INVESTIGATIONS ON THE POTASSIUM DYNAMICS IN THE MAJOR SOIL SERIES OF THANJAVUR DISTRICT IN RELATION TO RESPONSE OF RICE

Thesis submitted in part-fulfilment of the requirements for the degree of
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Certificate

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Coimbatore

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ABSTRACT

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The significant role of K in rice production is well known. However, due to the lack of knowledge on K dynamics in soil, its interaction with other plant nutrients, fixation and release characteristics, uptake and varying response pattern under different situations warrants elucidation in the experimental area viz., Thanjavur district, the rice granary of Tamil Nadu to achieve maximum benefit. In the present study, it was attempted to investigate the dynamics of K in 10 representative major soil series of Thanjavur district with broader objectives of comparing different methods of K availability and to fix a more reliable method to measure K availability and to evaluate the response of rice to K fertilization.

The studies were made in different phases involving laboratory investigations, greenhouse experimentation followed

by a field trial. The laboratory studies related to the characterization of soils based on forms and status of K, K fixation and release characteristics and comparison of K availability indices including Q/I parameters based on thermodynamic functions.

The biological K release studies were made by Exhaustive cropping technique. The pot experiment under green house was undertaken to highlight the influence of graded levels of K (K_0, K_{50}, K_{100}, K_{150} and K_{200} kg K_2O/ha) on rice and to elicit the response behaviour of rice to K fertilization in 10 major soil series.

The field trial was conducted in Madukkur soil series of Thamarankottai village of Pattukkottai taluk in Thanjavur district as a confirmative trial for the pot experiment and the soil and plant data generated in the field trial were related to the response behaviour of ADT 31 rice. The results of the investigation showed that in the 10 major soil series of Thanjavur district, considerable variations in the physico-chemical properties were observed.

The extent of K fixation differed markedly in these soils mostly due to clay mineralogical make up and amount of clay and for assessing K fixation in soils an incubation period of 7 days appears to be adequate. The cumulative K release of soils followed the order of $S_6 > S_5 > S_2 > S_2 > S_1 > S_8 > S_3 > S_4 > S_{10} > S_9 > S_7$. The pattern of K release was helpful to predict the response behaviour of soils.

The Kex used and Knex used by rice decreased and increased respectively with and without K application.

Cubic response of rice to K application could be ascribed to the reduced availability of N at intermediary levels of K application. The neutral N NH_4OAc has been found to be the best extractant for predicting the K availability in soils of Thanjavur district.

Application of K was found to be beneficial to rice crop in eight out of ten soil series studied. Padugai and Nedumbalam series did not respond to the application of K. Possible reasons for the cubic pattern of response of rice to K application have been elucidated. The K content of the third leaf of rice at tillering and flowering stages could be considered as an indicator leaf for fixing the critical level of K in rice plant. The optimum and economic doses of K for ADT 31 rice were found to be 59 and 54 kg K_2O/ha for achieving the highest grain yield and highest return respectively.

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ABBREVIATIONS USED

ml	..	Millilitre
ppm	..	Parts per million
CEC	..	Cation exchange capacity
me	..	Milli equivalent
m.mhos	..	Millimhos
mm	..	Millimetre
cm	..	Centimetre
g	..	Gram
kg	..	Kilogram
rpm	..	Revolutions per minute
ha	..	Hectare
N	..	Normal solution
M	..	Molar solution
°C	..	Degree centigrade
Cal	..	Calories
μ	..	Micron
Kex	..	Exchangeable-potassium
Knex	..	Non-exchangeable potassium
AR_o^k	..	Activity ratio of potassium
AR_e^k	..	Equilibrium activity ratio of potassium
PBC^k	..	Potential buffering capacity
$-\Delta K^o$	..	Labile K
ΔG	..	Free energy change
K_L	..	Total amount of K in labile pool

K_x	..	Specific adsorption sites
Av	..	Available
St_I	..	Tillering stage
St_{II}	..	Flowering stage
St_{III}	..	Post-harvest stage
S	..	Straw
G	..	Grain
r	..	Co-efficient of simple correlation
x	..	Independent variable
y	..	Dependent variable
S.E.	..	Standard error of mean
C.D.	..	Critical difference
*	..	Significant at 5 per cent level
**	..	Significant at 1 per cent level
N.S.	..	Not significant
Fig.	..	Figure
Contd.	..	Continued

INTRODUCTION

INTRODUCTION

CHAPTER I

INTRODUCTION

Potassium one of the essential elements needed for the nutrition of the plants is considered to be a regulator of all other nutrients and hence it is called "chemical traffic policeman". It is also referred to as Minister incharge of water regulation in plants for fostering crop production.

