of cumulative K was noticed in soils of hilly (e.g. Balehonnur) and coastal (e.g. Brahmavara) zones. This could be attributed to the presence of relatively lower amounts of illites and the micaceous minerals in soils. Similar observation was made by Agarwal (1965) and Boruah et al. (1990), who reported lower cumulative K release from coarse textured soils of the hilly regions than fine textured soils of the plains.

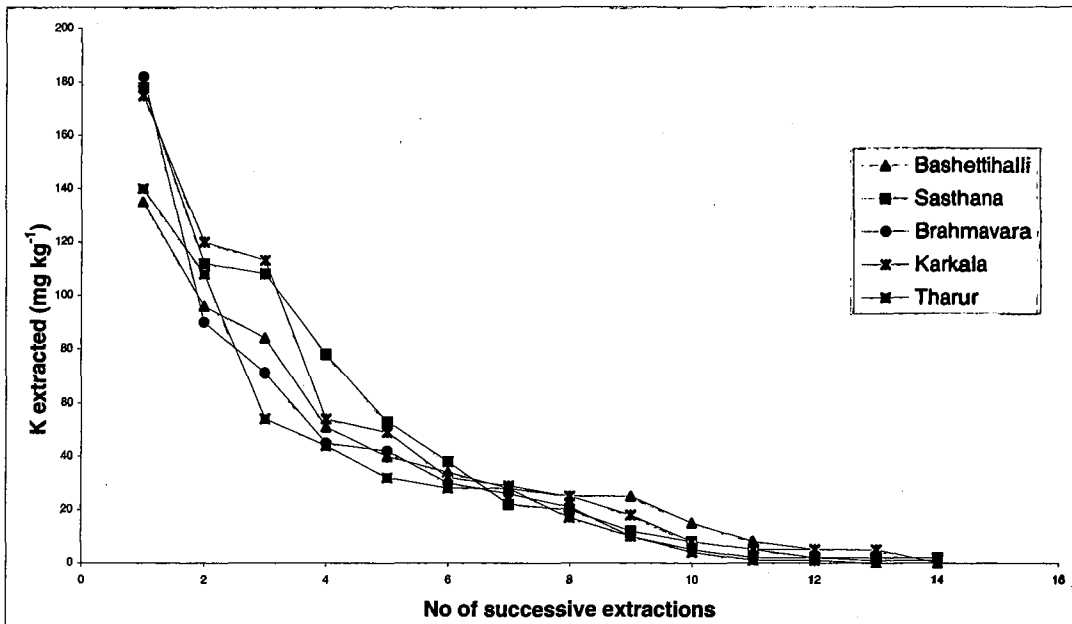


Fig. 3: Successive extraction of potassium by boiling 1N HNO<sub>3</sub> from 0-15cm depth of the soils

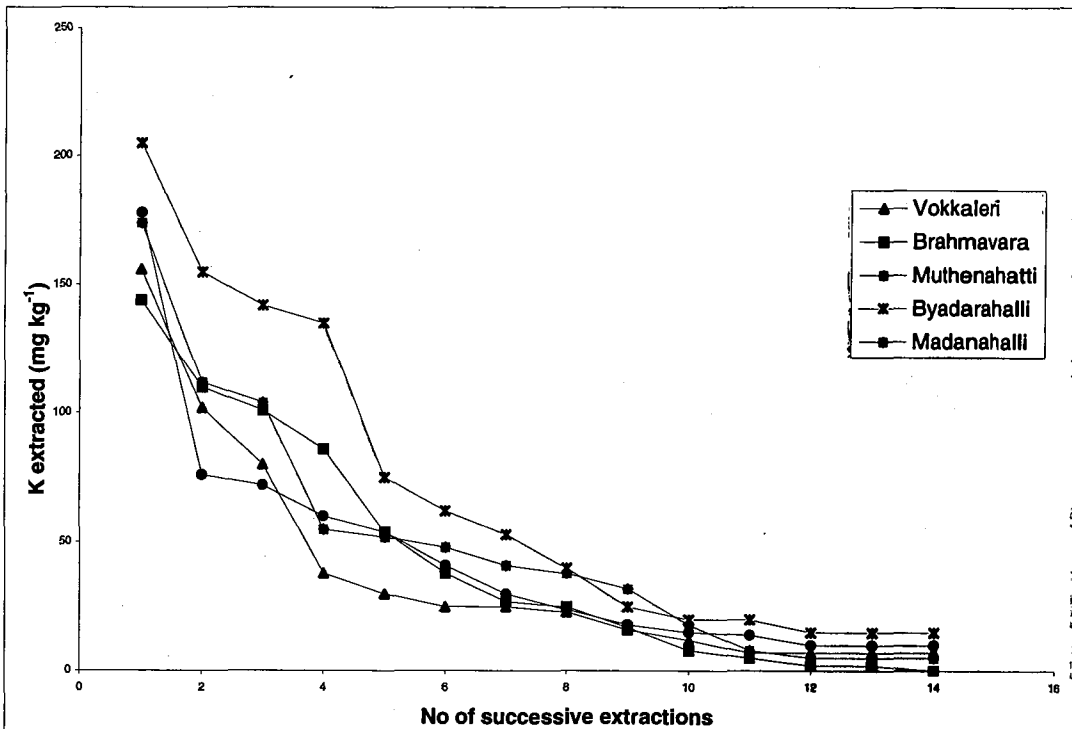
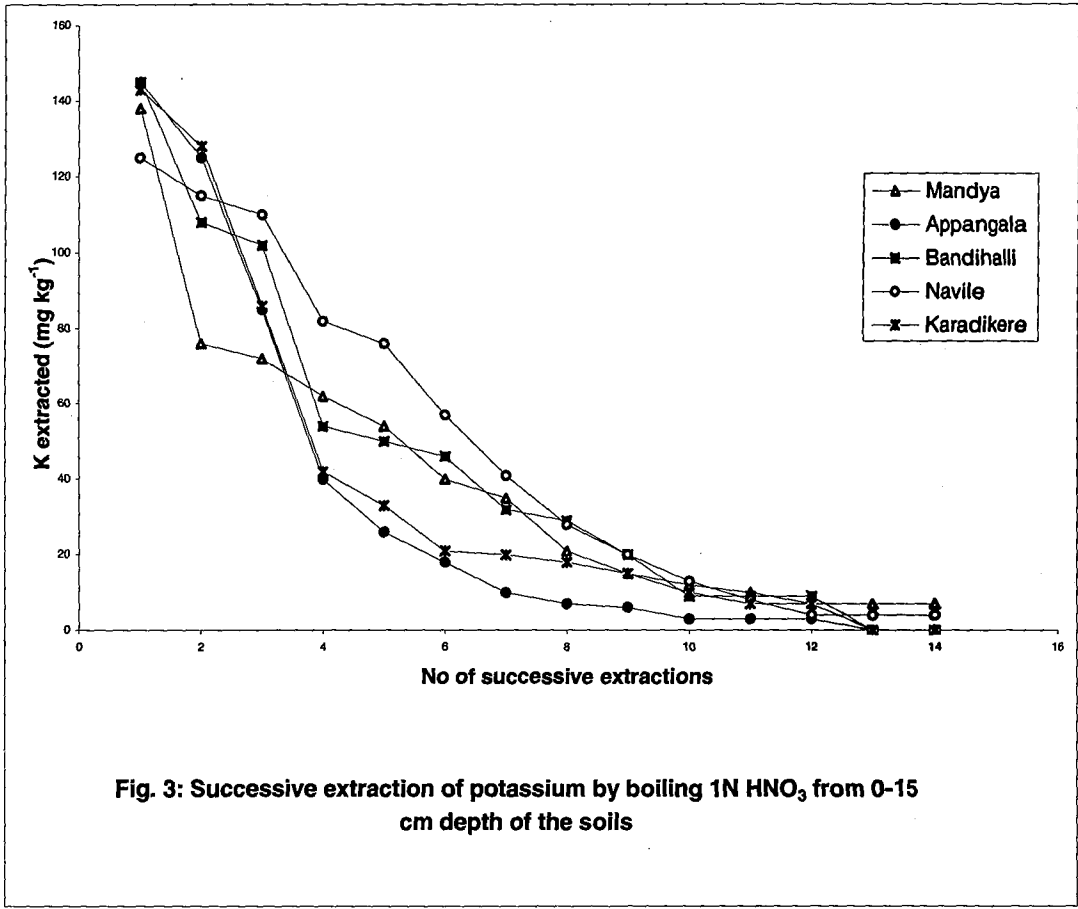
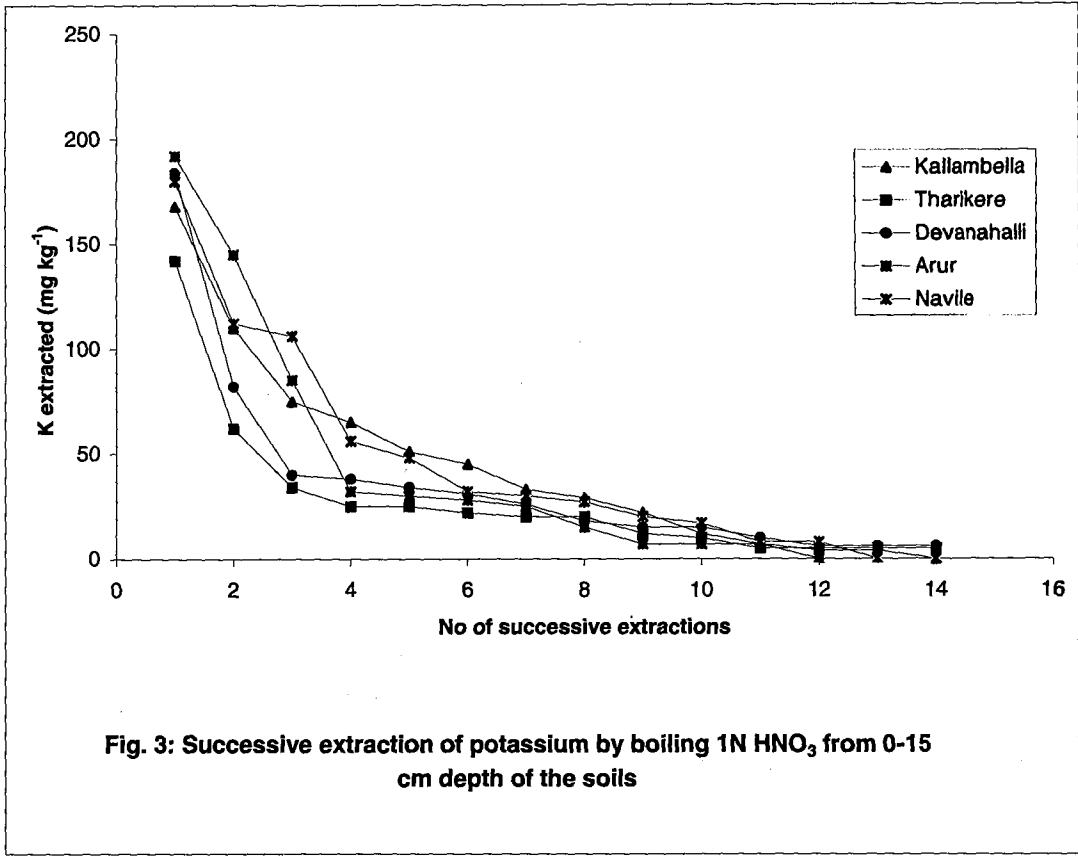
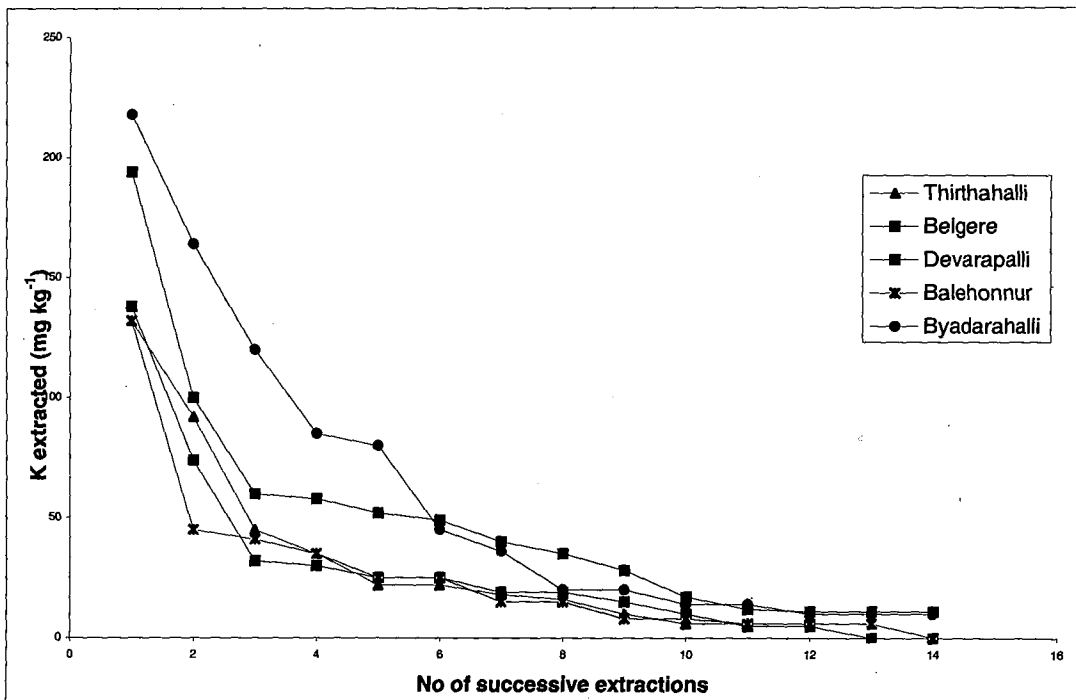


Fig. 3: Successive extraction of potassium by boiling 1N HNO<sub>3</sub> from 0-15 cm depth of the soils





**Fig. 3: Successive extraction of potassium by boiling 1N HNO<sub>3</sub> from 0-15 cm depth of the soils**

#### 5.4.2 Total step potassium

The total amount of step K (Table 11) in the surface layer of soils of different zones of Southern Karnataka ranged from 290.00 to 767.00 mg K kg<sup>-1</sup>. The amount of step K released in each successive extraction got reduced. Since there is not much difference between cumulative K and the total step K, the same explanations given in respect of CPR holds good for total step K of soils. If the range of values for interpretation of step K of soils suggested by Haylock (1956) is considered, the soils can be classified under category III (>19.00 mg K per 100 g soil) i.e. soils which may not respond at present to the application of potash fertilizers.

#### 5.4.3 Constant rate potassium

The constant rate K in the surface layer of soils of different zones ranged from 1.00 to 15.00 mg K kg<sup>-1</sup>. Metson (1968) was of the opinion that CR-K of soils could be obtained after two or three extractions with the reagent, excluding the first one. However, in the present case, the CR-K for most of the soils was obtained by the 11<sup>th</sup> /12<sup>th</sup> extraction. Other research workers (Ghosh and Ghosh, 1976; Sailakshmeshwari, 1985) have also reported about obtaining CR-K after 6 to 7 extractions with HNO<sub>3</sub> in soils of Nagaland and Andra Pradesh. By this, it could be understood that the reserve pool of available K was depleted very slowly in soils. This behavior seems to indicate that the reserve pool of available/non exchangeable K may contribute considerably to K nutrition of the crops over a long period of time. Incidentally, in the case of soils with higher amounts of cumulative release potassium, the CR-K in the samples was encountered rather late than in the case of those soils which had relatively lower amounts of CR-K. Hence there is every reason to believe that the soils from interior parts of Southern Karnataka (e.g. Byadarahalli and Belgere) may meet the K needs of crops for longer period of time as compared to the soils of hilly and coastal zones. (e.g. Thirthahalli and Brahmavara). This suggests that non-exchangeable form of K in soil meet the long-term needs of crop as suggested by Haylock (1956).

#### 5.4.4 Kinetics of potassium

The interest in the potassium fertility of soils has changed from the current simple estimations of exchangeable K as measurements of the rate at which K is supplied from exchangeable fraction (Srinivasa Rao et al. 1998). Hence a detailed investigation was made on kinetics of K desorption in different soils of Southern Karnataka.

##### 5.4.4.1 Cumulative potassium desorption

The results on cumulative K desorption with respect to the twenty-five soil samples representing varied K status under different agro-climatic zones of Southern Karnataka are presented in table 12.

Potassium desorption essentially followed similar pattern in all the soils. Some soils, particularly those containing relatively higher amounts of non-exchangeable K (e.g. Byadarahalli) showed high amount of K desorption through out the course of extraction. The reason for this could be attributed to the presence of more number of relatively loose K-O bonds in different interstratified micaceous minerals and the gradual release of K from these sites and also to other easily accessible sites of total available pool. Lower amounts of cumulative K desorption as observed in Brahmavara soils was probably due to relatively higher strength of K-O bond at different exchange sites and also the amount and type of clay minerals (Martin and Sparks, 1983). There was rapid desorption of K up to 72 hours of extraction and a slow pace of K desorption thereafter indicating that it was a diffusion controlled process. Dhillon et al. (1989) were of the same opinion for this kind of behaviour in respect of K desorption. The reason for the slow rate of desorption could be attributed to the gradual increase in the magnitude of exposure of total surface and the consequent effect on rate of diffusion (Pal and Mukhopadyay, 1992). In general, the cumulative K desorption was lower in acid soils (e.g. Balehonnur) containing larger amounts of kaolinites and sesquioxides of aluminium and iron which neither have much K in their crystal structure nor have much sites to hold  $K^+$  ions on their surfaces (Srinivasa Rao et al., 1998). Leaching can be a practical problem in such low CEC soils

(Schroeder, 1979), there by little response to K fertilizer was observed when K was applied even at high rates (Verghese and Byju, 1993). The amount of K desorbed was greater than the exchangeable K content in soils suggesting that some proportions of non exchangeable K was also desorbed and could be utilized by plants (Dhillon et al., 1989). This release of K from non-exchangeable K does not occur unless a 'minimum' level of exchangeable K is reached and this level of K is the measure of K supplying power of soils (Sparks, 1980).

#### 5.4.4.2 Potassium release kinetics

Linear relationships were obtained when  $\log (K_t/K_0)$  was plotted against 'time' in all the twenty-five soils (Fig. 4a-4y). The shape of the curves conformed to first order reaction kinetics with both slope and intercept being negative. Similar relationships between the two parameters have been reported by Srinivasa Rao et al. (1998) and Dhillon et al. (1989) The first order kinetic equation assumes that the rate of K desorption is proportional to either the number of exchangeable sites on the surface or the concentration of K in the occupied site (Martin and Sparks, 1983 and SrinivasaRao et al., 1998). Based on the nature of curve, K desorption can be resolved into two phases, as indicated by steep descending slope (up to 120 hours) for exchangeable K release followed by a plateau region extending from 120 to 336 hours for non exchangeable K desorption. This kind of a desorption behaviour of K in soils viz., a slow rate of desorption after a rapid rate of desorption has been well documented (Mehta and Singh, 1987 and Srinivasa Rao et al., 1998). Two linear regressions for the two regions and K desorption rate co-efficient ( $K_d$ ) values computed from slope values are given in table 13. The desorption rate co-efficients values were much larger in the initial phase (up to 120 hours) and smaller afterwards (120 to 336 hours). In general, in the initial phase, soils containing relatively higher amounts of both exchangeable and non-exchangeable K and recording relatively higher amounts of total desorbed K (e.g. Byadarahalli) registered relatively higher  $K_d$  values than the soils containing lower amounts of the same forms of K, particularly the exchangeable form of K. This would indicate the greater releasing and supplying power of K to the crops by the soils belonging to the former group than the