Potassium is required for various vital activities of the plant such as enzyme activity, synthesis of carbohydrates, protein, fat etc. It is also reported to increase the resistance of plants to pests and diseases and lodging and it is believed to counteract many of the undesirable effects of the excessive supply of N, Fe, etc.

Potassium is reglatively abundant and widely distributed constituent of the Earth's crust on weight basis. The prime sources of K in soils are primary minerals viz., feldspars and micas which upon weathering release K enriching the soil K. Compared to N and P, availability of K to plants is a complicated one since it occurs in different forms as water soluble-K, exchangeable-K, fixed-K and lattice-K and they are in dynamic equilibrium with each other. Plants utilise not only the K present in a readily available form but also from the difficultly available or fixed forms. The availability of K is controlled by fixation and release characteristics of soils. Fixation of plant nutrients is considered to be a factor of importance in agriculture especially where commercial fertilizers are added. Moreover, fixation of K regulates not only the supply of soil K for plants but also protects it against leaching. Hence in study aiming at the economic usage of fertilisers a knowledge of the fate of added fertilisers is necessary.

Potassium release characteristics of soils using acids, ion exchange resins, chelates and dilute electrolytes have been reported to give relatively more detailed information on its availability to plants than conventional soil test methods (Quemener, 1979). Although soils contain considerable amount of total K the releasing and supplying power of the soils in a given time is a limiting factor in most of the soils. The K releasing power of soils depends on number of factors, namely, nature of soil, amount and type of clay minerals, CEC, soil pH and level of manuring. The absence or response of crops to K application is controlled by the K releasing pattern of soil. Information on the source of K supply to crops and the fate of applied K is not adequate.

Different chemical extractants have been employed for predicting the K availability from time to time on varying situations. Dilute mineral acids, organic acids, neutral salt solutions, buffer solutions were some of the chemical extractants tried earlier. Efficiency and suitability of some of these extractants were also assessed in the present study as a measure to predict the K availability.

When such extractants were tried on a larger heterogeneous mass of soils they fail invariably or having limited use (Tamhane et al., 1958). Evidently, a reliable method for the evaluation of available K should be used to ascertain the utility of soil test values. The present method of soil test measures the amount of nutrient soluble in a particular solvent. It is not the amount of soluble nutrient alone that primarily controls the uptake by plant but the energy expended to withdraw it from the available pool. Hence the concept of nutrient potential based on physico-chemical measurement developed by Beckett (1964) using Schofield's ratio law (1947) and Woodruff free energy (1955) was also tried to predict K availability in soils.

With introduction of the high yielding varieties of rice and intensive cultivation, the K reserves of the soil are likely to be depleted in a shorter period due to high K requirement of these high yielders. A knowledge of the pattern of depletion of K from soil and uptake pattern of K by rice at different stages of rice growth is helpful for judicious use of K fertilizers especially in the context of economising fertiliser use.

While plants differ in their requirement of K as well as ability to absorb K from soils, precise information in the response of rice to added K would be of much practical significance in estimating the relative K requirements. Accordingly, the response to K have been studied in a well defined soil series representing larger area of the district. In hundreds of trials with rice in India responses to K were observed on soils even with high available K but in some cases low or no effect was reported even in soils with low K status. In extreme cases, negative responses were also reported. Many a time cubic response for added K have also been reported for added K. Exact scientific background of these phenomena is yet to be understood in the real perspectives. In Tamil Nadu very sporadic attempts have been made so far on the above aspect. Although much work to elicit such behaviour in soils was endeavoured elsewhere still it needs location specific investigations. Thus the behaviour of soil K, its interaction with other plant nutrients, fixation, release characteristic, its uptake and response pattern under different situations are varying and perplexing needing elucidation in the above aspects in the experimental area. The above parameters upon integration might throw valuable information to enlighten the perplexicity.