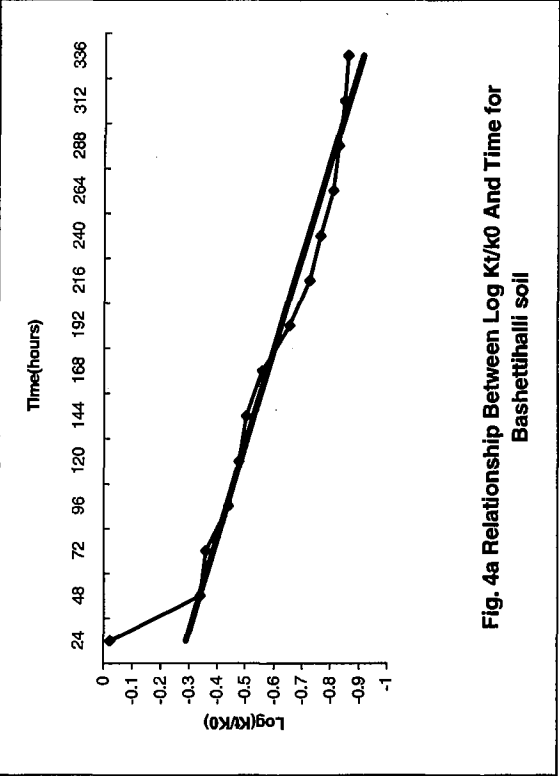


Fig. 4a Relationship Between Log  $Kt/k_0$  And Time for Bashethihalli soil

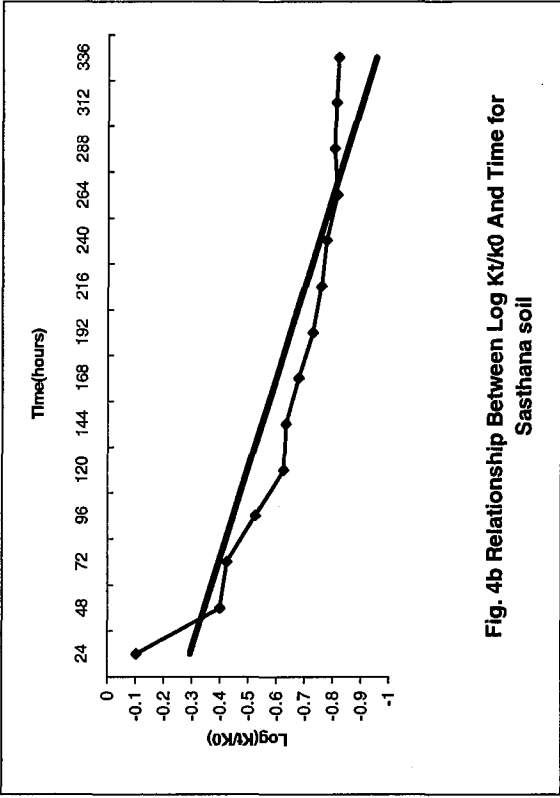


Fig. 4b Relationship Between Log  $Kt/k_0$  And Time for Sasthana soil

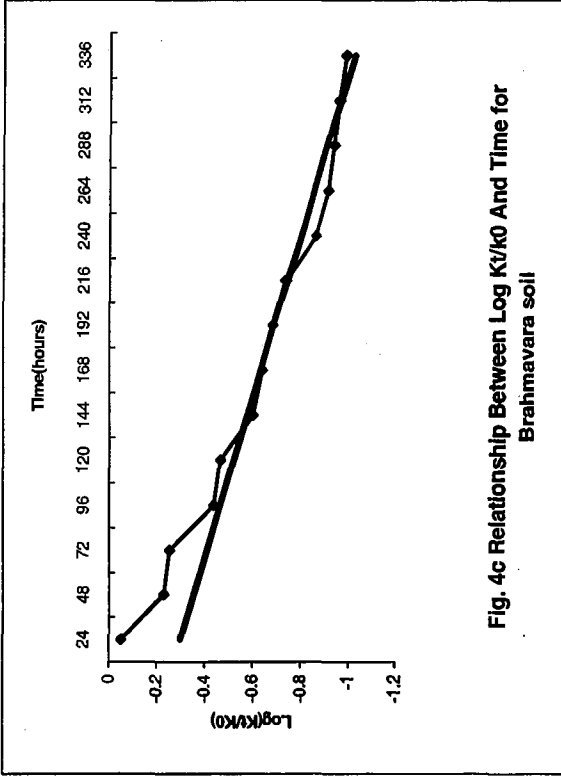


Fig. 4c Relationship Between Log  $Kt/k_0$  And Time for Brahmavara soil

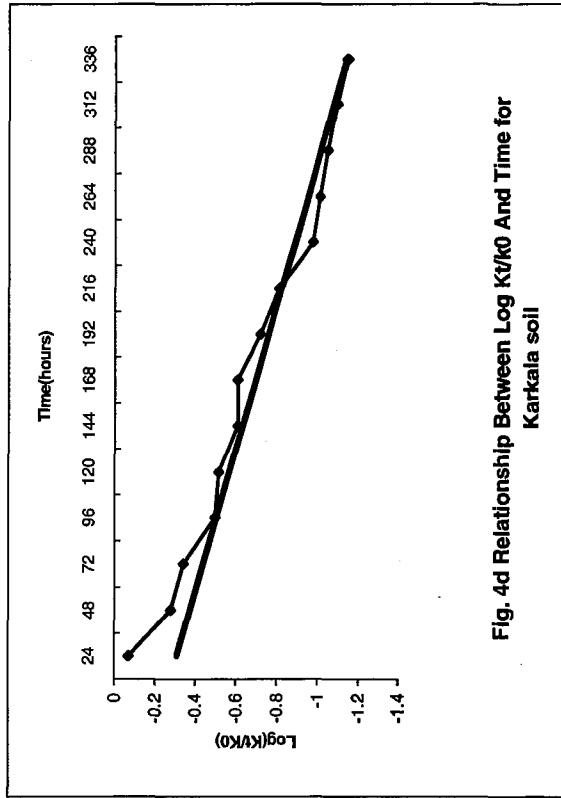
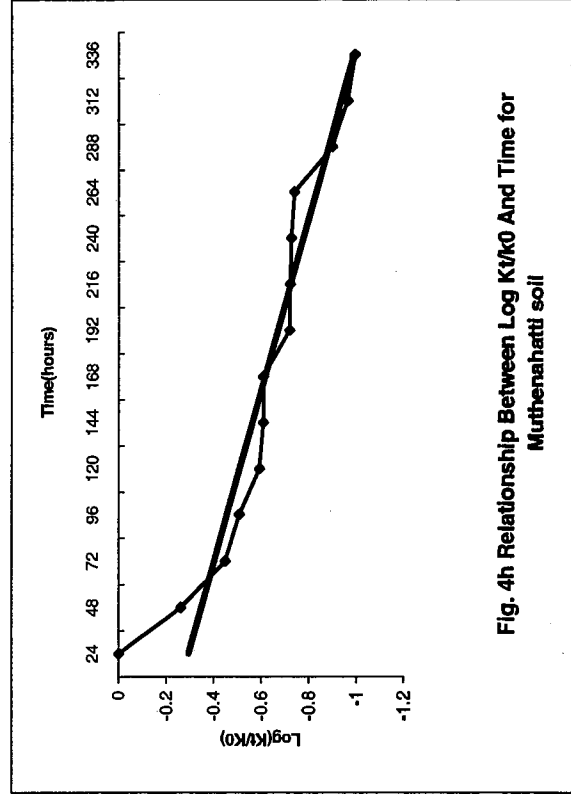
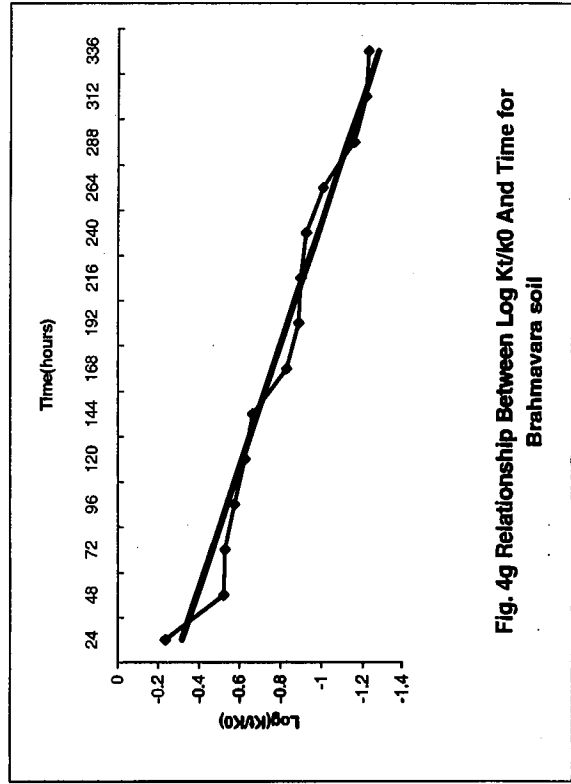
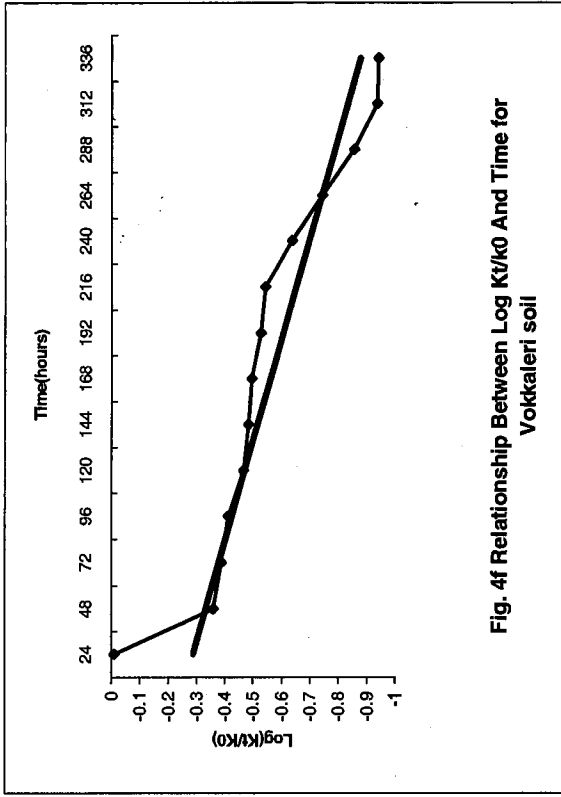
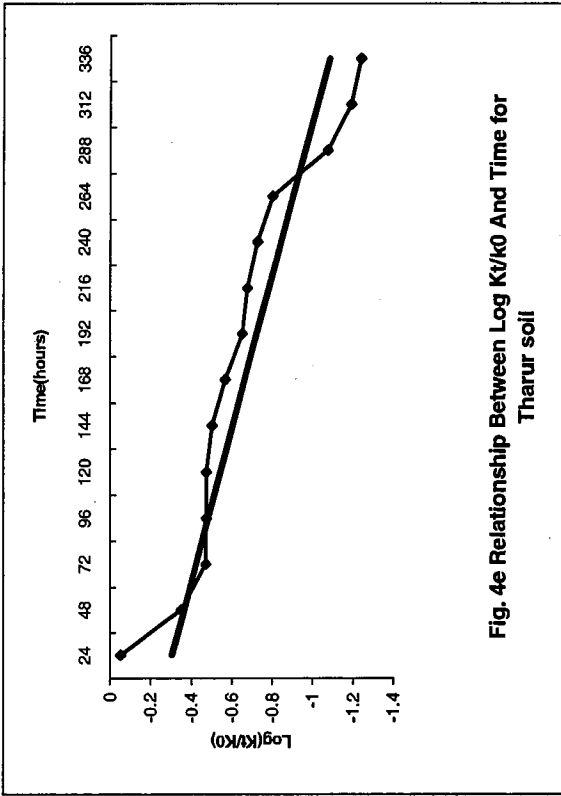
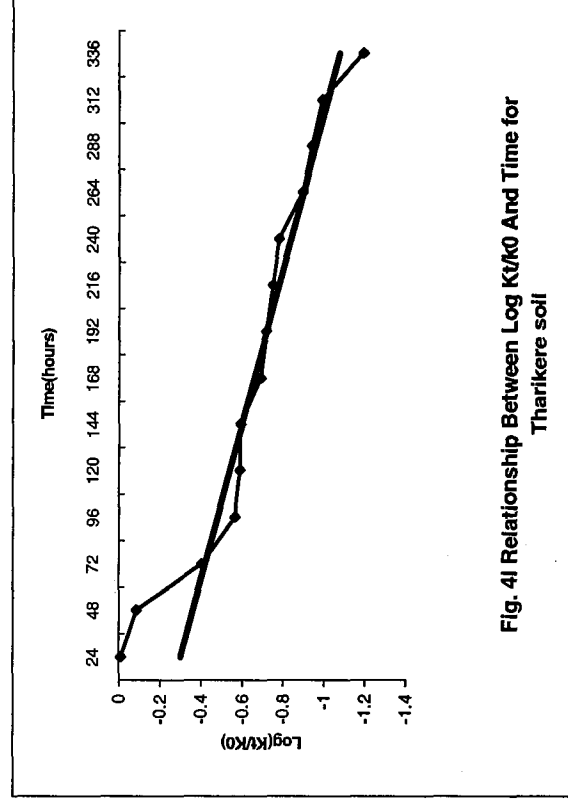
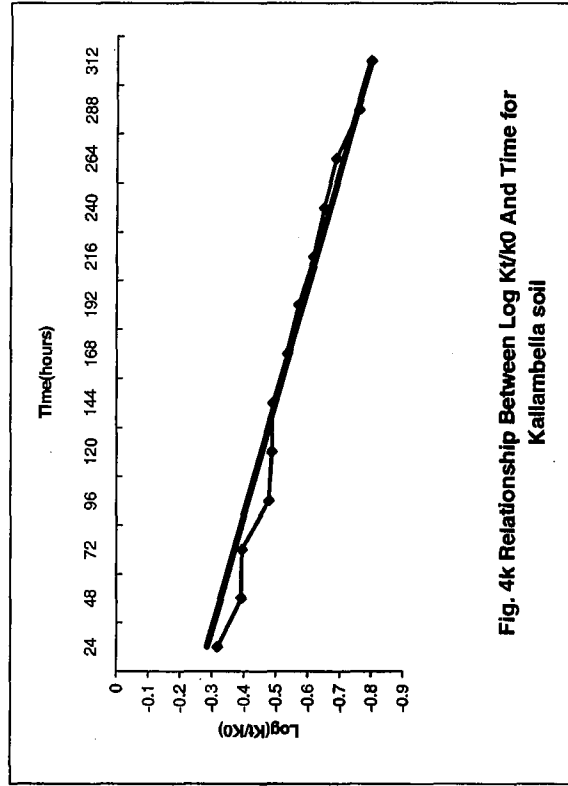
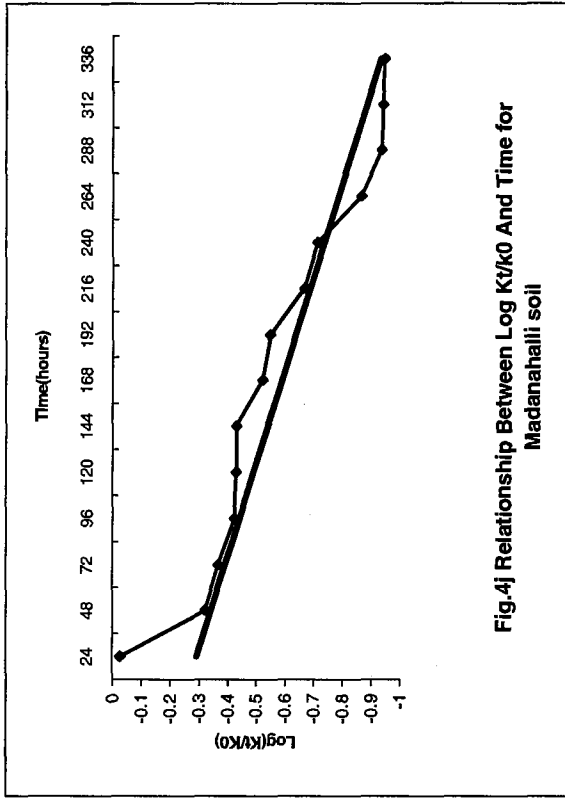
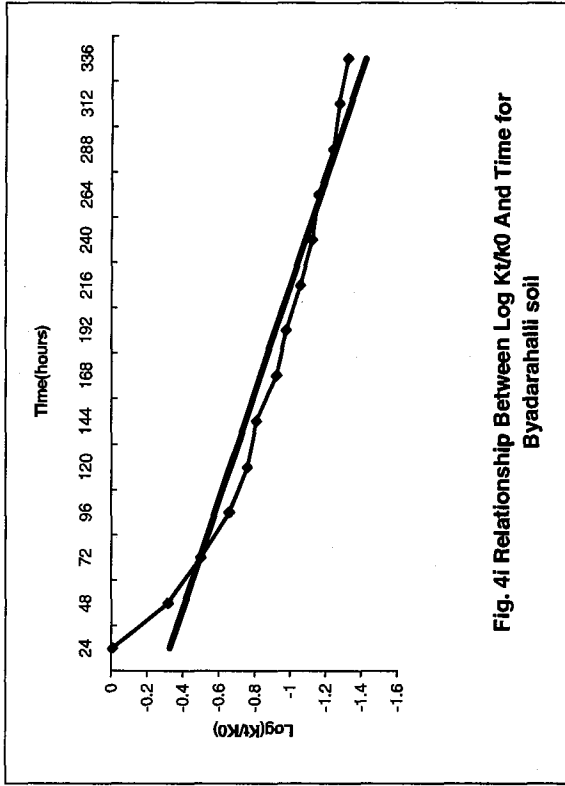
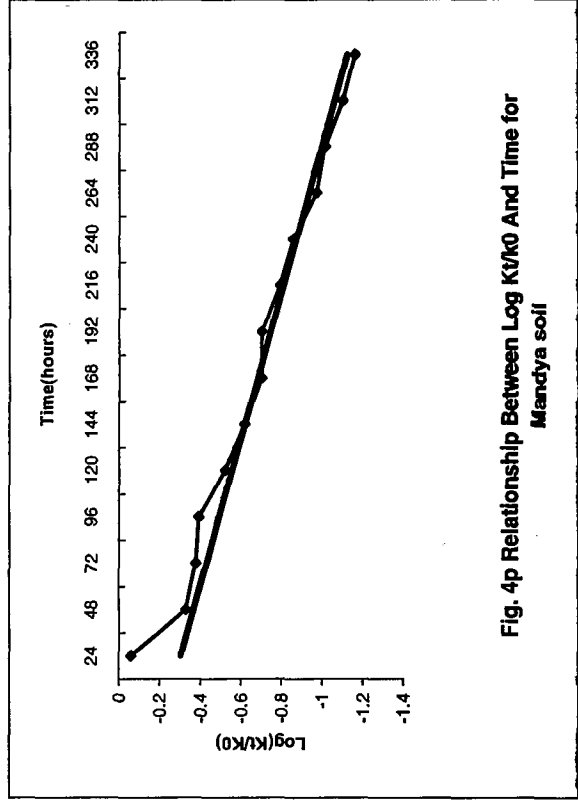
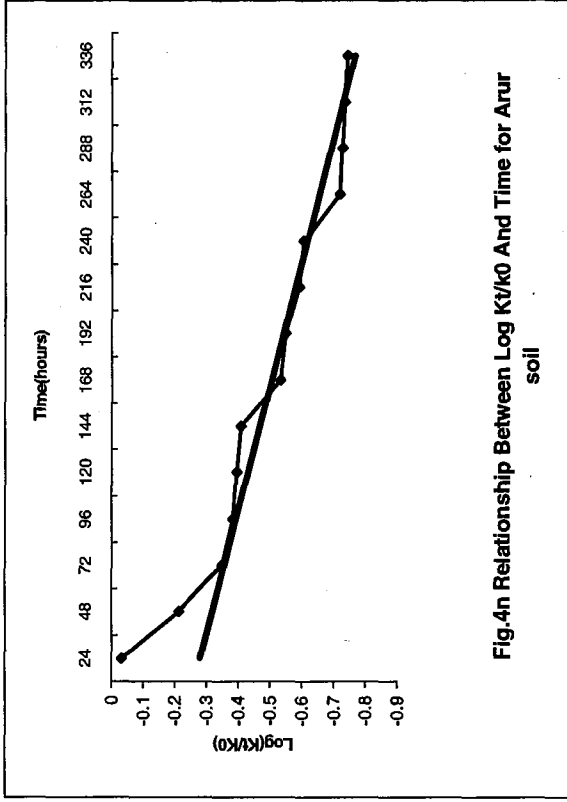
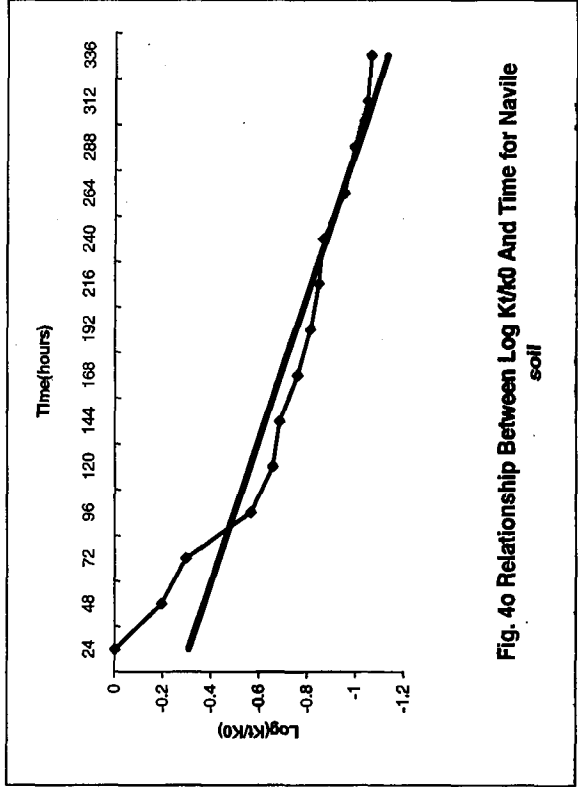
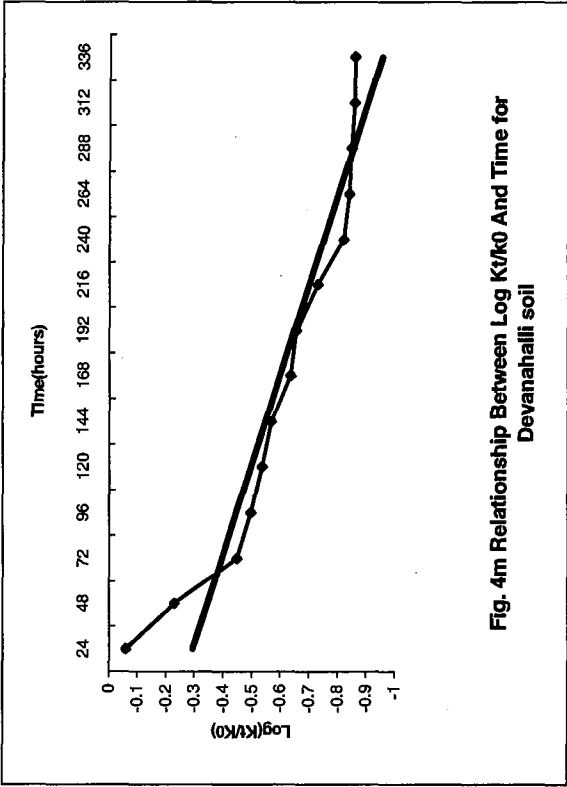
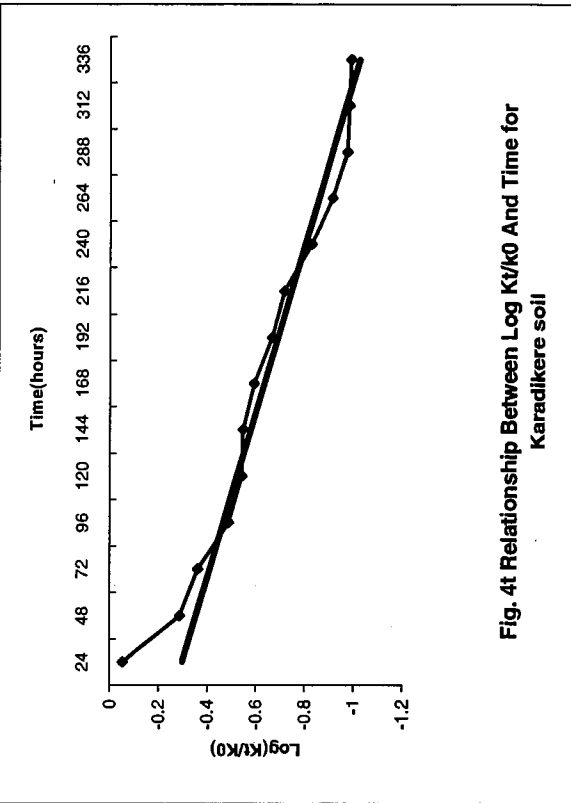
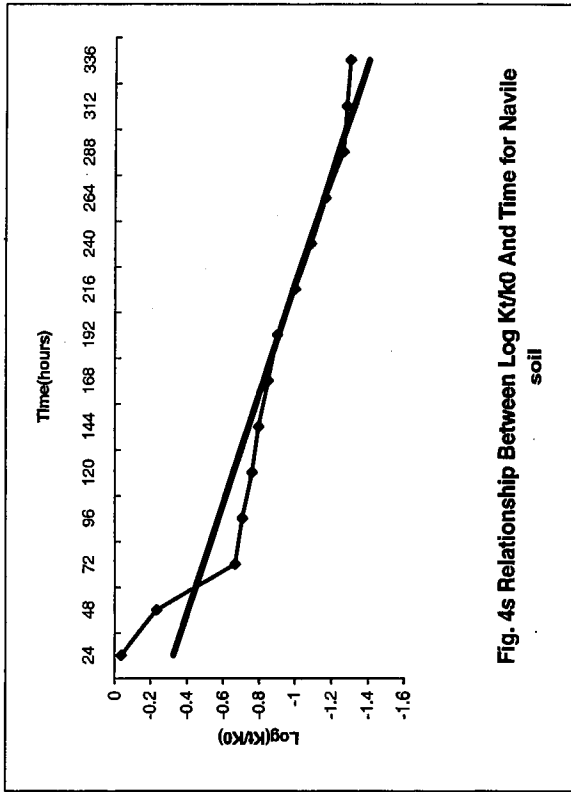
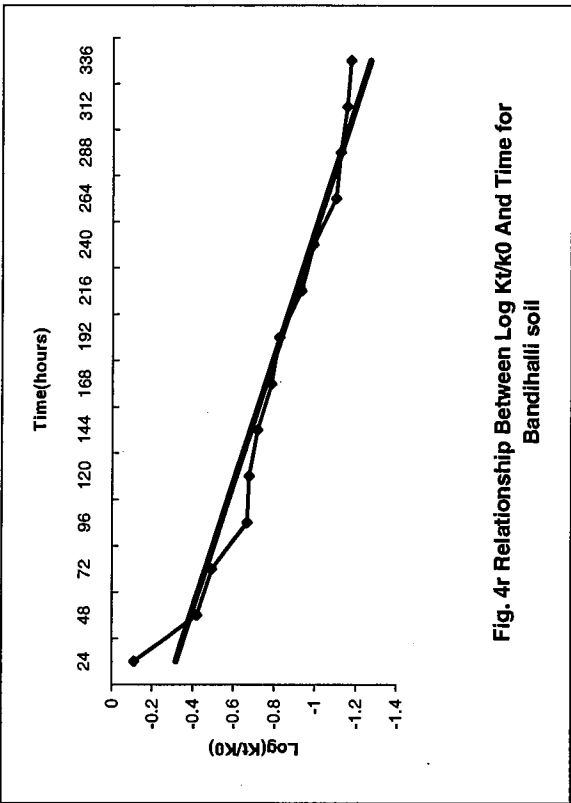
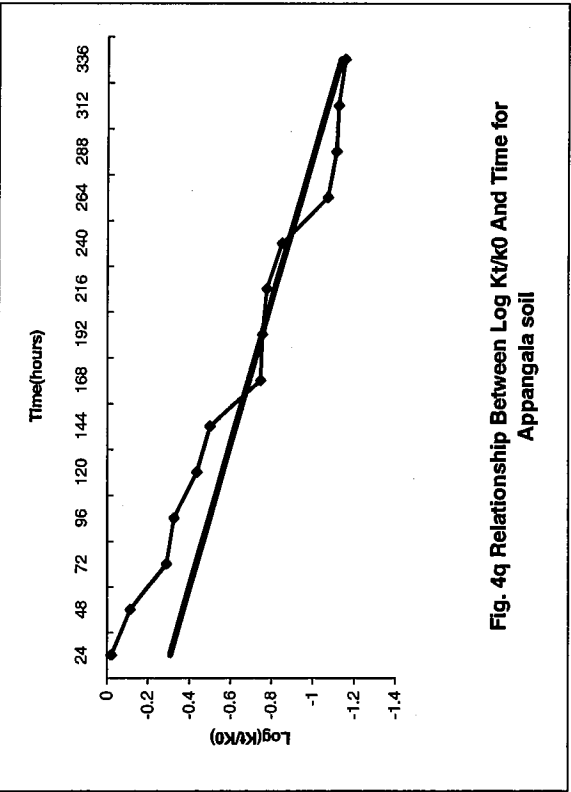