The experimental area, viz., Thanjavur is the rice bowel of Tamil Nadu having an area of 9700 Km^2. It includes old delta commanded by river Cauvery and its distributaries and New delta fed by Grand Anicut Canal. There are 22 soil series occupying an area of 7,66,888 hectares of which 10 major soil series constitute 6,37,839 hectares (Dhamapalan Mosi *et al.*, 1974). The area certainly warrants a detailed study in respect of dynamics of soil K and response of rice to K to sustain higher yields.

In order to fill up the voids in our knowledge on the various aspects of K dynamics in Thanjavur soils and also in the light of controversy over response behaviour and K needs of rice soils, the present study was taken up at soil series level with the following objectives.

i) To investigate the K status of the major soil series of Thanjavur district for various forms of K.

ii) To study the K fixing capacity, release and supplying power of soils by chemical and biological methods and to relate them to crop response.

iii) To study the efficiency of different methods for assessing the K availability indices by using different extractants and to suggest a simple and rapid method of K determination.

iv) To study the suitability of different K potential parameters as indices of K availability.

v) To study the response of rice (ADT 31) to applied K in different soil series.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

The literature relating to the present investigation is reviewed below under the following aspects.

2.1. Potassium equilibrium in soils

2.2. Forms of K in soils

2.3. Distribution of different fractions of soil K

2.4. Potassium fixation in soils

2.5. Degree and extent of K fixation

2.6. Correlation studies between K fixation and factors influencing K fixation

2.7. Potassium release and supplying power of soils

2.8. Potassium availability indices

2.9. Q/I parameters as a measure of K status in soil

2.10. Effect of K on the yield of rice

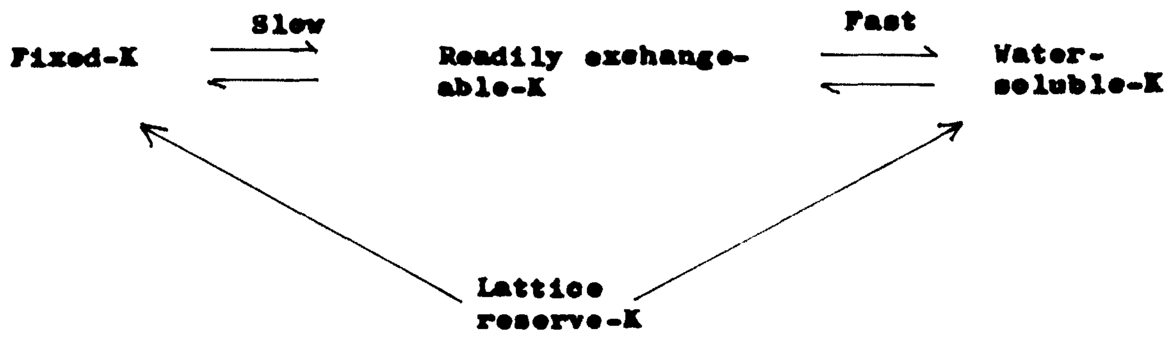
2.11. Influence of K on the availability of K in soil

2.12. Influence of K on the concentration and uptake of nutrients by rice

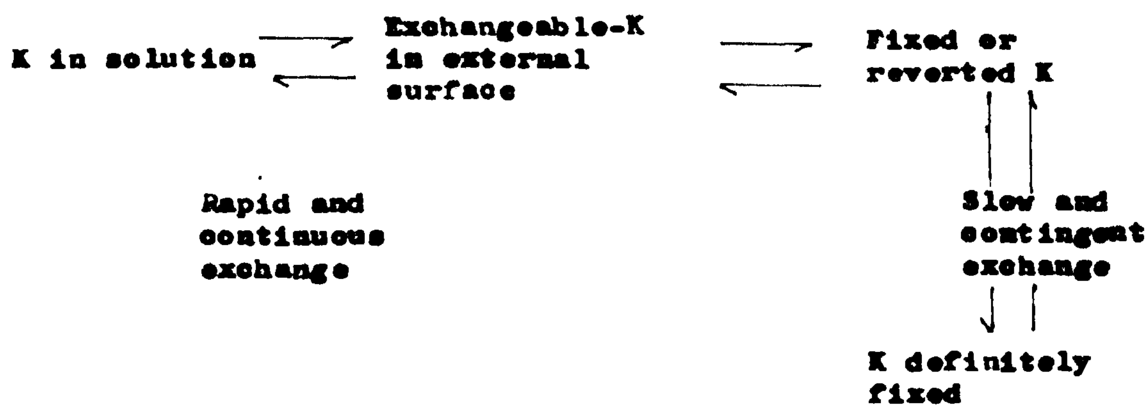
2.13. Interaction of K with other nutrients in soil and plant.

2.1. Potassium equilibrium in soils

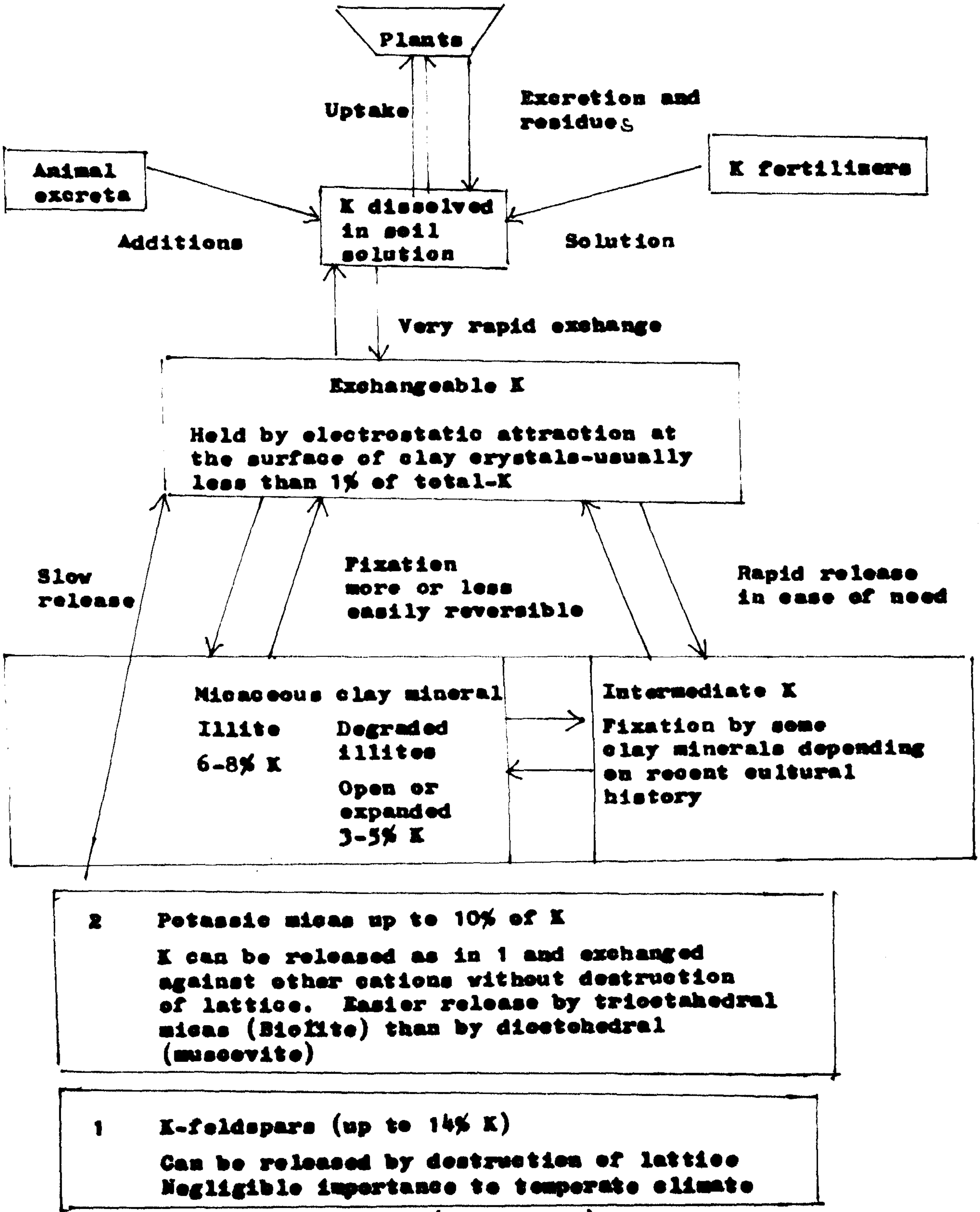
Potassium exists in soil in different forms as water-soluble, exchangeable, non-exchangeable (fixed) and mineral or lattice K which are in dynamic equilibrium with each other and overall equilibrium may be represented as follows.