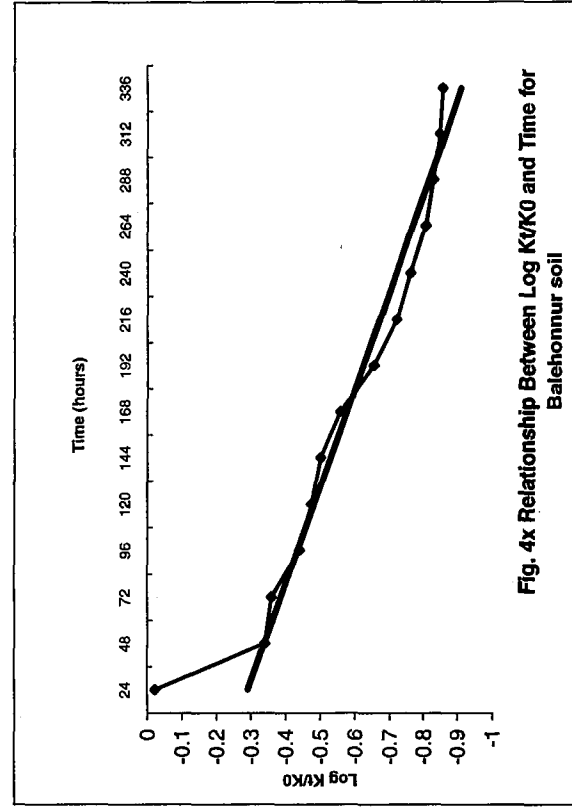
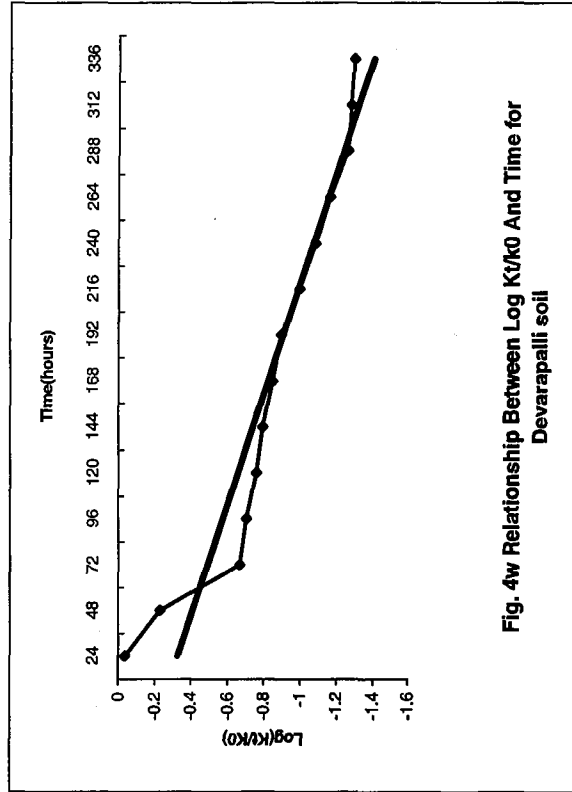
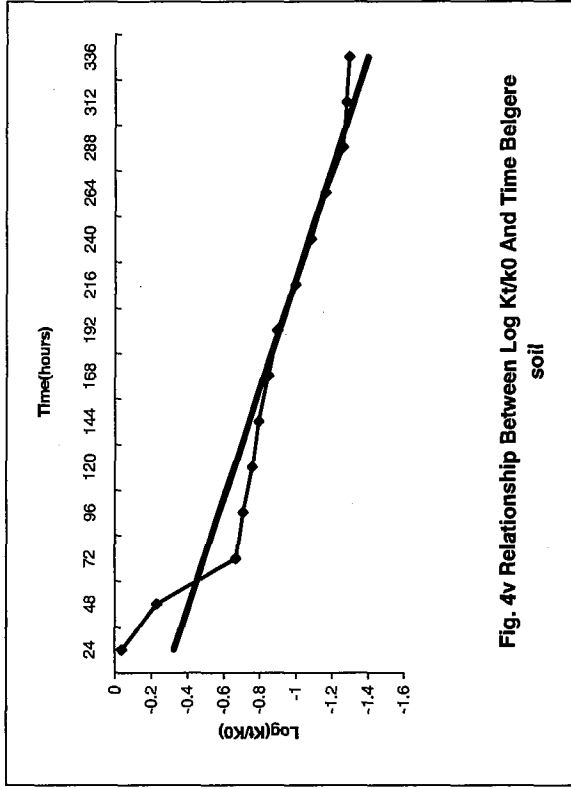
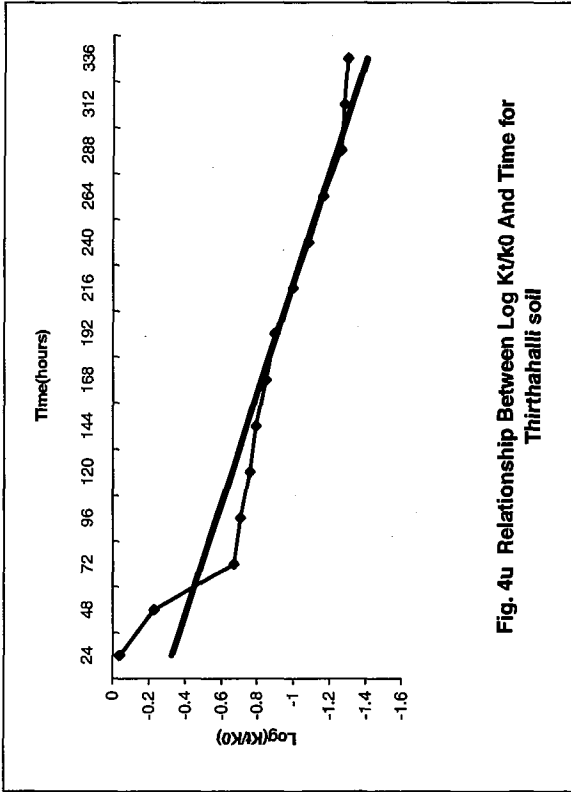
Fig. 4d Relationship Between Log  $Kt/k_0$  And Time for Karkala soil











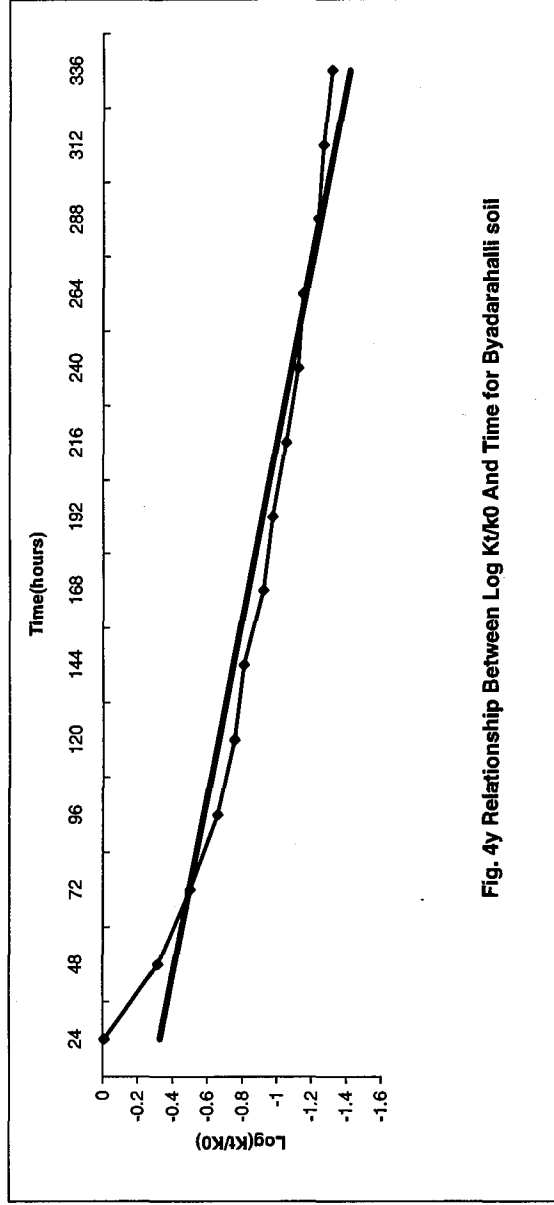


Fig. 4y Relationship Between  $\text{Log } K_t/K_0$  And Time for Byadarahalli soil

latter group. The K release up to 120 hours indicated the immediate K supplying capacity of soils (Srinivasa Rao et al., 1997a). Potassium desorption after 120 hours indicated long term K supplying power of soils which was particularly noticed in soils having relatively higher amounts of non-exchangeable K and hence higher  $K_d$  values.

## 5.5 Quantity –Intensity (Q/I) relationships of K

### 5.5.1 Quantity- Intensity (Q/I) curves

The activity ratios ( $AR^k$ ) and corresponding change in K ( $\pm\Delta K$ ) for samples equilibrated with  $K^+$ -  $Ca^{2+}$  system are presented in table 14. The curves (Fig. 5a-5y) obtained for different soils by plotting the  $AR^k$  values on X-axis and  $\pm\Delta K$  values on Y-axis of the graph papers showed that there was a linear upper part and a curved lower part in the case of every soil used in the study. Beckett (1964a) opined that the curved part was related to the release of specifically adsorbed K, when very little K was present in the soil solution. This would offer an explanation as to why exchangeable K determinations were not always precise. The release of K might be a diffusion process, where by K may be moved from inter lattice position to the labile pool. Such a release should be relatively independent of shaking, but should depend mainly on the diffusion path and K gradient existing in the system. On the other hand when the same sample is shaken, the possibility of abrasion of edges of clay crystals with the surface of container cannot be over looked. Any such abrasion of mica could be expected to release more K. This results in an artificial increase in the labile pool. This process is important and particularly enhances when large amounts of labile Ca and Mg ions are present in the equilibrating system, which tend to open up the mica lattice (Le Roux and Sumner, 1968 and Rich, 1968).

The intensity factor ( $AR_e^k$ ) in different soils varied from 0.62 to  $9.20 \times 10^{-3}$   $(M/L)^{0.5}$  (Table 15). In general, the  $AR_e^k$  was relatively higher in soils with higher amounts of exchangeable K and lower in the case of soils with lower amounts of exchangeable K. This signifies a positive relationship between the two entities. But

results contrary to the above statement were also recorded in few cases e.g. (Karadikere) wherein soils with even higher exchangeable K status recorded lower  $AR_e^k$  values. This could be because of the higher amounts of Ca and Mg present in the soil and hence an inverse relationship with  $AR_e^k$ . This result is in conformity with that of Niranjana (1994). The labile potassium ( $K_L$ ), which is a quantity factor, varied from 0.10 to 0.90  $\text{cmol (p}^+) \text{ kg}^{-1}$  in different soils. Generally, soils containing relatively higher amounts of clay, CEC and non-exchangeable K in the soil recorded lower values for  $K_L$ . This would indicate the dependence of  $K_L$  values on these soil attributes. Dhillon et al. (1990), Nilima et al. (1997), and Pal and Subba Rao (1997) have also reported similar results.

Specifically bound potassium ( $K_x$ ) in soils varied from 0.05 to 0.38  $\text{cmol (p}^+) \text{ kg}^{-1}$  as given in table 15. The higher values of  $K_x$  for soils indicated larger exchange surface exposed by higher amount of clay and as such offering more number of specific sites for binding K. This may also be due to presence of 2:1 type of clay mineral in the soil. On the other hand, a few soils such as Kallambella and Thirthahalli recorded lower  $K_x$  values, which may be attributed to less number of specific sites due to relatively higher proportion of coarser fractions in soils. Similar findings were also reported by Chandi and Sidhu (1993), Dhillon et al. (1990) and Surekha and Subba Rao (1996).

The  $K_0$  values indicated the quantity of K held on non-specific sites. In all the soils the  $K_0$  values were lower than the values of  $\text{NH}_4\text{OAc}$  extractable K. These observations are in conformity with the findings of Beckett and Nafady (1967) who reported that part of exchangeable K does not contribute to  $K_0$  pool.

Result of the table 15 reveal that the potential buffering capacity of K ( $\text{PBC}^k$ ) values varied from 20.80 to 146.34  $\text{cmol (p}^+) \text{ kg}^{-1}/(\text{M/L})^{0.5}$ . The  $\text{PBC}^k$  values closely followed the trend of clay content of different soils showing a positive relationship with it. This suggests that higher  $\text{PBC}^k$  values are indicative of capacity of the soils to supply K to crops for longer periods of time (Ghosh and Ghosh, 1976; Nilima et al., 1997 and Surekha and Subba Rao, 1996). However, it depends on the concentration of K in soil

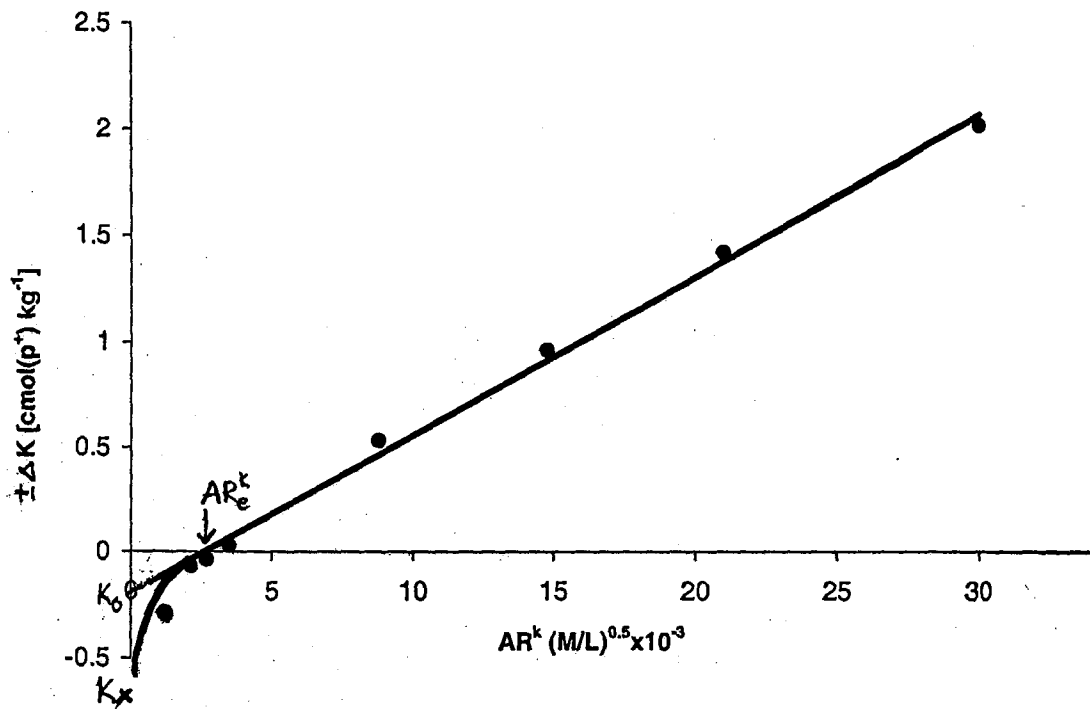


Fig. 5a Q/I Curve for Bashettihalli Soil

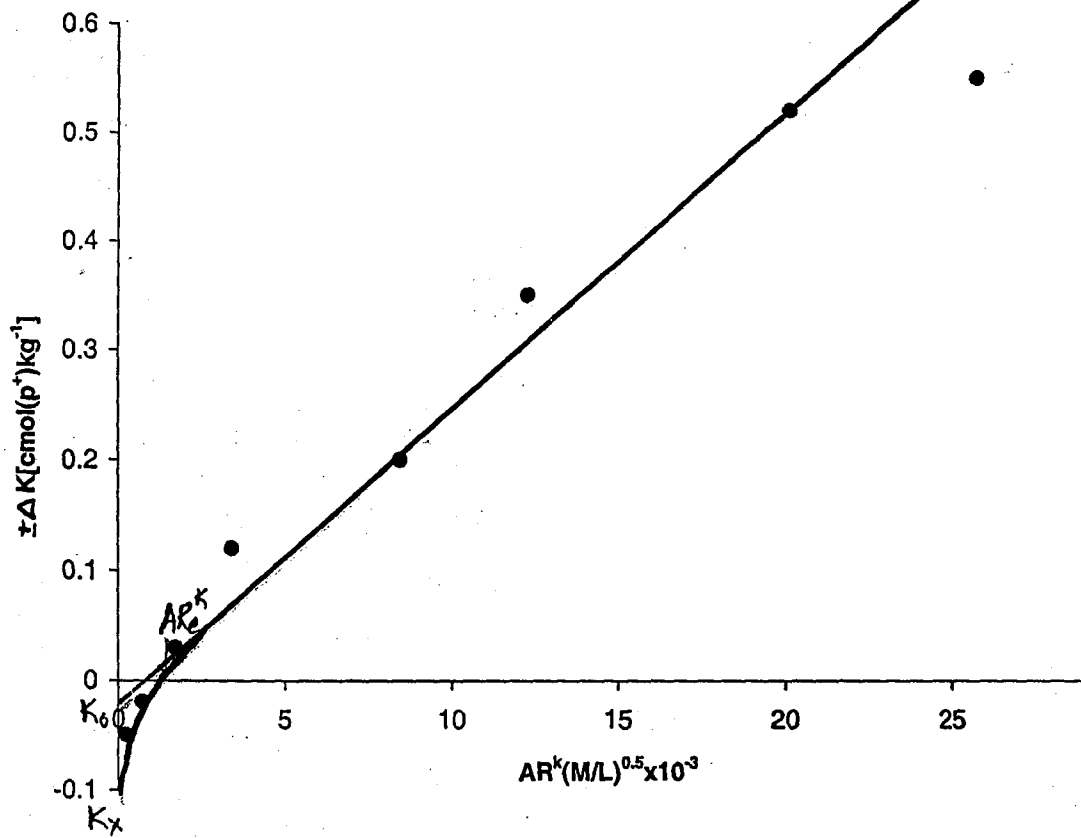


Fig. 5b Q/I Curve for Sasthana Soil

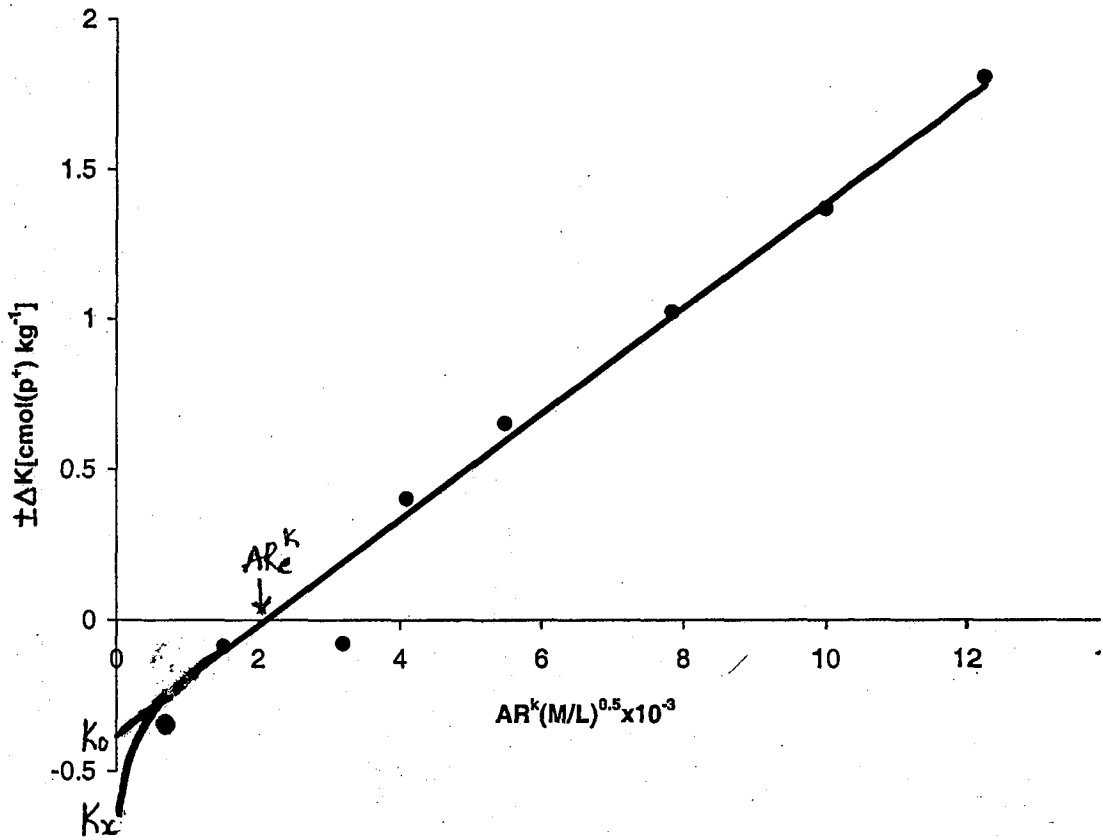


Fig. 5c Q/I Curve for Brahmavara Soil

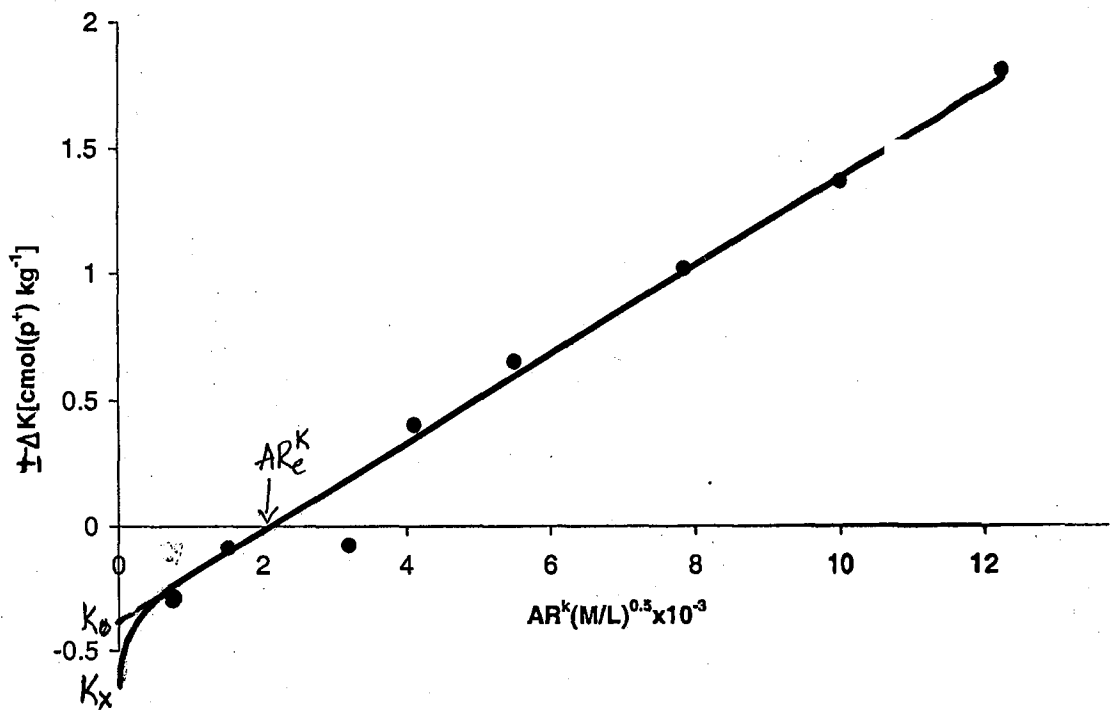


Fig. 5d Q/I Curve for Karkala Soil

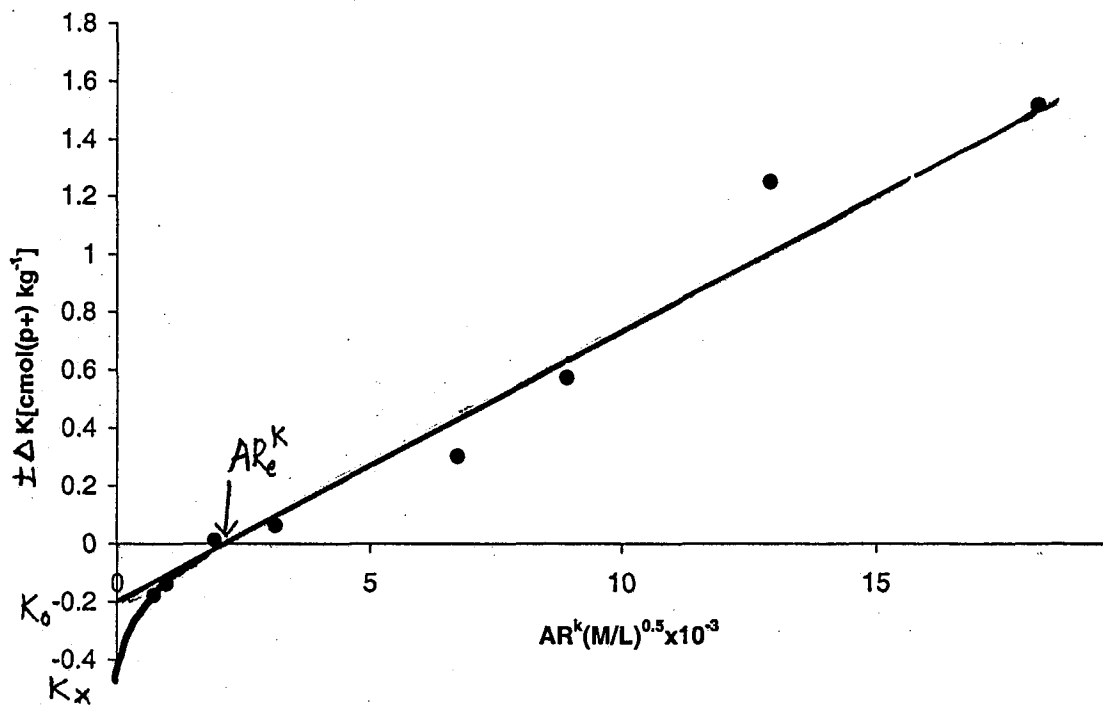


Fig. 5e Q/I Curve for Tharur Soil

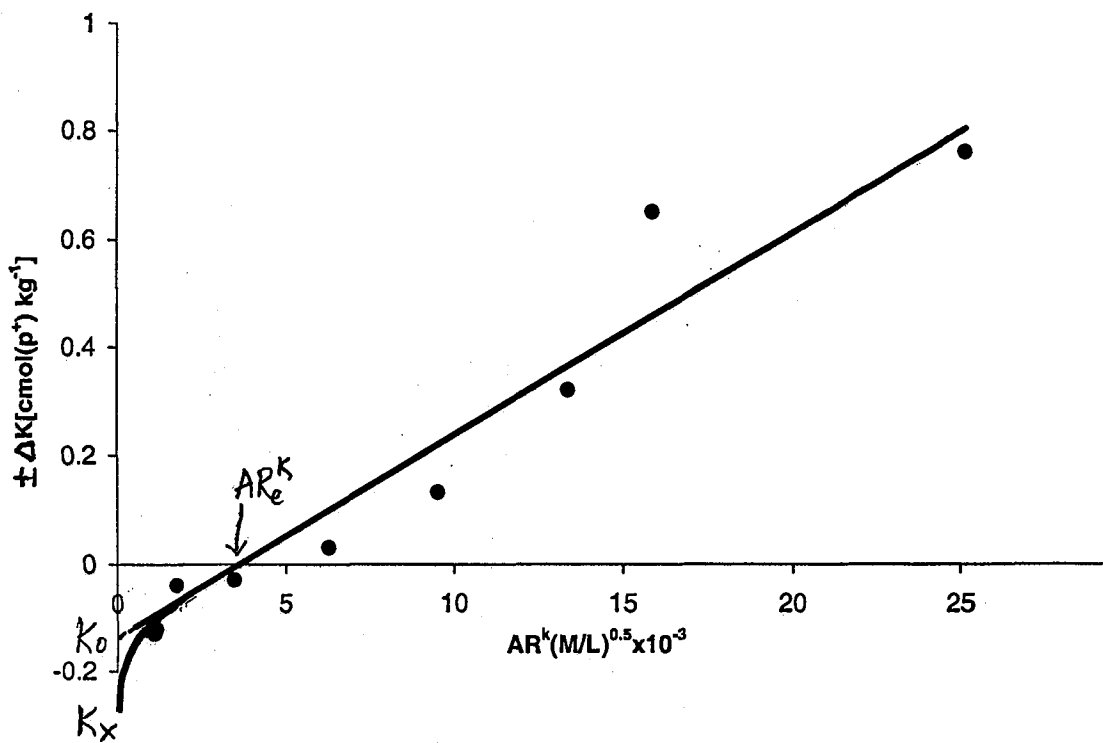


Fig. 5f Q/I Curve for Vokkaleri Soil

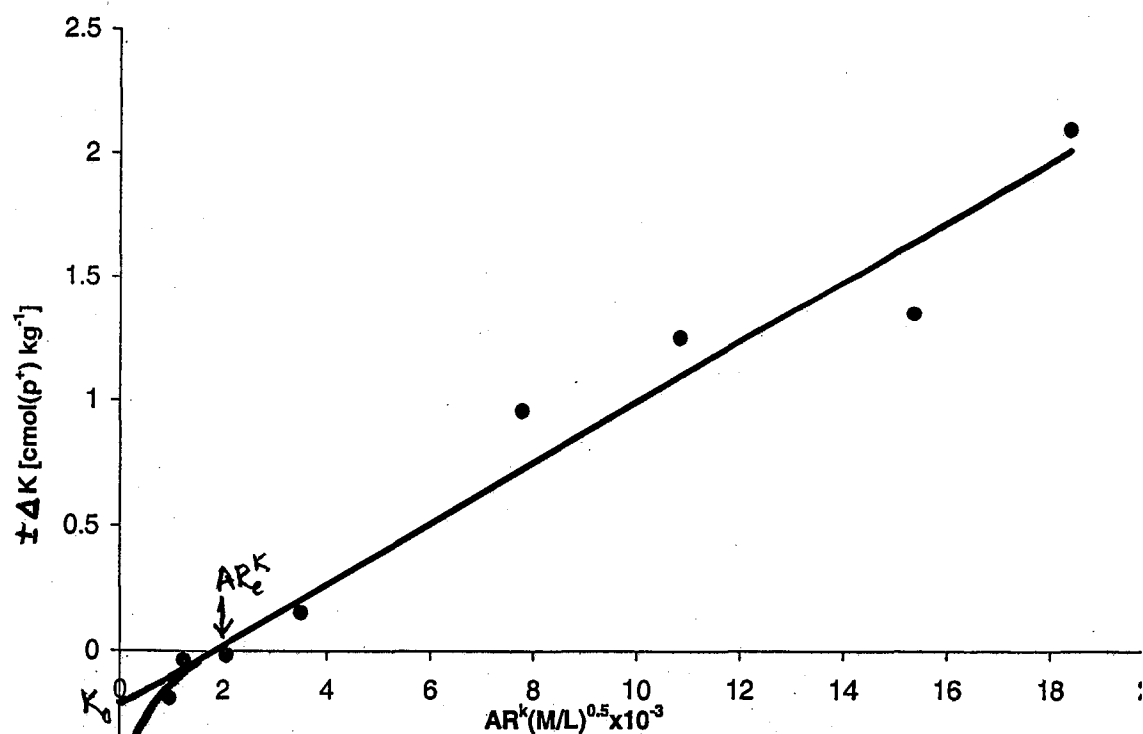


Fig. 5g Q/I Curve of Brahmavara Soil

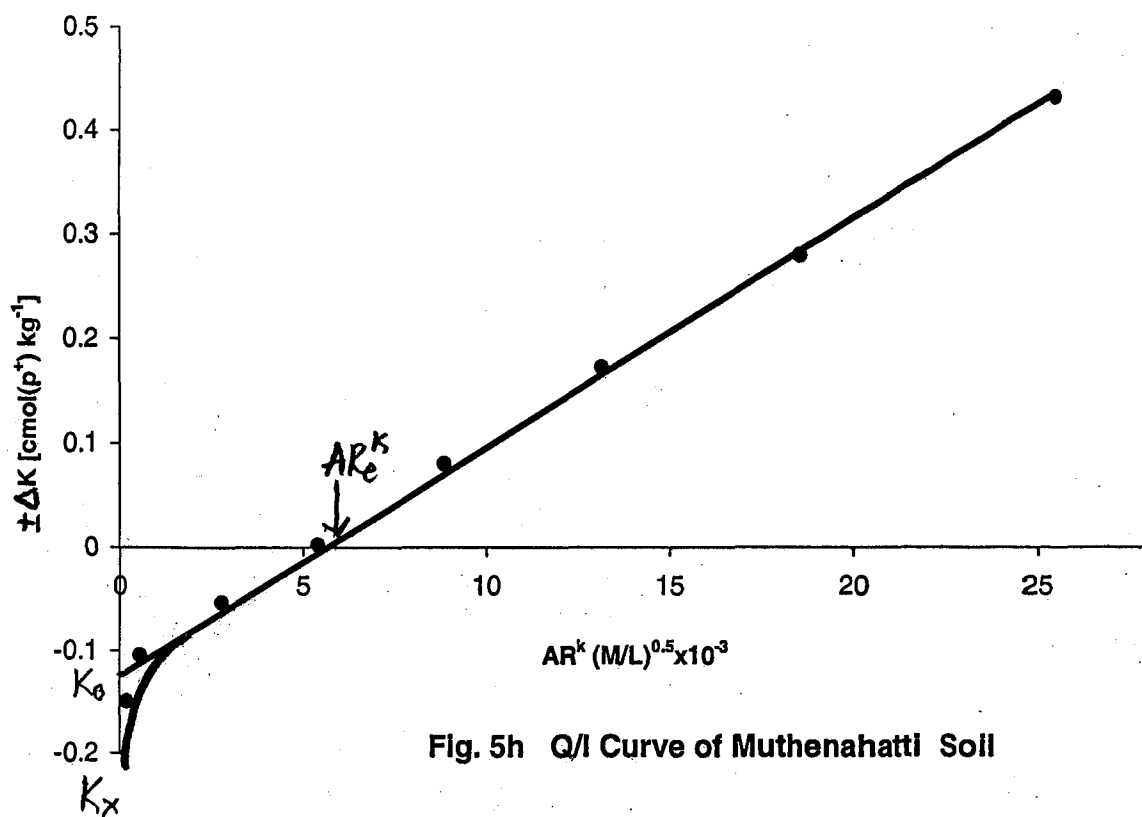
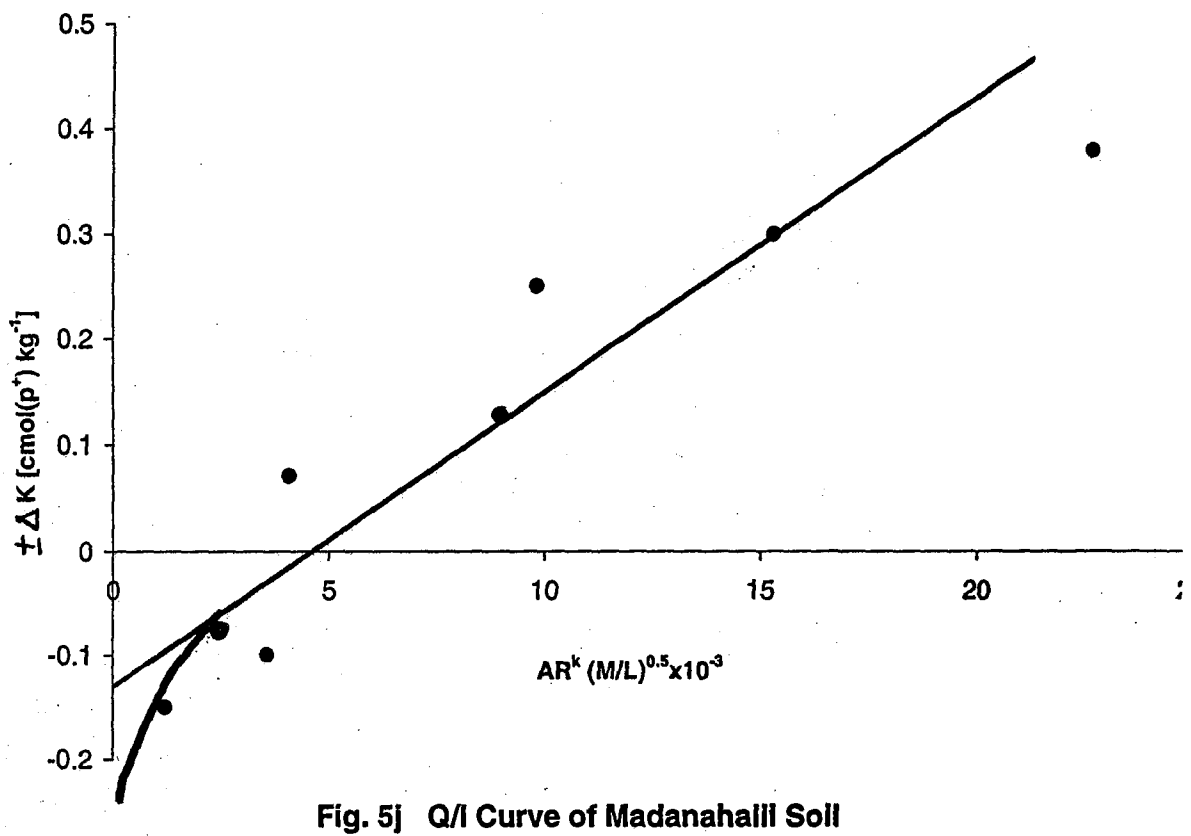
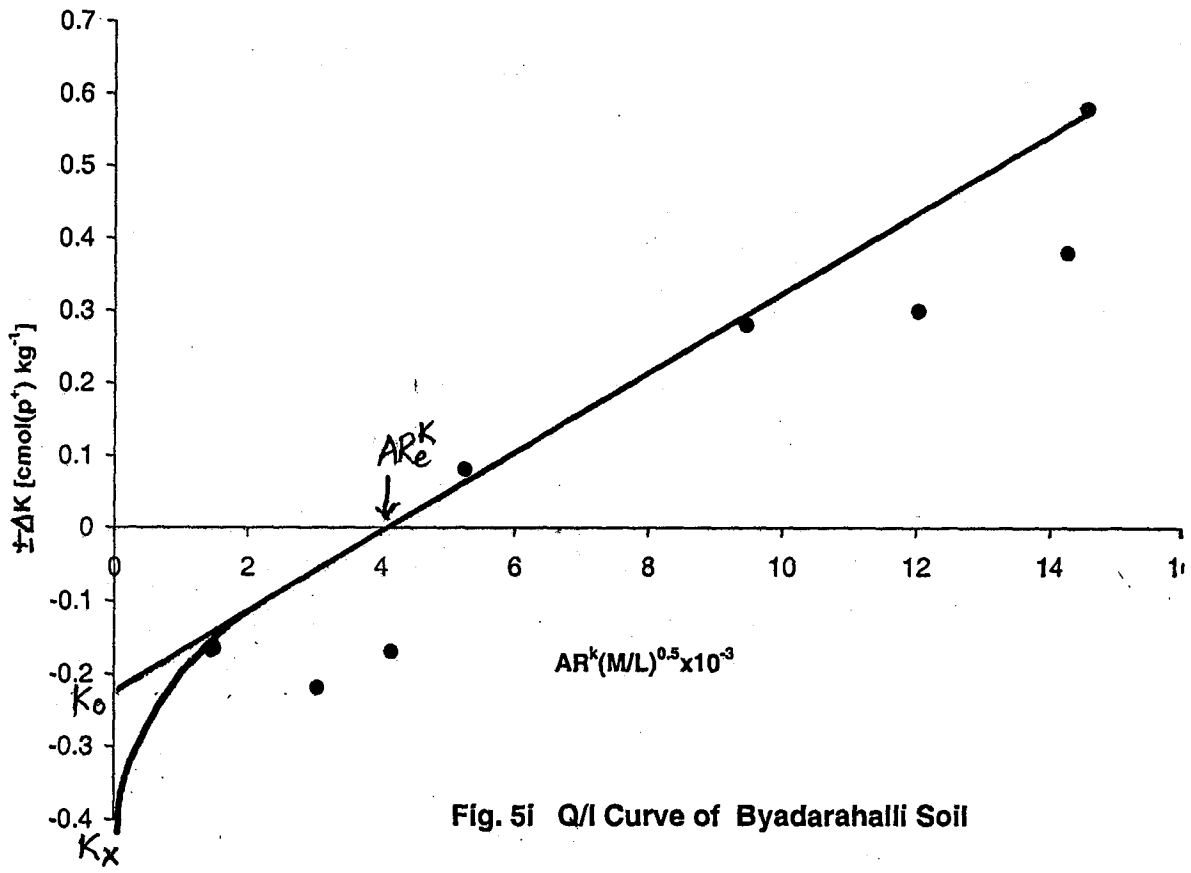