Duthion (1968) gave the schematic summary of different forms of K in soil as follows:



Possible forms and sources of K in soil-transformations between forms as enunciated by Quemener (1979) are as follows:



Reserve K (Main forms)

2.2. Forms of K in soils

2.2.1. Water-soluble K

Potassium present as soluble cation in soil solution is termed as water-soluble K (Ramamoorthy and Velayutham, 1976). The distinction between this form and others is arbitrary as by mere dilution with water, the soluble K will increase because of hydrolysis of Kex (Reitemeir, 1951).

Cooke (1963) hinted that water-soluble K is fully utilised by crops. Addition of K fertilisers increased the water-soluble K (Rajkovic, 1967). Water-soluble K is inadequate to meet the K demand of crops and it is high in alluvial soil (Mishra *et al*., 1970). The amount of water soluble K fraction in the major soil groups followed by the order of alluvial $<$ black $<$ red $<$ laterite (Ramanathan, 1977). A close correlation was established between water-soluble K and 0.01M $CaCl_2$ extractable K (Biddappa and Sarkunan, 1981).

2.2.2. Exchangeable K (Kex)

The exchangeable fraction constitutes the K adsorbed on clay complex and the K ions held around the negatively charged colloidal particles by electrostatic attraction. The cations so held are exchanged when soil is placed in contact with neutral salt solutions. Various methods have been used to describe the Kex. In current standard practice, the reference is to neutral N NH_4OAC extractable K. Generally, the Kex is held at three types of exchange sites on clay lattices viz., planar, edge and interlattice. The Kex held on edge position is easily available while the Kex on the planar sites since held with more bonding energy is relatively less available. Similarly the K ion on interlattice positions is also available but to a much lesser degree. Regarding the specificity of K ions with reference to the above three sites it is said that the planar position does not represent specific K binding sites while edge positions bind K more selectively. The interlattice positions have the highest selectivity (Anonymous, 1977).

About two per cent of the total K is in exchangeable form. The highest amounts of Kex was obtained in clay plus silt fractions of black soil followed by red, alluvial and laterite soils (Jayaraj and Dhamapalan Mosi, 1973). Prolonged cropping of soil reduced Kex to a minimum level (Bach, 1974). There was a decrease in available K during the first week of submergence (Murthy and Singh, 1975). Black soils from rice growing areas of West Godavari recorded 229 to 498 ppm of Kex with 0.95 to 2.32 per cent K saturation (Venkatasubbiah et al., 1976).

The Kex is an unsatisfactory measure of K availability (Ghosh and Ghosh, 1976; Goswami et al., 1976 and Grimme, 1976). The Kex tended to increase with increase in clay content (Ranganathan and Satyanarayana, 1980 and Subba Rao et al., 1984). Even if clay content is high the Kex may be less when soil pH is low (Ranganathan and Satyanarayana, 1980).

2.2.3. Non-exchangeable K (K_{nex})

By definition, all the soil K except soluble and exchangeable forms are included in K_{nex}. Generally the K held at inter-lattice positions is K_{nex} and this form is not exchangeable by N NH_4OAC (Ramamoorthy and Velayutham, 1976).

On an average two-thirds of the K used by the crop came from forms that were K_{nex} and the amount of K_{nex} removed from different soils varied between 39 and 87 per cent of the total K uptake by the crop (Stewart and Volk, 1946). Utilisation of K_{nex} was much greater on upland rice than low land (Prasad, 1974). The per cent utilisation of fixed K decreased as the level of added K increased in rice crop (Ramanathan, 1977 and Nagarajan, 1980). While Kex content of soils did not change appreciably even after long period there were pronounced changes in K_{nex} form and contribution of K_{nex} to crops was more in untreated plots than those receiving fertiliser K and there was close relation between K removal in crops and K_{nex} released from soil (Ganeshamurthy and Biswas, 1985).

2.2.4. Mineral lattice K

This form constitutes the major part of the total K in mineral soils and is present in primary minerals such as muscovite, biotite and potash feldspars. Of the clay minerals, only illite has a substantial K content. Bear (1958) reported the following K content in different minerals: illite 4-7 per cent

According to Tiwari et al. (1967) the alluvial soil groups of Bihar contained a total K of 64.8 me/100 g. Of this 5.8, 5.3, 0.45 and 0.20 per cent represented HNO_3-K, K_{nex}, Kex and 0.01M $CaCl_2$-K respectively. The Kex showed significant correlations with only 0.01M $CaCl_2$-K. Besides a highly significant correlation existed between HNO_3-K and K_{nex}.