Fig. 5h Q/I Curve of Muthenahatti Soil



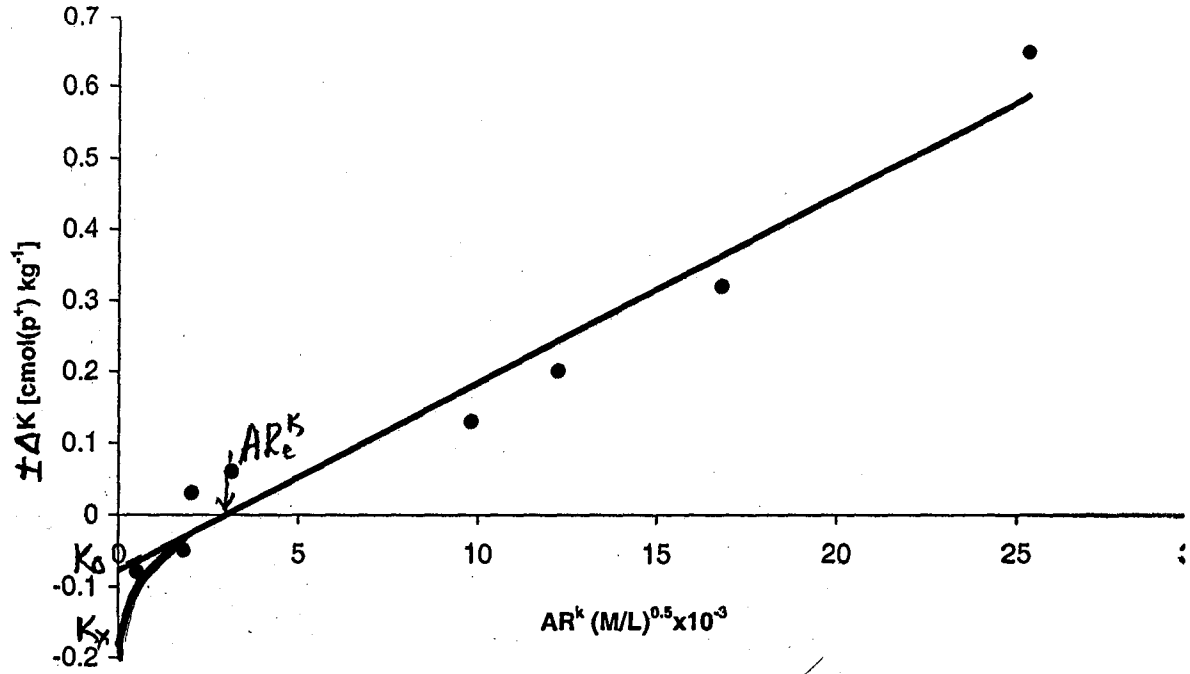


Fig. 5k Q/I Curve of Kallambella Soil

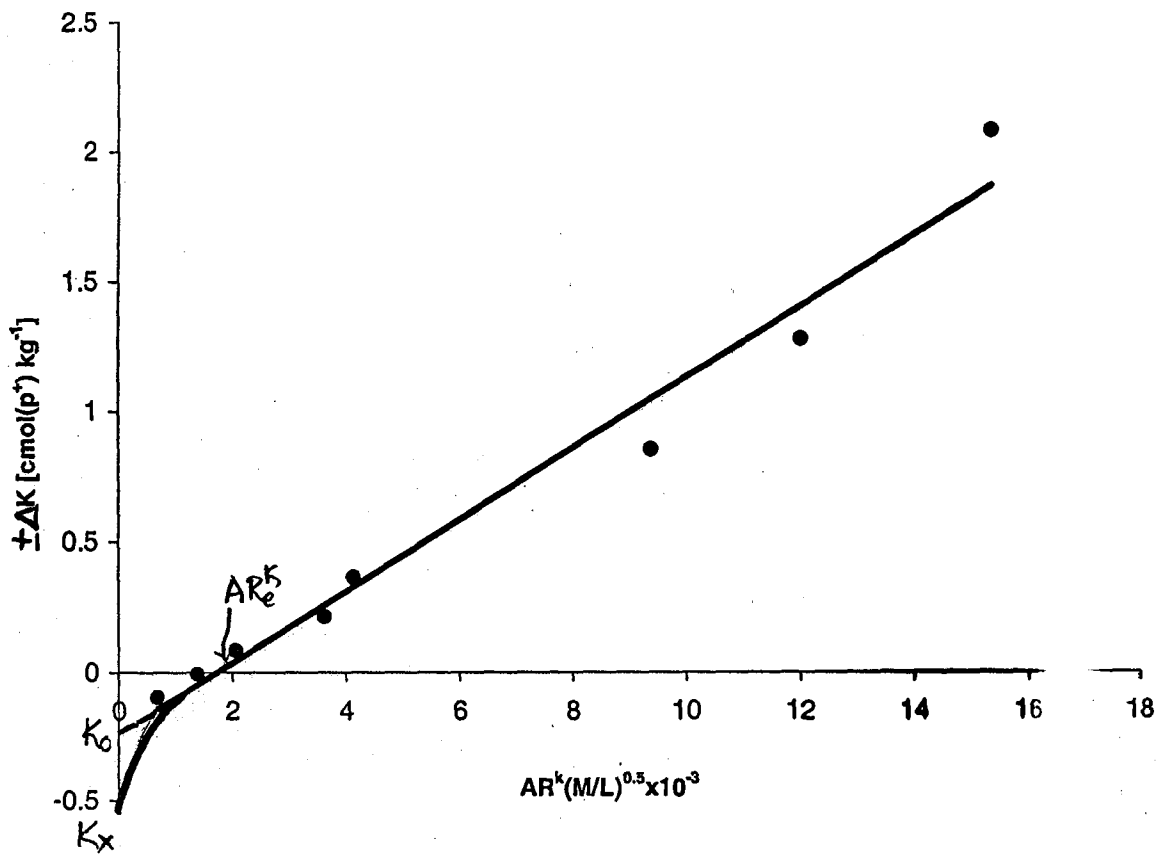


Fig. 5l Q/I Curve of Tharikere Soil

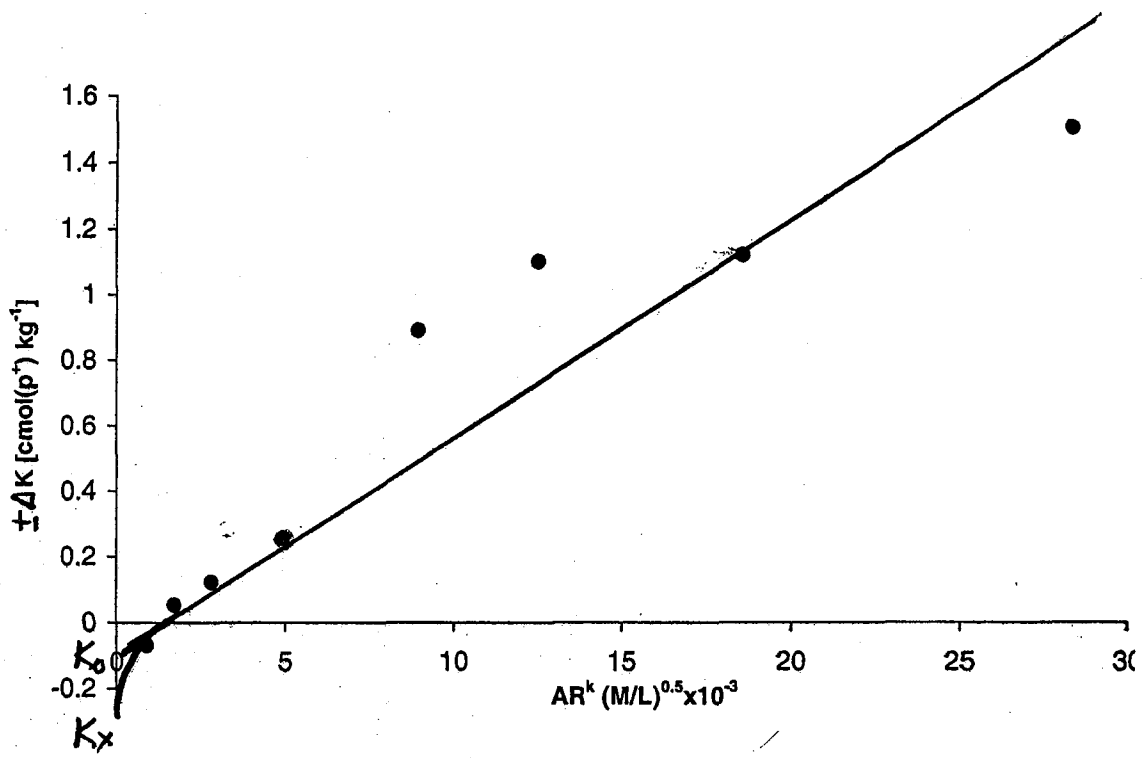


Fig. 5m Q/I Curve of Devanahalli Soil

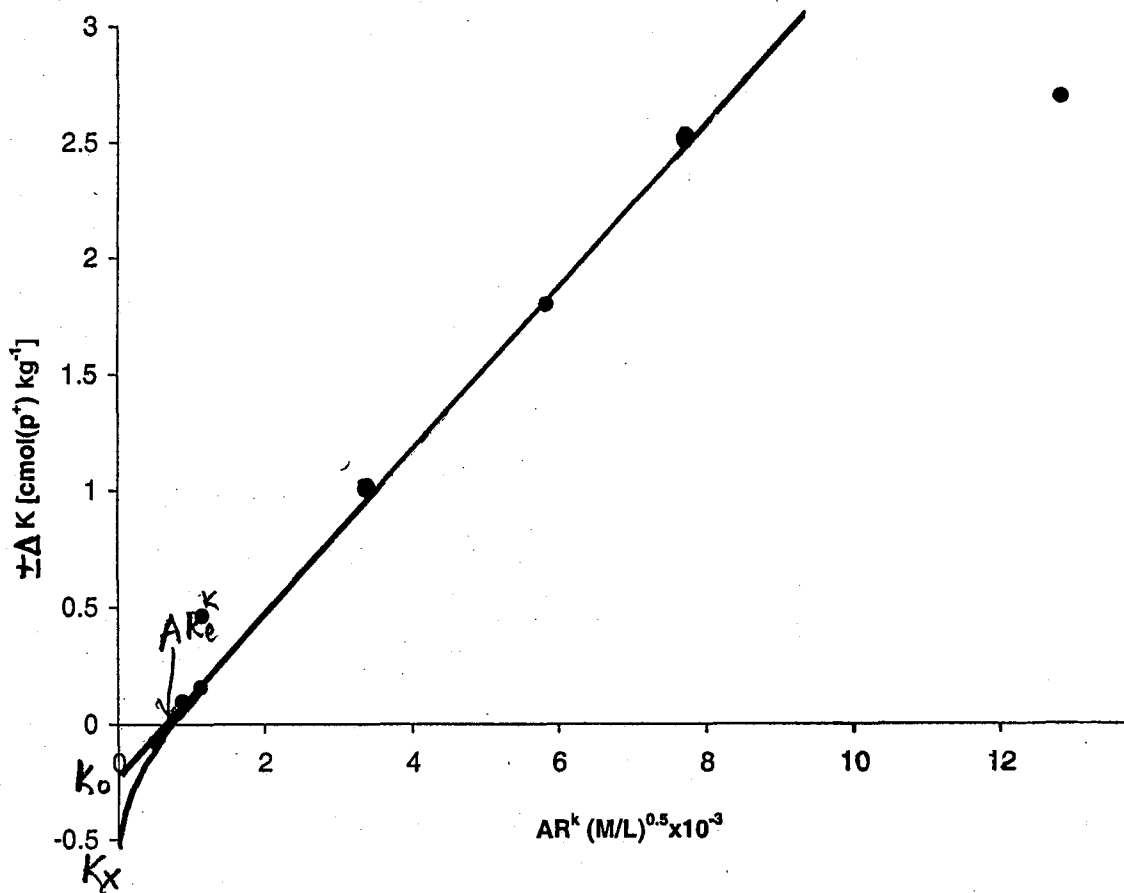


Fig. 5n Q/I Curve of Arur Soil

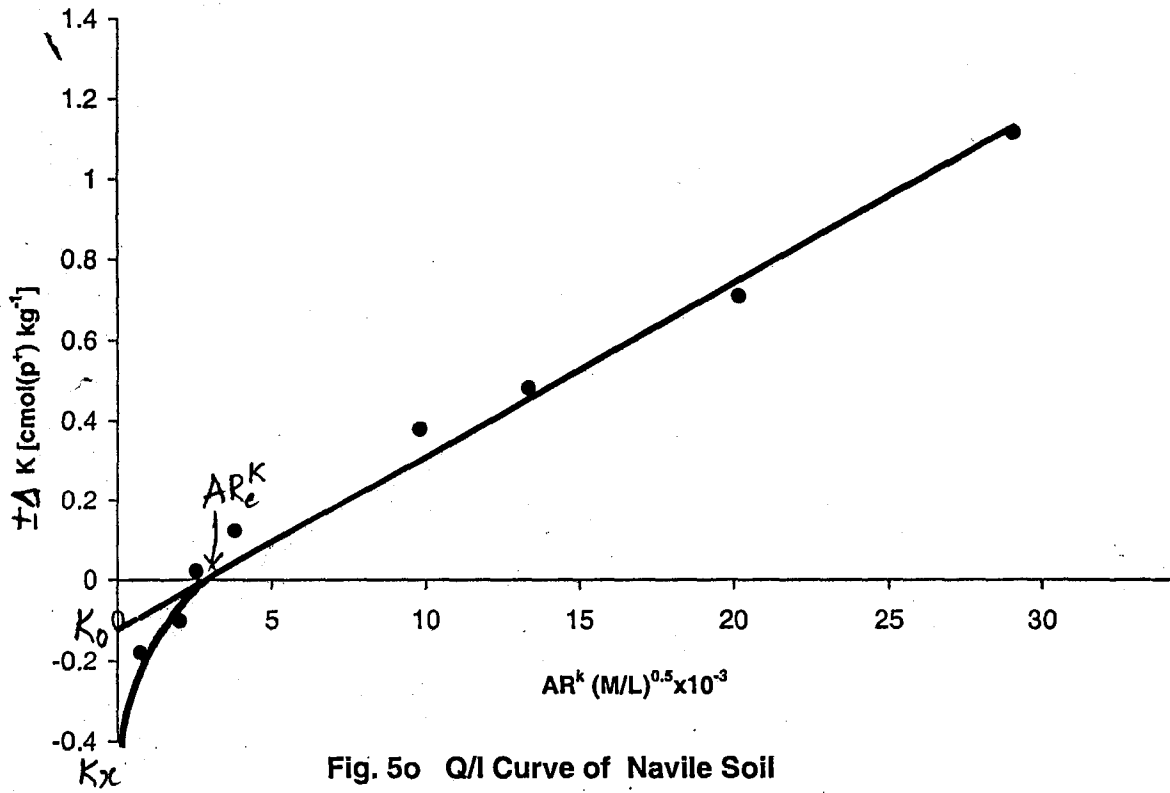


Fig. 5o Q/I Curve of Navile Soil

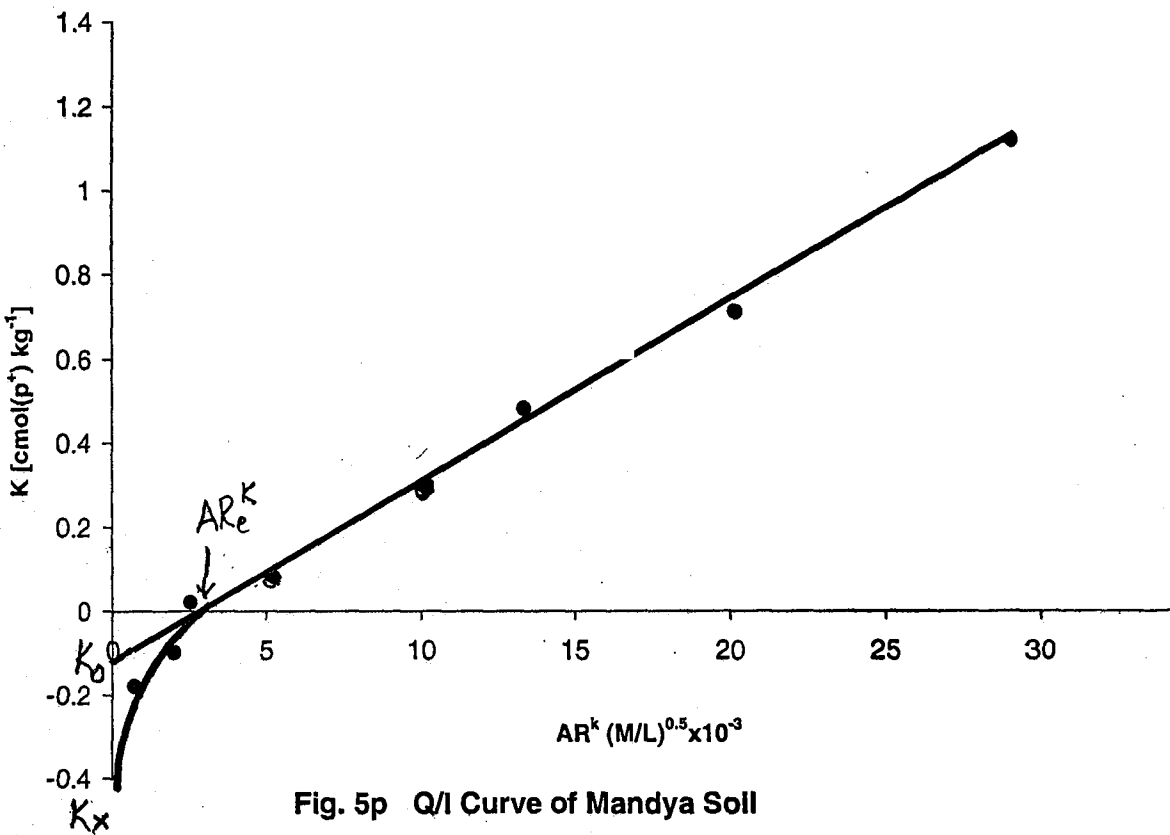


Fig. 5p Q/I Curve of Mandya Soil

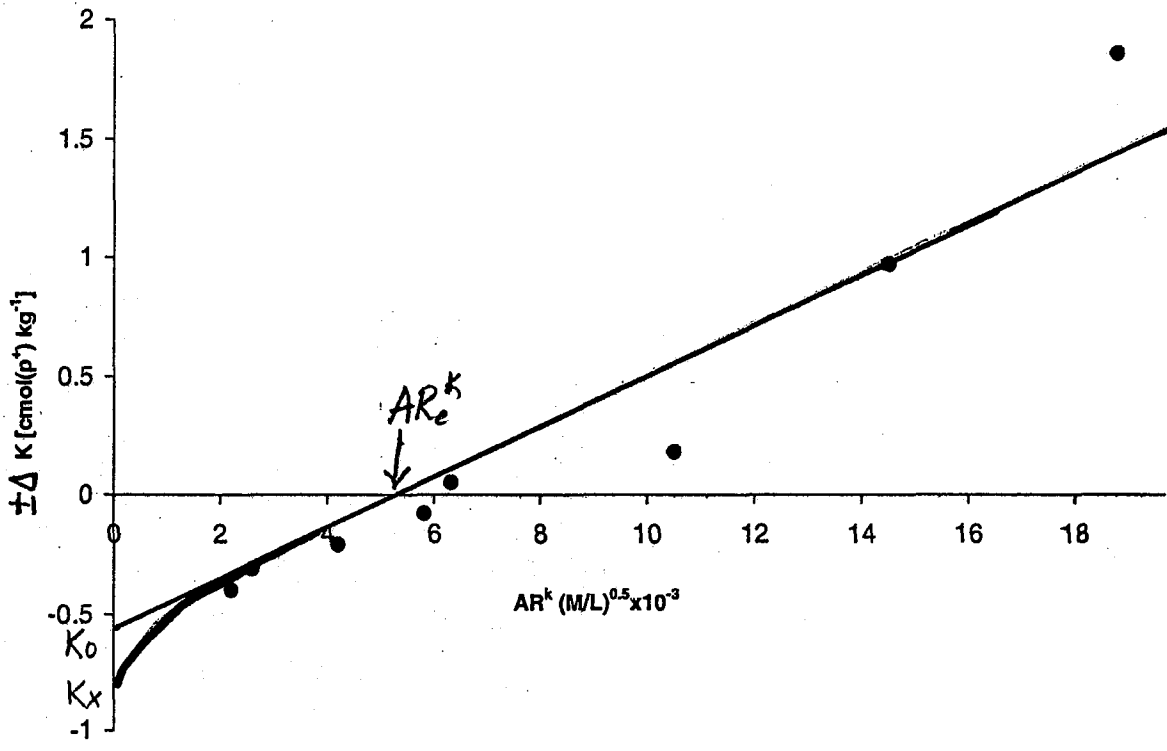


Fig. 5q Q/I Curve of Appangala Soil

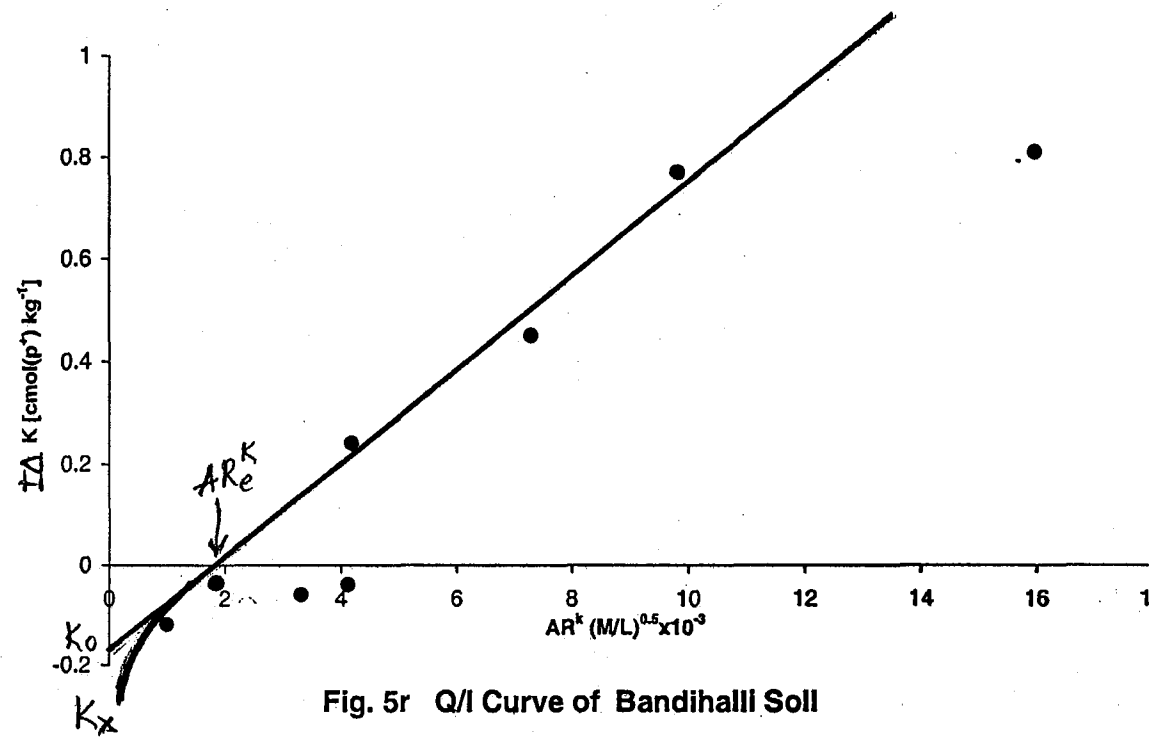
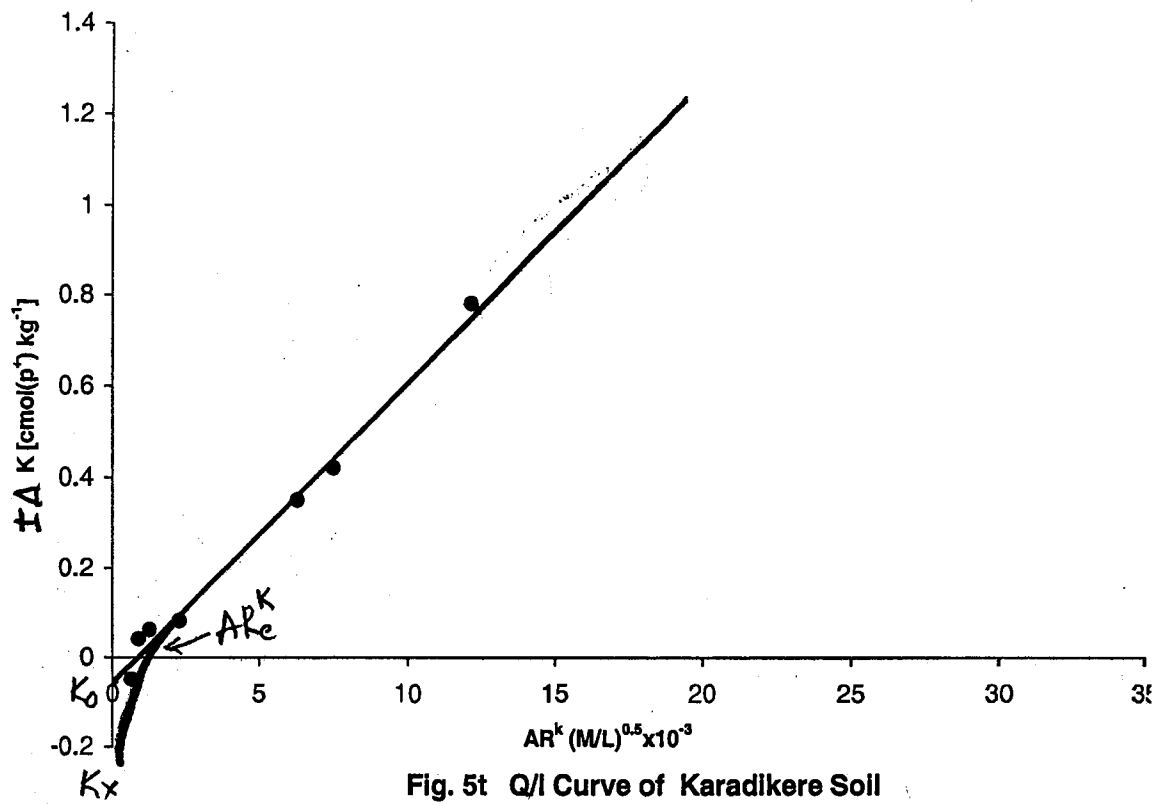
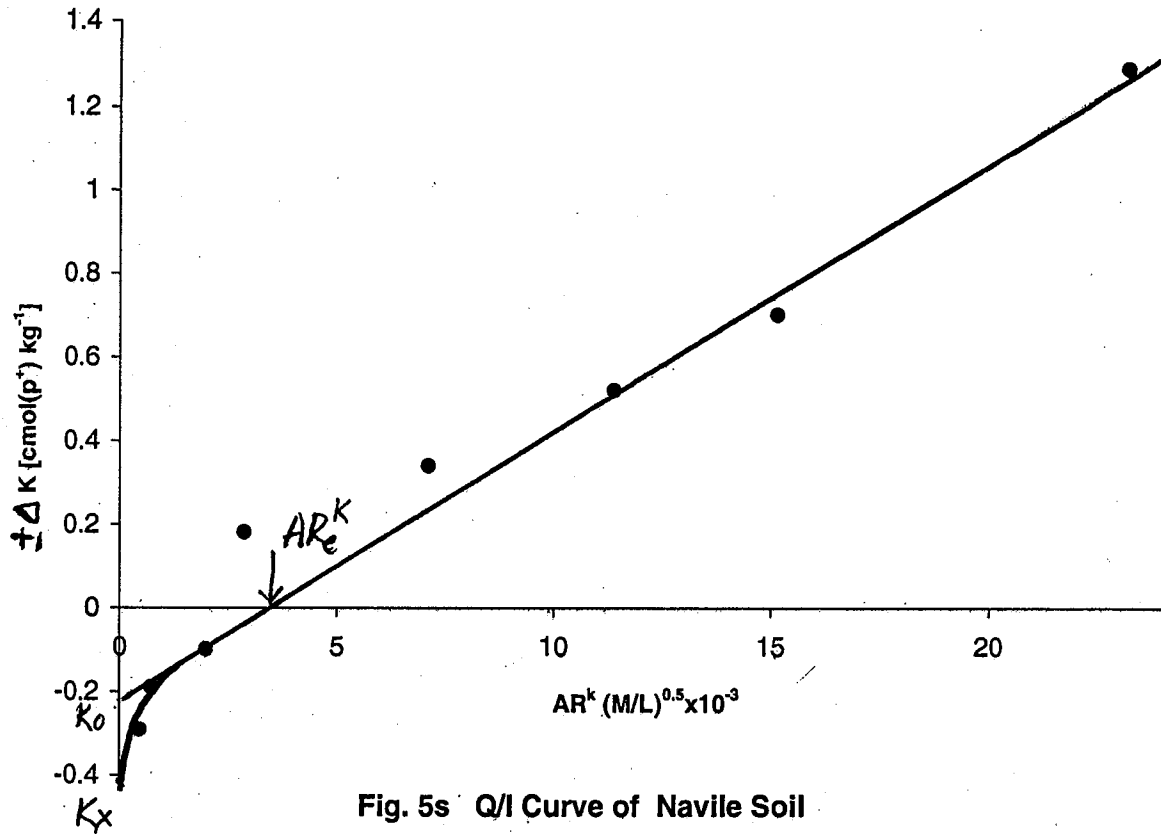


Fig. 5r Q/I Curve of Bandihalli Soil



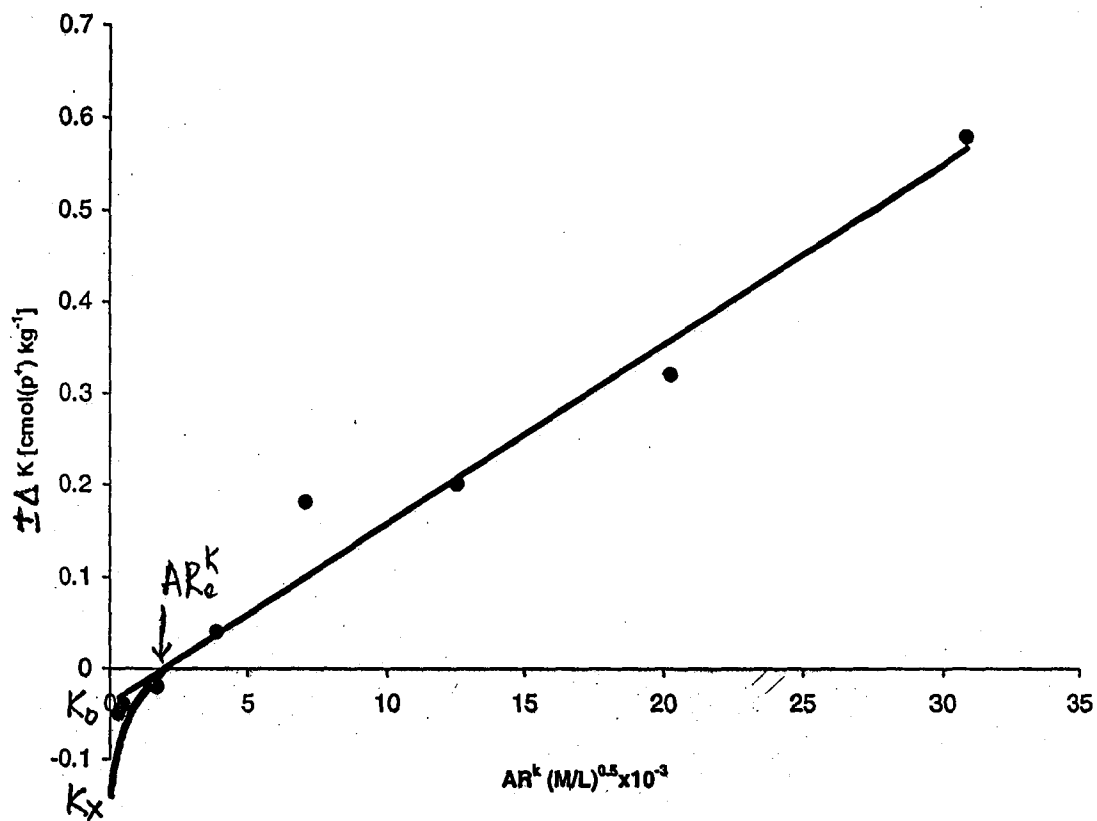


Fig. 3u Q/I Curve of Thirthahalli Soil

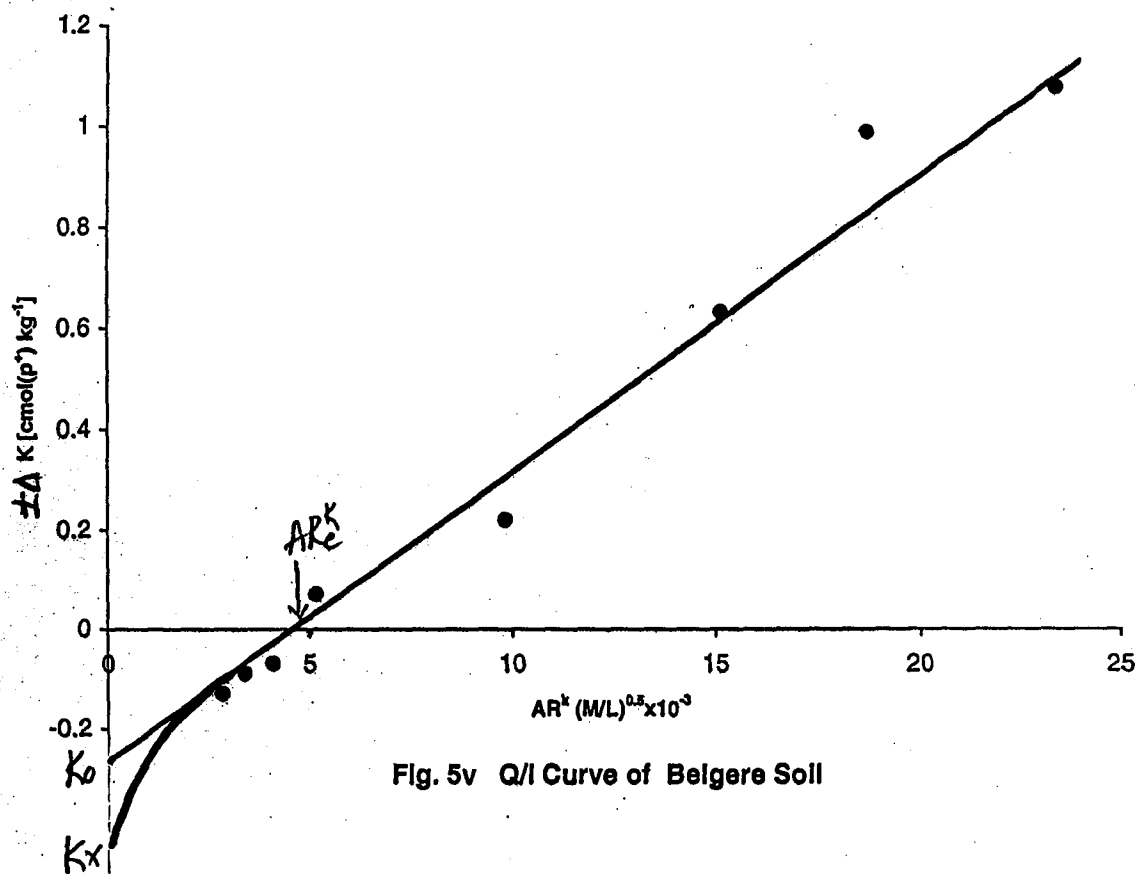


Fig. 5v Q/I Curve of Belgere Soil

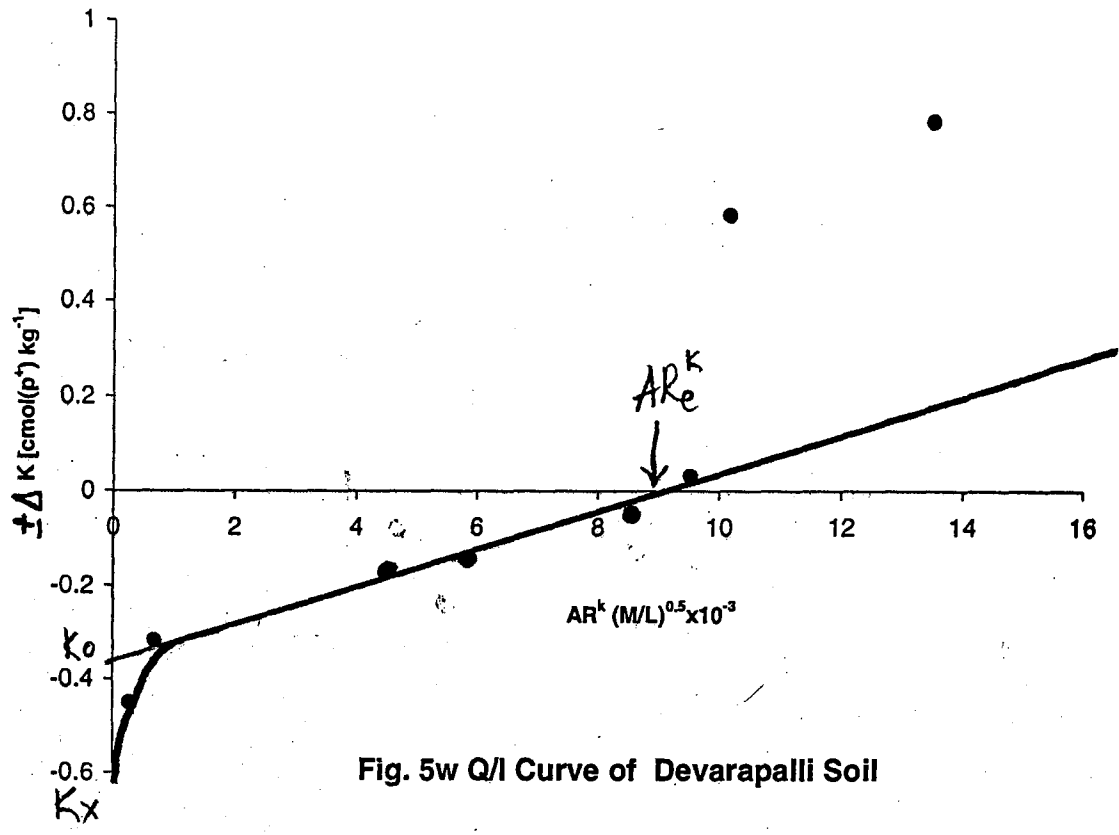


Fig. 5w Q/I Curve of Devarapalli Soil

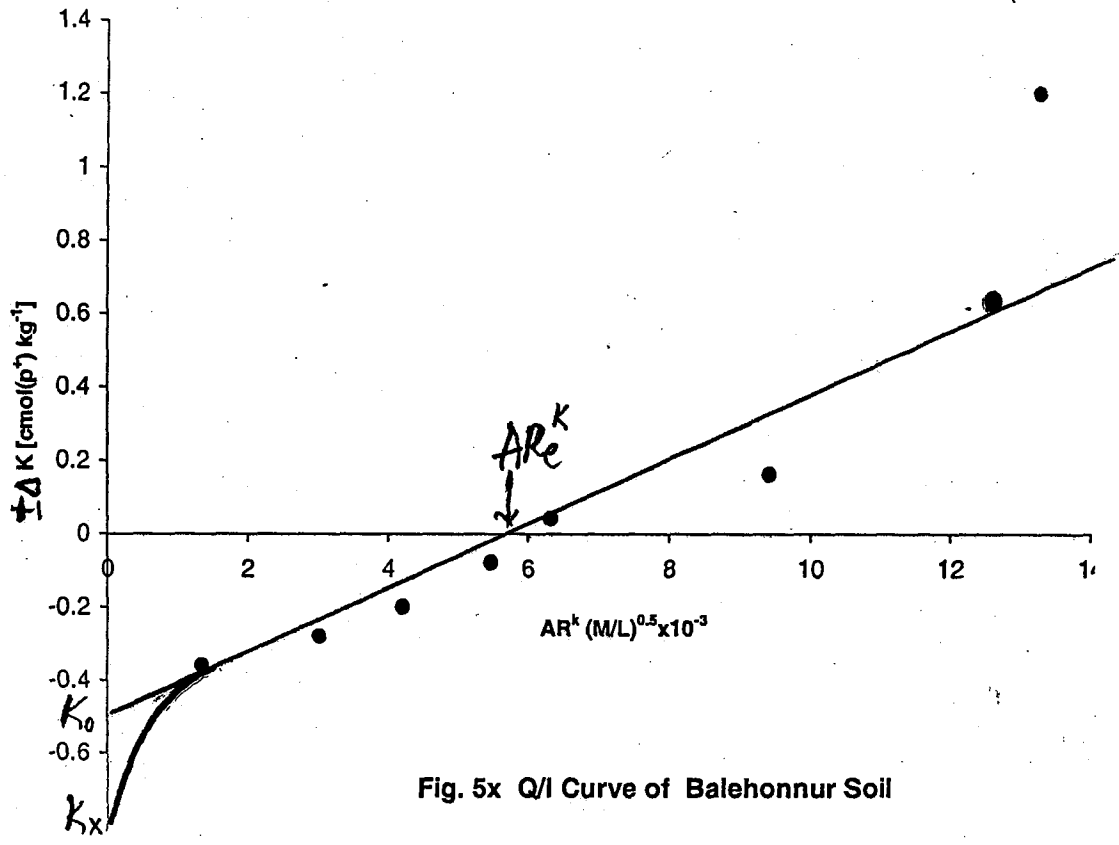


Fig. 5x Q/I Curve of Balehonnur Soil

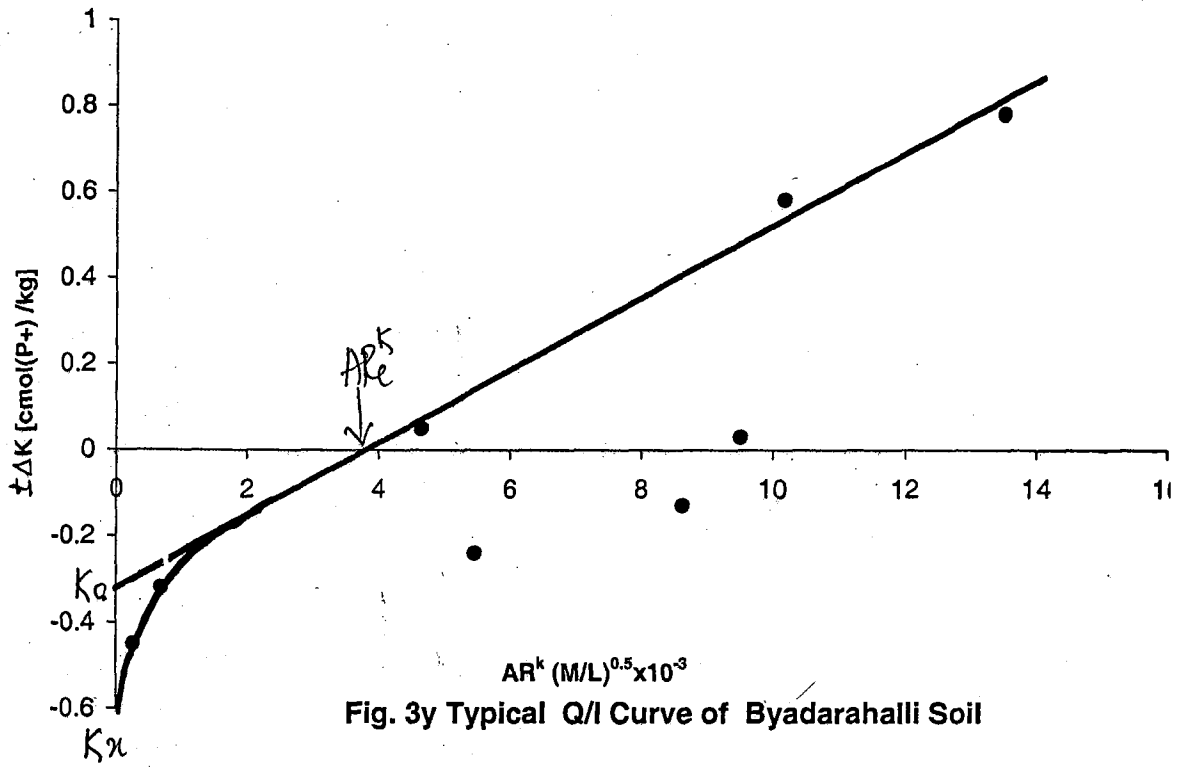


Fig. 3y Typical Q/I Curve of Byadarahalli Soil

solution at equilibrium, which is more important in meeting the crop demand (Barrow, 1966 and Sharma et al., 1992b).

The energy exerted by plants to absorb nutrient ions from solid phase is known as chemical potential. The  $-\Delta G^0$  is a measure of difference between chemical potential of K and Ca plus Mg and it is referred to as free energy of K - (Ca +Mg) exchange. The free energy change ( $-\Delta G^0$ ) values ranged from  $-4.43 \text{ k cal eq}^{-1}$  to  $-2.80 \text{ k cal eq}^{-1}$ . Woodruff (1955) defined the threshold values of  $-\Delta G^0$  as follows:  $-2.50 \text{ k cal eq}^{-1}$  or less - excessive amount of available K;  $-2.50$  to  $-3.50 \text{ k cal eq}^{-1}$  - optimum amount of available K;  $-3.50$  to  $-4.50 \text{ k cal eq}^{-1}$  - deficient in available K. When compared to these threshold values, most of the soils in the present study were found to be closer towards optimum K availability.

### 5.5.2 Correlation between forms of K and Q/I parameters

The positive and significant correlation among  $AR_e^k$  and,  $K_0$ ,  $K_L$  and  $K_X$  indicated the dependence of Q/I parameters on the various forms of K. The negative correlation between  $AR_e^k$  and the amount of free energy of exchange indirectly indicates the greater magnitude of energy required to be utilized by the plants as more and more K is depleted from the soil solution. The labile ( $K_L$ ) was significantly and positively correlated even with  $PBC^k$  and  $-\Delta G^0$  and exchangeable K (Table 16). This would indicate the dynamic equilibrium existing among the various Q/I parameters of K. Significant and positive relationship of  $PBC^k$  with non-exchangeable K and clay indicated an increase in K retentive capacity of soils as the content of finer fraction of soil increased. Quite evidently the relationship of  $PBC^k$  with  $AR_e^k$  was negative. The correlation worked out between Q/I parameters and soil properties are in accordance with the findings of Beckett and Nafady (1967), Chandi and Sidhu (1983), Yadav and Swamy (1987), Dhillon et al (1990), Nilima et al (1997) and Surekha and Subba Rao (1996).

## 5.6 Clay mineralogy as related to potassium

The mineralogy of clay fraction of the soils largely influences their physical, chemical and physico-chemical properties. Cations such as potassium, calcium and magnesium play an important role in the nutrition of plants and dynamics of these mineral elements especially that of potassium are governed by the type of clay mineral.

The clay fraction of subsurface layer of Belgere, representing soils from the central dry zone (Fig. 6a) consisted of kaolinite, illite as a randomly interstratified smectite with mica, quartz and feldspar. The order of minerals present in the soil is given in table 17.

The clay fraction of Brahmavara soil, representing the coastal zone (Fig. 6b) contained better crystallized kaolinite as the dominant mineral, followed by vermiculite, chlorite and gibbsite in appreciable amounts. Minor amounts of feldspar and quartz are also present in the clay fraction.

The clay fraction of Shimoga (Fig. 6c), representing the soils from the southern transition zone was found to have poorly crystallized kaolinite, illite as randomly interstratified mica with vermiculite and smectite and gibbsite. Quartz and feldspar are also present in minor amounts.

clay fraction of Thirthahalli (Fig. 6d), representing the soils from hilly zone was dominated by kaolinite, followed by gibbsite and feldspar. Traces of vermiculite and quartz were also identified in this soil.

The clay fraction of Mysore (Fig. 6e), representing soils from the southern dry zone was predominantly kaolinitic that is moderately crystallized. Gibbsite and quartz were also found in appreciable amounts. Minor amounts of even illite as randomly interstratified mica with vermiculite and traces of feldspar were also noticed.

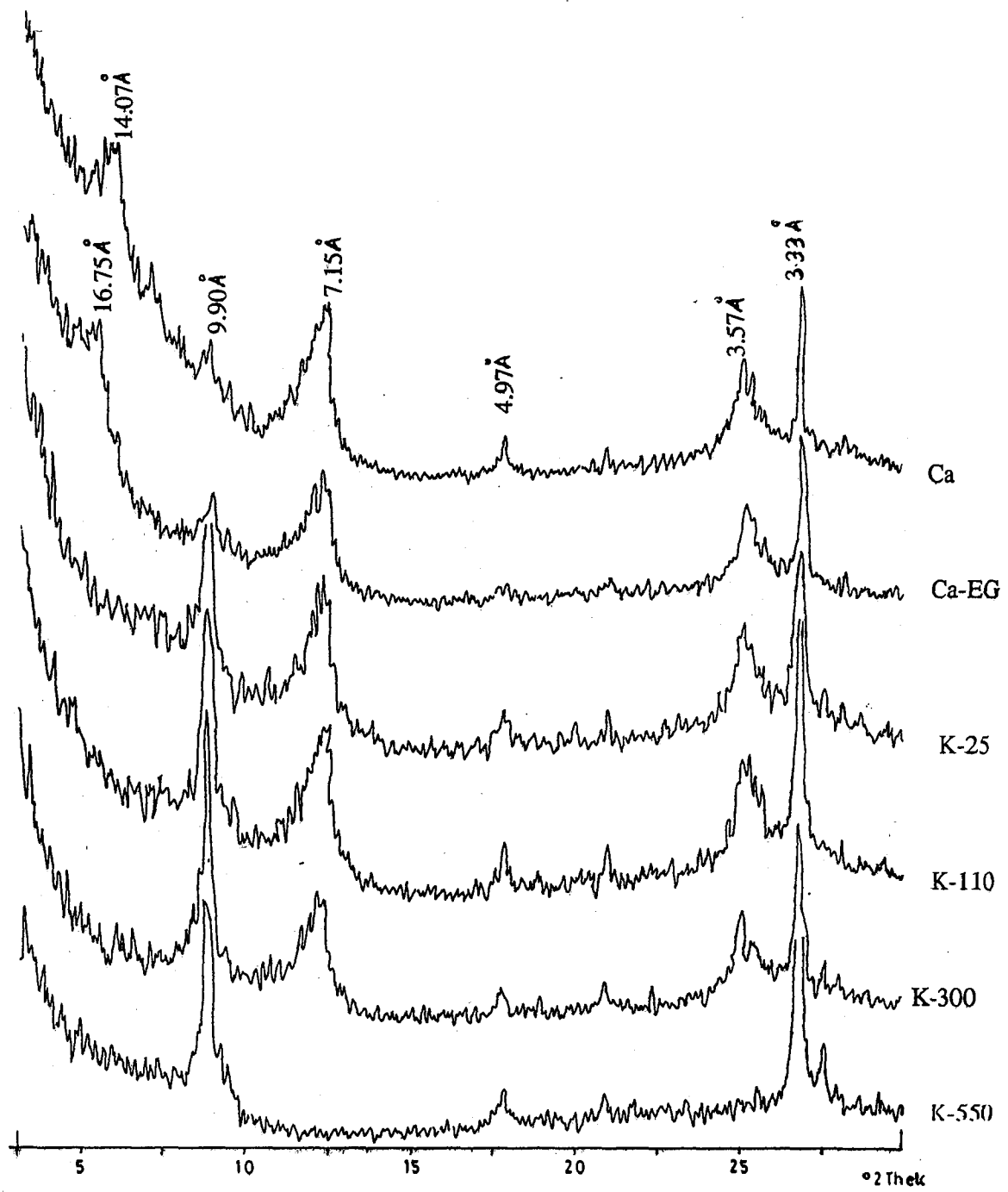


Fig. 6a: X ray diffractograms of clay sample-Belgere

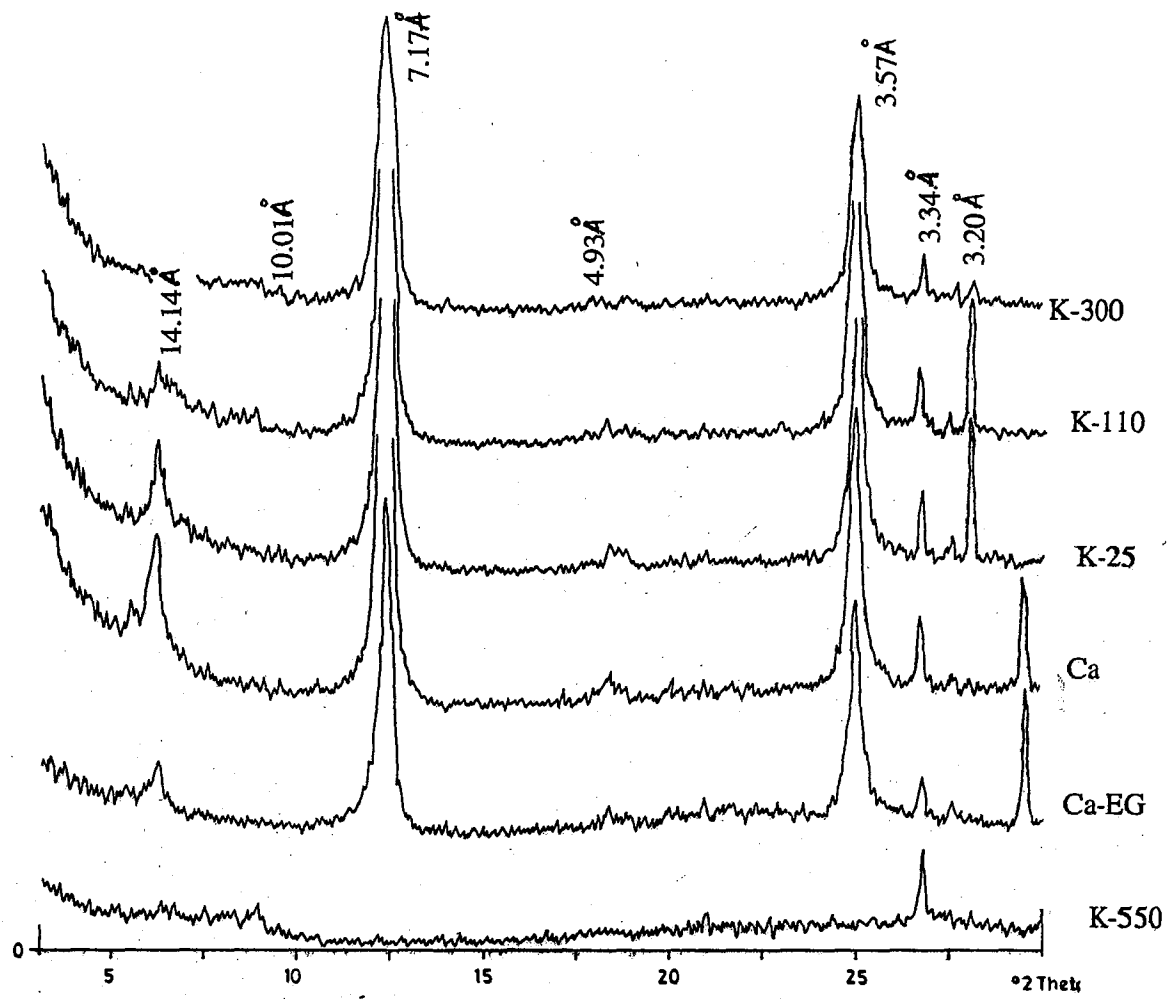


Fig. 6b: X ray diffractograms of clay sample- Brahmavara

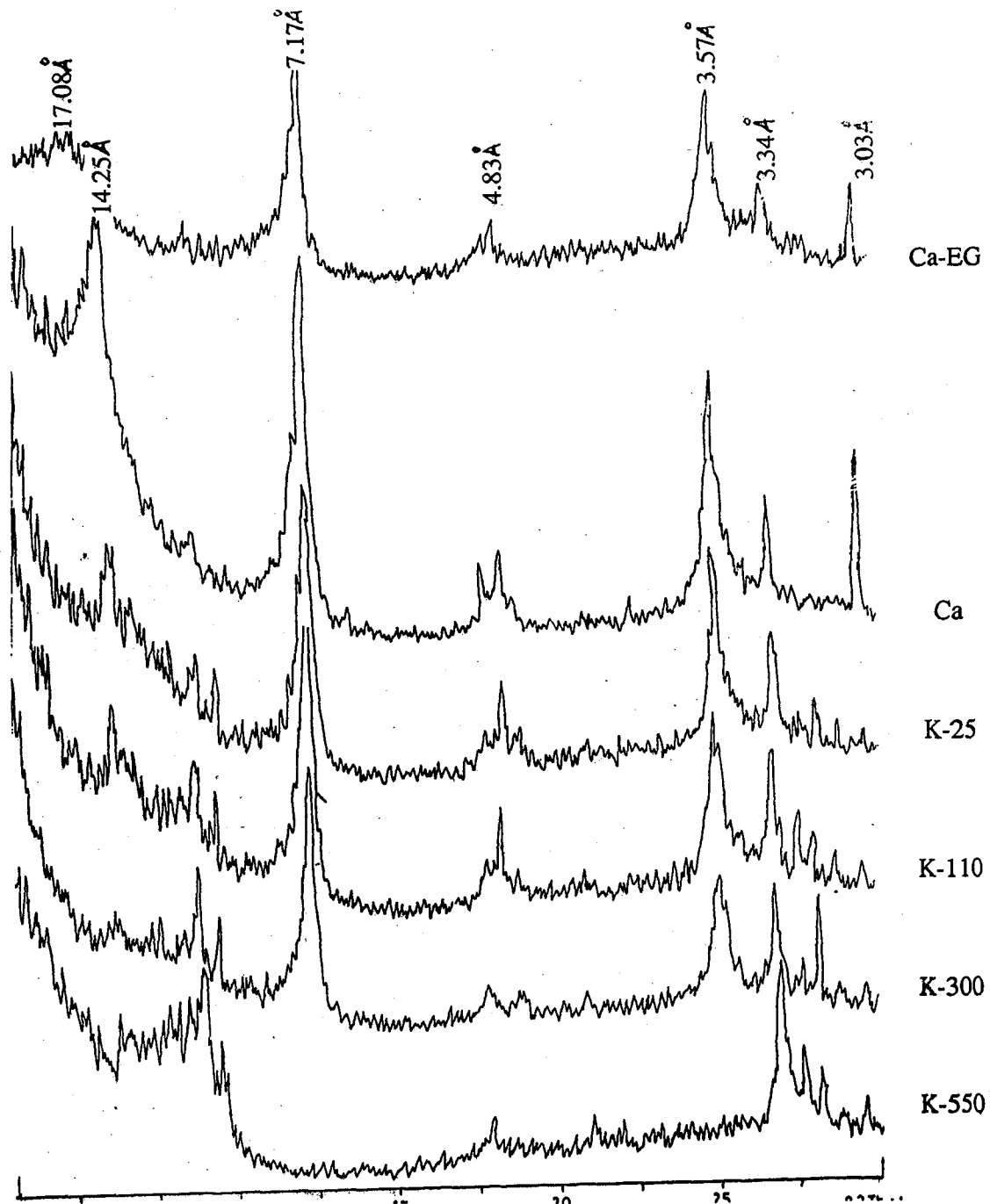


Fig. 6c: X ray diffractograms of clay sample-Shimoga

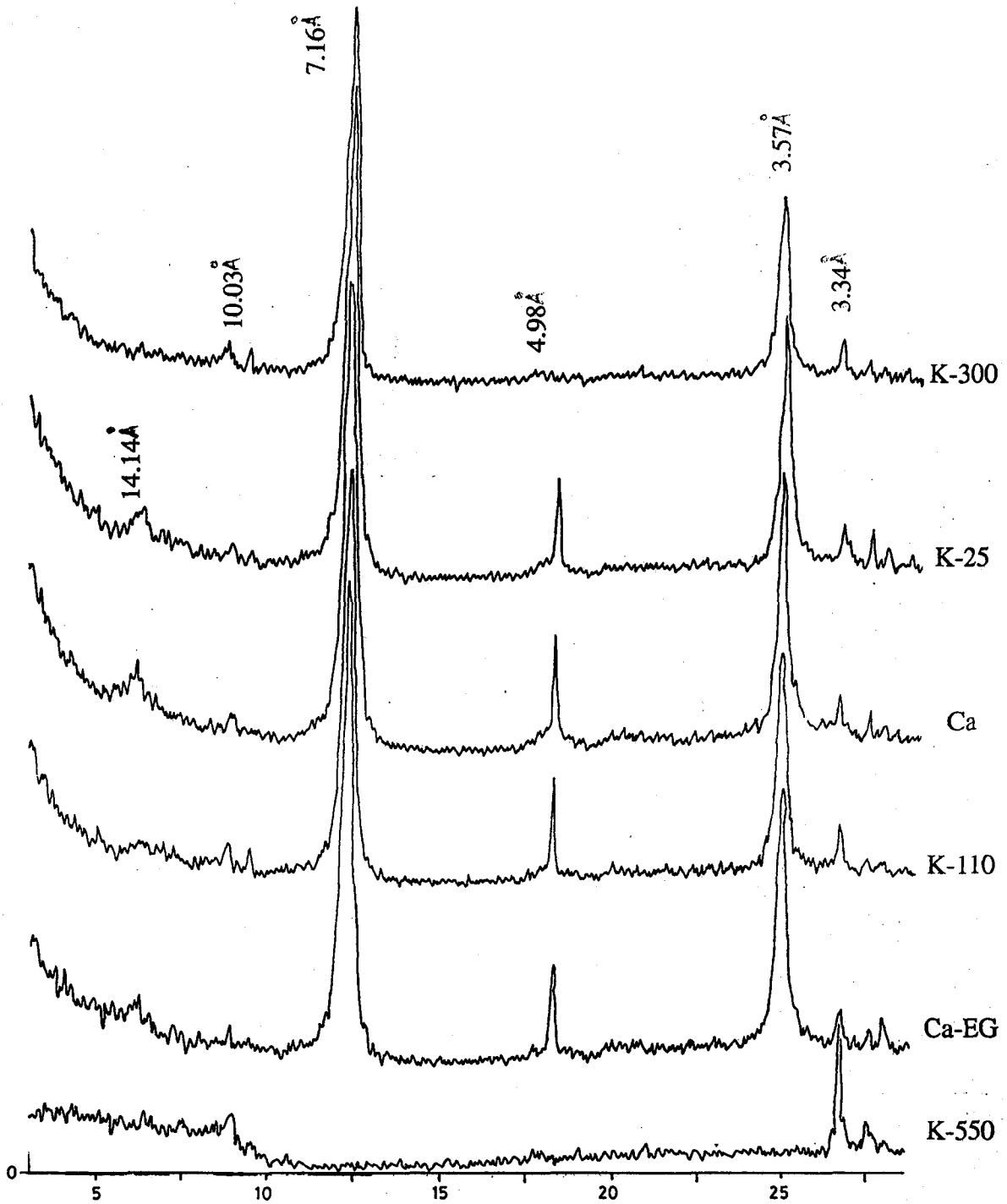


Fig 6d: X ray diffractograms of clay sample - Thirthahalli

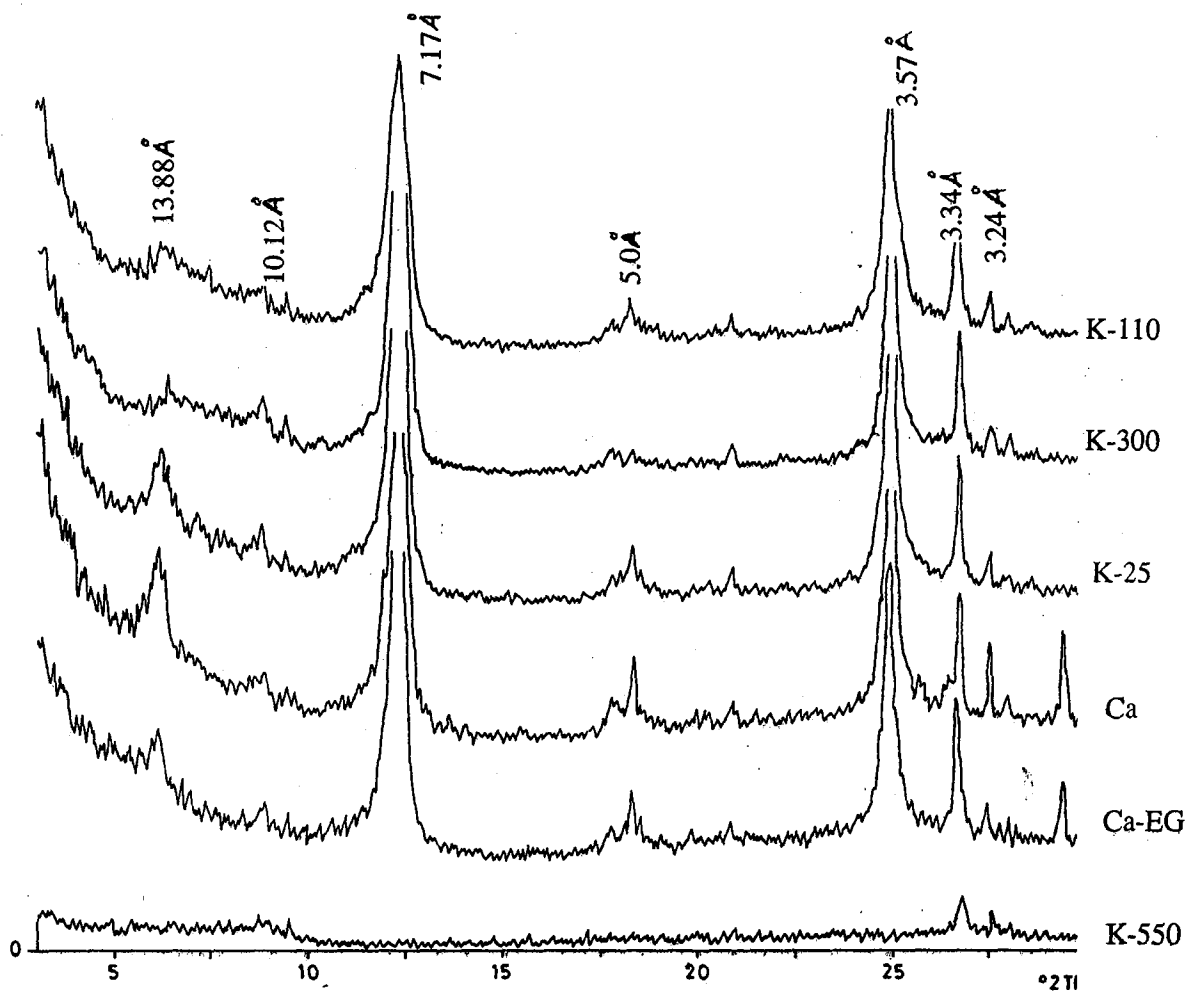


Fig. 6e: X ray diffractograms of clay sample- Mysore

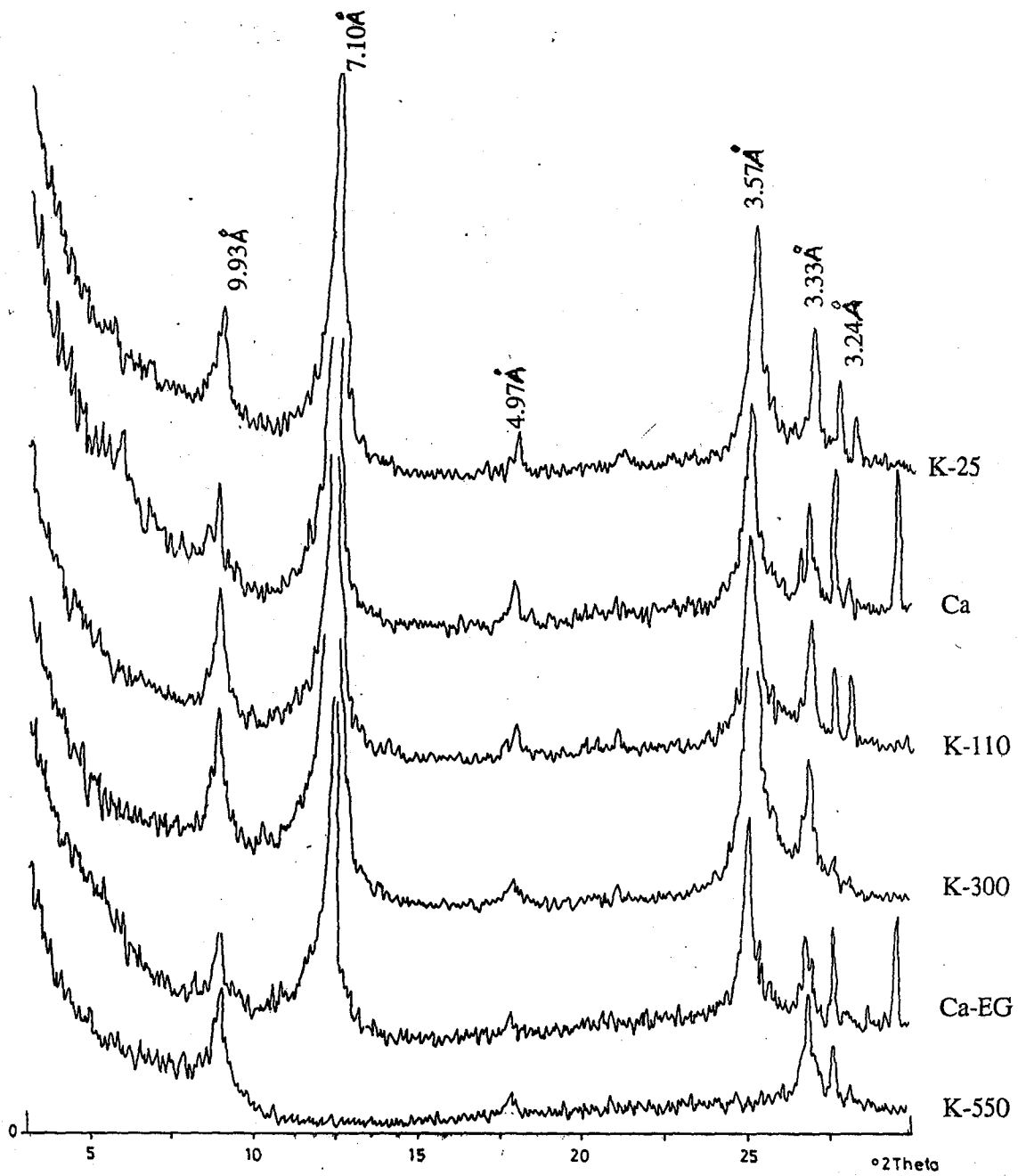


Fig. 6f: X ray diffractograms of clay sample-Malur

The clay fraction of Malur (Fig. 6f), representing the Eastern dry zone soils was dominated by kaolinite, followed by interstratified mica and quartz. Traces of feldspar was also observed.

The information on mineralogy of clay fraction of the soils as given above very clearly indicates the dominance of kaolinite, a 1:1 layer silicate in soils of all the six zones in Southern Karnataka. The other layer silicate minerals viz., illites as interstratified mica with either smectites or vermiculites, or with both smectites and vermiculites, chlorites and vermiculites were present in relatively smaller amounts. The nature and amount of the latter group of stratified/interstratified clay minerals containing potassium, varied from soil to soil. All the soils contained small amounts of even feldspars in the clay fractions. From this it could be inferred that the mineralogy of clay fractions, and may be the other fractions of soils also do not vary much from zone to zone. The presence of only small amounts of 2:1 layer silicate minerals and their nature indicates the lower cation exchange capacity of the soils and lower amounts of exchangeable potassium except probably in soils well fertilized with K. The nature of minerals found in these soils would also reveal the fact that the non-exchangeable K content of soils was also marginal. Since the feldspars were also found eventhough in small amounts, it could be concluded that the lattice bound K was mainly in the form of K-feldspars.

### 5.7 Evaluation of different extractants for estimating available potassium in soils

Different extractants were used to select suitable extractants for diagnosing available potassium status of soil by growing rice as the test crop. Among the five extractants studied viz.,  $0.01M$   $CaCl_2$ ,  $NMNH_4OAc$ ,  $1N$   $HCl$ ,  $1N$   $HNO_3$  and  $0.03M$   $NaTPB$ , the highest degree of correlation was noticed between potassium extracted by  $1N$   $HNO_3$  and the plant parameters like percent yield response, relative yield and potassium uptake in control (Table 20). This would suggest that the soils of Southern Karnataka, which are sandy loam to sandy clay loam in texture contained enough quantities of reserve K and hence had a good K releasing and K supplying power. The reasonably

## Evaluation of soil test methods for available potassium



**Plate 1:** Response of rice crop to application of different doses of potassium ( $T_1 = K @ 0 \text{ kg ha}^{-1}$ ,  $T_2 = K @ 25 \text{ kg ha}^{-1}$ ,  $T_3 = 50 \text{ kg ha}^{-1}$  and  $T_4 = K @ 75 \text{ kg ha}^{-1}$ ) for GKVK soil



**Plate 2:** Response of rice crop to application of different doses of potassium ( $T_1 = K @ 0 \text{ kg ha}^{-1}$ ,  $T_2 = K @ 25 \text{ kg ha}^{-1}$ ,  $T_3 = 50 \text{ kg ha}^{-1}$  and  $T_4 = K @ 75 \text{ kg ha}^{-1}$ ) for Brahmavara soil

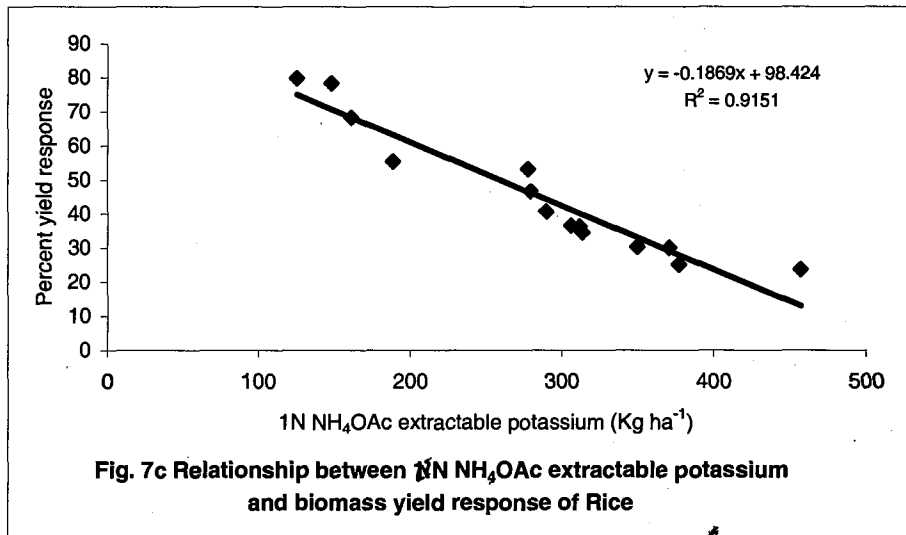
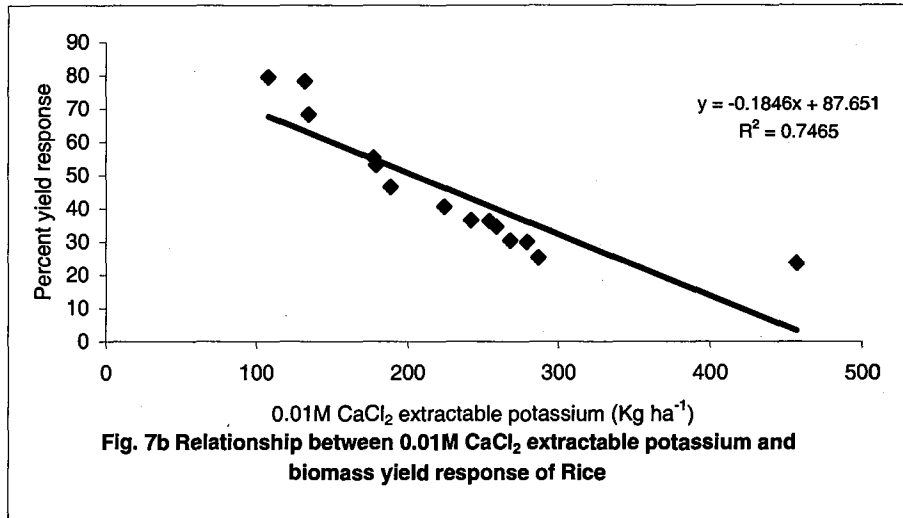
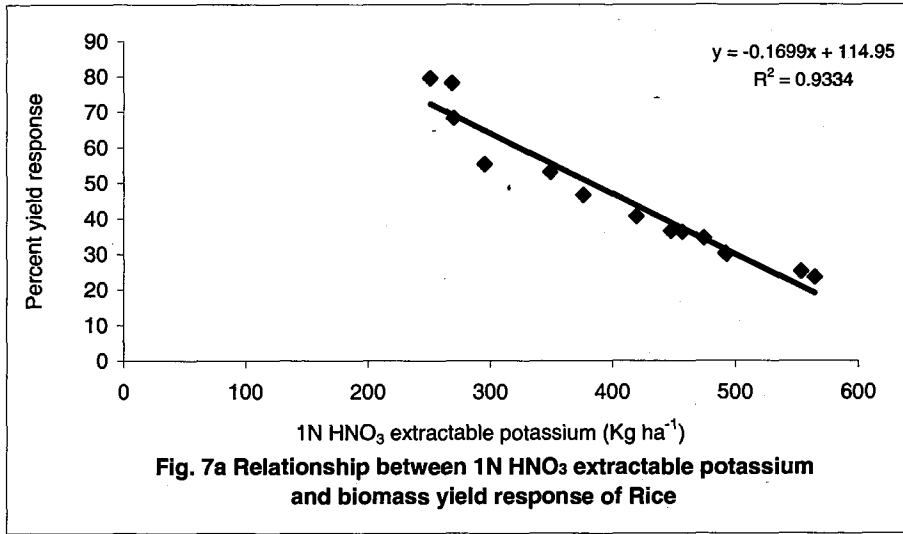
## Evaluation of soil test methods for available potassium

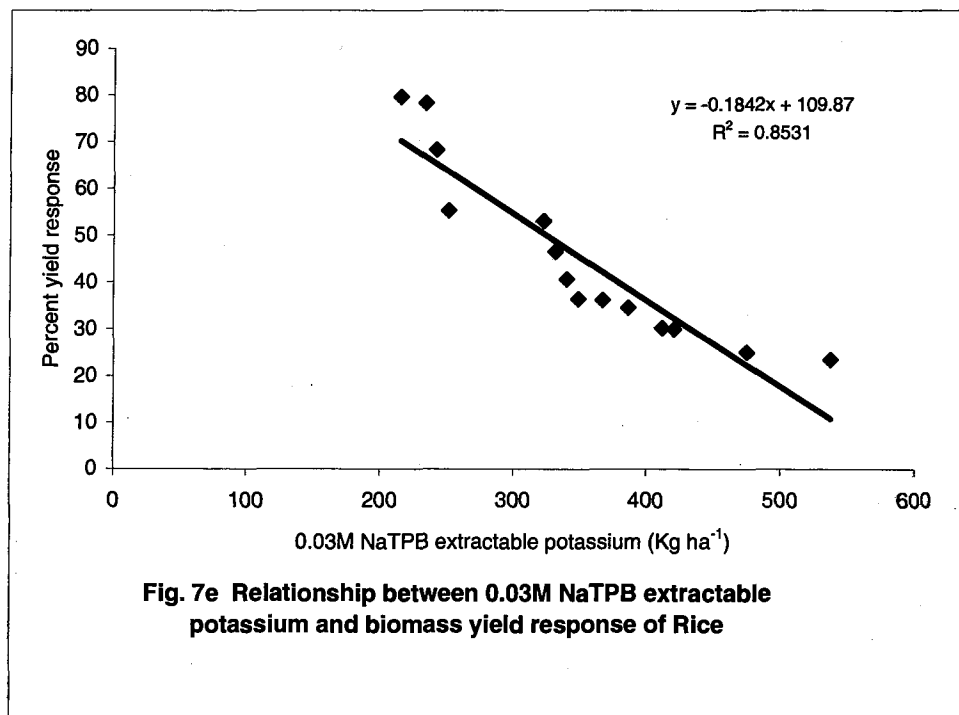
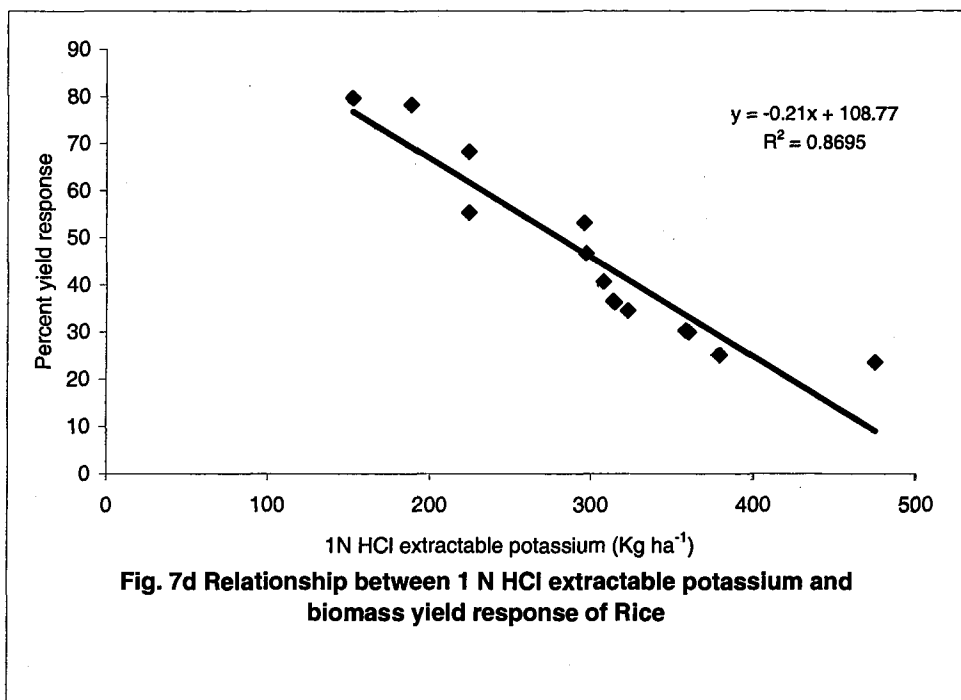


**Plate 3:** Response of rice crop to application of different doses of potassium ( $T_1 = K @ 0 \text{ kg ha}^{-1}$ ,  $T_2 = K @ 25 \text{ kg ha}^{-1}$ ,  $T_3 = 50 \text{ kg ha}^{-1}$  and  $T_4 = K @ 75 \text{ kg ha}^{-1}$ ) for Bashettihalli soil



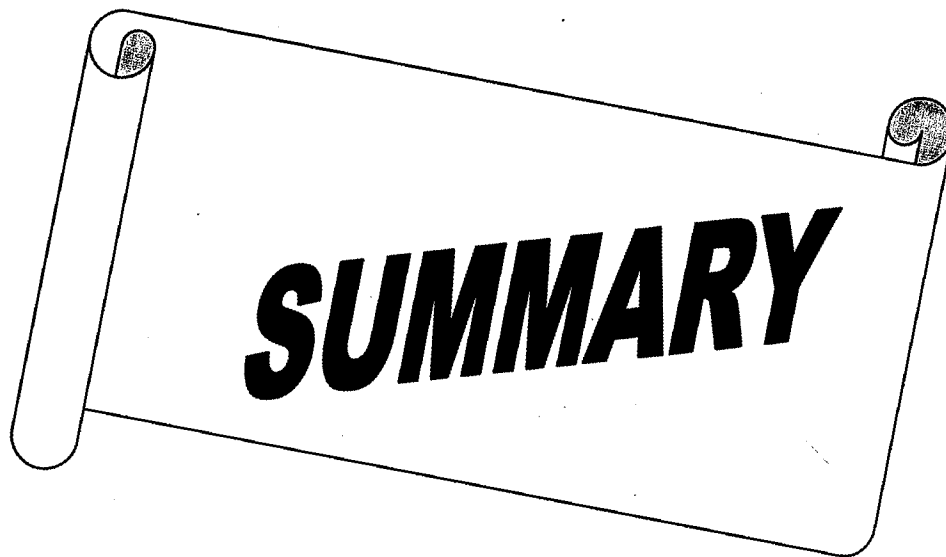
**Plate 4:** Response of rice crop to application of different doses of potassium ( $T_1 = K @ 0 \text{ kg ha}^{-1}$ ,  $T_2 = K @ 25 \text{ kg ha}^{-1}$ ,  $T_3 = 50 \text{ kg ha}^{-1}$  and  $T_4 = K @ 75 \text{ kg ha}^{-1}$ ) for Thulasidoddi soil





higher amounts of non-exchangeable K extracted from different soils also conform this finding. Subba Rao and Srinivasa Rao (1995), Mailappa (2000), and Bedi et al (2002) have also reported significant relationship between K extracted by  $1N$   $HNO_3$  and the crop response based on the results of STCR experiments conducted by them.

Potassium extracted by even  $NV$   $NH_4OAc$  and  $0.03M$   $NaTPB$  exhibited significant correlation with most of the plant parameters. Neutral normal  $NH_4OAc$  is the universally accepted extractant for estimation of available K and is reported to predict crop response to K application fairly well under most situations. This extractant is supposed to remove K mainly from the exchangeable fraction at the time of analysis of the sample. In most of the soils included in the present study, there was appreciable amount of exchangeable K. Added to this significant relationship was also observed between the exchangeable and the non-exchangeable forms of K in the soils. Hence, as most of the researchers opine, the amount of K initially present and extractable by either distilled water or dilute solutions of neutral salts could also serve as a good indicator of K availability in soils. These results corroborate with findings of Ramanathan (1978), Ramanathan and Krishnamoorthy (1981), Ashok Tiwari and Mishra (1995) and Surekha et al. (1997).



## VI. SUMMARY

Potassium is present in very large amounts in most of the soils in the world. But its availability to crops is conditioned by several factors such as the type of primary\_ and secondary minerals present in the soil, the climatic conditions of the region and the intensity of weathering, the thickness of vegetation in the region and the organic matter content of the soil and application of potassic fertilizers to the soil. The soils vary greatly in respect of the types and amounts of the various clay minerals which are formed by the weathering of the primary minerals and the mechanical composition. The reaction of these clay minerals with other solids in the soil, and the soil solution may vary due to varying influences of the climatic components and the farm management practices, from time to time. Accordingly, the behavior of potassium contained in different forms in the soil, particularly of that fraction of it held by the clay minerals may change considerably depending upon the occasion.

Soils formed from rocks containing potassium rich minerals under semi-arid and arid situations and dominant in 2:1 clay minerals have been found to be rich in available potassium, whereas soils formed from potassium deficient minerals formed under semi-humid and humid situations, dominant in 1:1 clay minerals, have been found to be low in available potassium. However, response to the application of K fertilizers in the former group of soils and non-response of the crops under certain situations in some soils of the latter groups demand a thorough investigation on the behavior of this element in soils formed under different climatic conditions and varying in their texture, chemical properties and nutrient contents.

Hence, to have an in depth understanding of potassium dynamics of soils, both surface (0-15cm) and sub surface (15-30cm) samples were collected from six agro-climatic zones in Southern Karnataka and laboratory analytical studies were carried out to elucidate information on the forms and distribution of K, K fixation characteristics, K release pattern, K desorption kinetics, quantity-intensity parameters of K and mineralogy of the clay fraction by following standard methods. Another investigation was also

carried out to select suitable extractants for the estimation of available K in soils of these zones and to serve as availability indices for K, by collecting bulk samples and conducting a pot experiment in the green house by selecting rice as the test crop. The salient findings of the investigation are summarized hereunder:

### **Physico-chemical properties and available nutrient status of soils**

The soils varied in texture from sandy loam to sandy clay loam, both in the surface and the sub surface layer. The content of clay was relatively higher in the sub surface layer than in the surface layer of soils. Soil pH varied from moderately acidic to neutral with coastal and hilly zones having more number of acidic soils and the other zones having slightly acidic to neutral soils at both the depths. The soluble salt content of soils of all the zones recorded electrical conductivity values of less than  $1 \text{ dSm}^{-1}$  in both the depths and hence were non-saline. The organic carbon content of soils varied from medium to high with most of the soils of hilly zone and coastal zone recording relatively higher OC values than soils of the remaining zones. But exceptional higher values noticed in case of few soils of interior zones of southern Karnataka was due to the regular addition of organic manure and crop residues under wise management situations. The OC content in the surface layer was relatively higher than that in the sub surface layer in all the samples of soils. Cation exchange capacity of soils also varied widely from low to moderate in soils of the different zones. Soils of Central dry zone, Southern dry zone, Eastern dry zone and Southern transition zones recorded relatively higher CEC values than soils of coastal and hilly zones. The CEC of soils depended mainly on the clay content of soils. Relatively higher CEC values were noticed even in respect of few soils containing high amounts of organic matter.

Available phosphorous (Bray 1) in soils varied widely from very low to high amounts. It was relatively lower in amounts in soils of coastal and hilly zones containing higher amounts of sesquioxides and kaolinite than in soils of the remaining zones. Available potassium ( $NV \text{ NH}_4\text{OAc}$ ) content of soils depended mainly on the amount of clay minerals, addition- regularly or otherwise- of organic manures and K fertilizers. It

varied from low to high quantities in both the depths of soils with marginally higher quantities in the upper layer relative to the lower layer. Exceptionally high values were observed in soils of coffee plantation because of regular application of K fertilizers at high doses.

### **Forms and distribution of potassium in soils**

Water soluble K content of soils was low to high and varied from 4 to 16 mg K kg<sup>-1</sup> in the upper layer and from 4 to 14 mg K kg<sup>-1</sup> in the lower layer, in soils of the different zones. Exchangeable K was also low to medium in most soils and varied from 32 to 180 mg K kg<sup>-1</sup> in the surface layer and from 23 to 135 mg K kg<sup>-1</sup> in the sub surface layer of soils. The content of both these forms of K depended mainly upon the nature and amount of clay and organic matter content of soils. Non-exchangeable K content of soils depended mainly on the amount of clay and it was relatively higher in the sub surface layer than in the surface layer. The non-exchangeable K content ranged from 110 to 280 mg K kg<sup>-1</sup> and from 130 to 320 mg K kg<sup>-1</sup> respectively in the upper and the lower layer of soils. All the three forms of K were relatively higher in amounts in soils of interior agro-climatic zones of Southern Karnataka as compared to soils of the coastal and hilly zones. The total K content of soils, the amount of which depended mainly on the contents of different K bearing minerals and the clay content, varied from 1600 to 3600 mg K kg<sup>-1</sup> at 0-15 cm and from 2000 to 4000 mg K kg<sup>-1</sup> at 15-30 cm depth. In general, the amount of total K was relatively higher in soils of Central dry zone than in the rest of the zones.

### **Potassium fixation capacity of soils**

Fixation capacity for potassium by soils depended mainly upon the K-saturation of the exchange complex and the total clay content of the soils. The values varied from 0.09 to 1.44 cmol (p<sup>+</sup>) kg<sup>-1</sup> in different soils. Since the soils from all the zones were dominant in kaolinitic clays, the fixation capacity was not as great as it is observed in black soils of Karnataka which are dominant in 2:1 layer silicate clays. Potassium

fixation capacity was found to have a significant positive correlation with non-exchangeable K content of soils.

### **Potassium release characteristics of soils**

Major portion of cumulative K from all the soils was released by the fourth extraction with the reagent viz.,  $1N$   $HNO_3$ . The total amount of cumulative K release varied from 368 to 975 mg K  $kg^{-1}$  in different soils. Soils belonging to the coastal and hilly zones released relatively lower amount of K than soils of the rest of the zones. The cumulative release depended much on the amount and nature of clay. Soils containing relatively higher amounts of non-exchangeable K recorded higher amounts of cumulative K than soil with lower amounts of non-exchangeable K. Step K of soils was also found to have the same behavior in different soils as observed in the case of cumulative release K. Step K in different soils ranged from 290 to 767 mg K  $kg^{-1}$ . In most soils, particularly those belonging to the interior zones, constant rate K was encountered by 11<sup>th</sup> or 12<sup>th</sup> extraction indicating K releasing power of soils for a long period of time. The constant rate K ranged from 1.00 to 15.00 mg K  $kg^{-1}$  in different soils. The CR-K values were lower for soils of coastal and hilly zones.

### **Potassium desorption pattern and desorption kinetics**

Desorption of potassium ( $0.01M$   $CaCl_2$ ) was fast during the first 72 hours and became slow thereafter in soils of all the zones. However, more or less constant desorption occurred even up to 336 hours in the case soils from the interior agro-climatic zones. The amount of K desorbed was also more in the soils of the interior zones. The soils of central dry zone, southern dry zone, eastern dry zone and southern transition zone indicated both good K supplying power and K releasing power for reasonably longer period of time than soils of coastal and hilly zones. Potassium desorption rate coefficients ( $k_d$ ) were found to be much greater for the first 120 hours ( $3.24 \times 10^{-3}$  and  $6.91 \times 10^{-3} h^{-1}$ ) than for the 120-336 hours period ( $9.47 \times 10^{-4}$  to  $5.46 \times 10^{-3} h^{-1}$ ). The  $K_d$  values were

relatively greater for soils of the interior agro-climatic zones than for the soils of coastal and hilly zones.

### **Quantity –Intensity parameters of potassium**

The equilibrium activity ratio for potassium ( $AR_e^k$ ) in soils varied widely from 0.62 to  $9.20 \times 10^{-3} (M/L)^{0.5}$ . This was found to have a direct relationship with exchangeable K content of soils. The values for  $AR_e^k$  correlated positively with Q/I parameters like  $K_L$ ,  $K_x$  and  $K_o$ . Labile K ( $K_L$ ) values ranged from 0.10 to 0.90 cmol ( $p^+$ )  $kg^{-1}$  in different soils. Both  $K_L$  and  $K_x$  (K on specific adsorption sites) correlated positively with clay content of soils and non-exchangeable K of soils. The values for  $K_o$  (K on non-specific adsorption sites) was found to be lower than that for exchangeable K of soils. Potassium buffering capacity of soils ( $PBC^k$ ) correlated positively with the clay content and the non-exchangeable K in soils. But  $PBC^k$  correlated negatively with  $AR_e^k$ , the content of which is an important availability index for K in soils. The values for the free energy change ( $\pm \Delta G^0$ ) ranged from  $-4.43$  to  $-2.80$  K cal  $eq^{-1}$  in different soils. There was negative relationship between  $\pm \Delta G^0$  and  $AR_e^k$ , but positive relationship between  $\pm \Delta G^0$  and  $PBC^k$ . The studies on Q-I parameters indicated relatively higher K supplying power ( $PBC^k$ ) of most soils from the interior zones as compared to soils from Coastal and Hilly zones. However, many soils even from coastal and hilly zones had enough of readily available K as revealed by  $AR_e^k$  values. The studies on K release characteristics and K desorption pattern also reveal many supporting findings to this. The free energy of exchange values place most soil as having enough available K at present.

### **Mineralogy of clay fraction of soils**

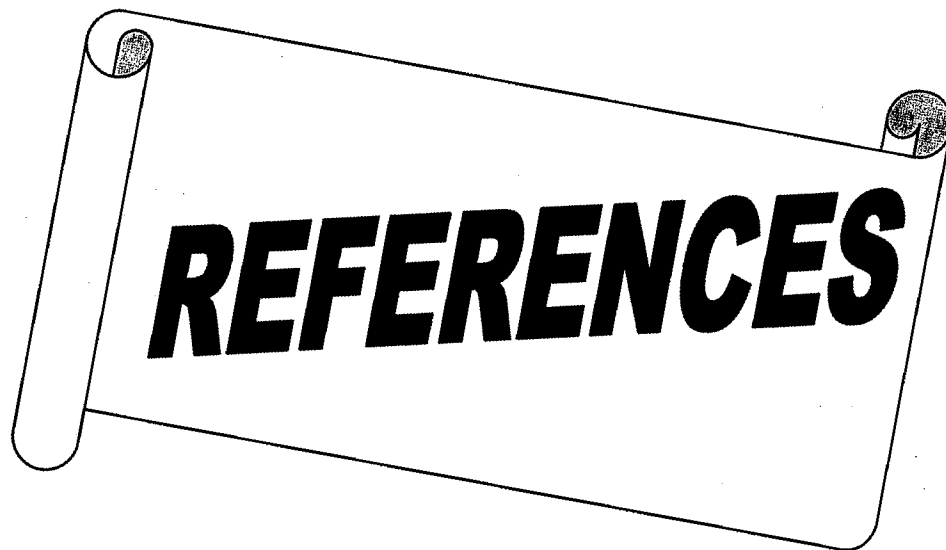
The soils irrespective of the zones from which they were collected, contained kaolinite, in different states of crystallization as the dominant clay mineral. In respect of 2:1 layer silicates, which are present in small amounts, Belegere soil (central dry zone) contained illite as interstratified smectite with mica, Mysore soil (southern dry zone) contained illite as interstratified mica with vermiculite, Malur soil (eastern dry zone)

contained interstratified mica, Shimoga soil (southern transition zone) contained illite as interstratified mica with smectites and vermiculite, Thirthahally soil (hilly zone) contained illite as interstratified mica with vermiculite and Brahmavara soil (coastal zone) contained vermiculite and chlorite. Feldspar is the K containing primary mineral present in minor amounts in the clay fraction of all the soils. The soils seemed to have formed mainly from acidic igneous rocks under semi arid, semi humid and humid climatic conditions.

#### **Evaluation of soil testing methods for available potassium**

Among the different extractants tried viz., *0.01M* CaCl<sub>2</sub>, *NN* NH<sub>4</sub>OAc, *1N* HCl, *1N* HNO<sub>3</sub> and *0.03M* NaTPB for selecting the best availability index for K, *1N* HNO<sub>3</sub> correlated (r-value) most with parameters like percent yield response, relative yield and K uptake by rice in control treatment. Neutral normal ammonium acetate and *0.03M* NaTPB ranked next in that order.

Even though many soils from the interior agro-climatic zones of Southern Karnataka and few soils from the other zones seem to be possessing good K supplying and K releasing power, it cannot be concluded that they do not respond to the application of K fertilizers. For maintaining the K supplying power of these soils, regular application of K through K fertilizers and organic manures is necessary because kaolinite is the dominant type of clay and the interstratified micacious minerals with smectites and vermiculites are present in smaller amounts in these soils. Hence, the values for many parameters of K in these soils should be compared with values for the same parameters obtainable for soils dominant in 2:1 layer silicates of various types, for arriving at a proper conclusion as to their real ability in providing K to the crops.

A stylized banner or scroll with a white background and a black outline. The banner is tilted slightly upwards from left to right. It has a vertical strip on the left side, suggesting it is a scroll. Two circular fasteners or rings are attached to the top edge, one on the left and one on the right. The word "REFERENCES" is written in a bold, black, sans-serif font across the center of the banner.

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\* = Original not seen