Dhawan et al. (1968) reported that Rajasthan soils contained 1.7 mg water-soluble K, 20.7 me/100 g of Kex, 97.6 me/100 g of K_{nex} and the above fractions formed respectively 0.21, 2.56 and 12.1 per cent of the total K. Khanna and Anand Prakash (1970) stated that light textured soils contained small amount of HCl-K (4.29 to 13.20 me/100 g) than heavy textured soils (6.75 to 22.5 me/100 g). Roy and Bagchi (1973) showed that out of the total K of 2159 mg K/100 g, 3.06 per cent was in fixed form, 1.43 per cent in HCl-K and 0.56 per cent in Kex. Significant positive correlations were found between various forms of K. Ram and Singh (1975) revealed that paddy soils of Uttar Pradesh contained 6.5 to 39.5, 64.0 to 258.5 and 187.5 to 650.0 mg/100 g of available, fixed and HCl-K respectively. Available K was positively correlated with pH, $CaCO_3$ and clay. HCl-K was positively correlated with fixed K. Kalbande and Swamynatha (1976) reported that black soils of Tungabhadra contained out of 913 mg of total K_2O/100 g of soil, 9.12 per cent HNO_3-K, 2.86 per cent Kex, 0.94 per cent citric acid K and 0.11 per cent water-soluble K. No correlation existed between total K and other forms.

Ramanathan (1977) stated that the mean values of K extracted by water, N NH_4OAC, 0.1N HCl, 0.5N HCl, 0.1N HNO_3, 0.5N HNO_3, 0.5N EDTA, 0.5N HCl, 1 per cent citric acid, N HNO_3 and 0.01M $CaCl_2$ were 0.11, 1.11, 0.80, 0.91, 0.77, 1.10, 0.65, 0.51, 0.74, 4.8 and 0.70 per cent of the total K respectively in Tamil Nadu soils.

Ranganathan and Satyanarayana (1980) established a significant correlation between water-soluble K and Kex. Lopez (1980) showed positive correlations between HCl-K and clay content and Kex with clay content.

Biddappa and Sarkunan (1981) reported 1.5, 23.8, 46.5 and 205 ppm water-soluble K, $CaCl_2$-K NH_4OAC-K and 1N HNO_3-K respectively in rice soils of Orissa. Potassium extracted by various extractants was closely correlated.

Dutta and Joshi (1983) reported that the soils of arid zone contained 77.5 to 550, 36 to 325, 9.5 to 26.5 and 29 to 164 mg/100 g of HCl-K, HNO_3-K, NH_4OAC-K and fixed K respectively. Singh et al. (1983) concluded that water-soluble K and Kex respectively contributed 17.6 and 82.4 per cent towards available K. Valliappan (1984) stated that soils of Madurai recorded 576, 65, 45, 56, 116, 165, 62, 95, 80, 170, 15, 67 ppm of boiling N HNO_3-K, 0.5N HCl-K, 1 per cent acetic acid K. 0.5N NaCl-K, 0.1N HCl-K, 6N H_2SO_4-K, 0.1N HNO_3-K, Morgan's reagent-K, 1 per cent citric acid K, neutral N NH_4OAC-K, distilled water K, 0.01M $CaCl_2$-K respectively.

Singh et al. (1985) reported that soils of Haryana contained total K from 1.02 to 2.02 per cent, 1N HNO_3 soluble K from 131 to 675 ppm, ammonium acetate K from 16 to 197 ppm and water-soluble K from 2 to 38 ppm. All forms of K were directly related to each other except water-soluble K.

2.4. Potassium fixation in soils

Potassium fixation refers to conversion of added K to less available forms. In the laboratory determination it is the added K not extracted by N NH_4OAC. The reversion of added K in soil depends on a number of factors viz., alternate wetting and drying, pH of soil, CEC, mineralogy, mechanical composition, time of contact, complimentary ions, amount of added K, exchangeable sites, K saturation of soils etc. Besides, these the relationship between the above factors and K fixation and the degree and extent of K fixation in different soils are also reviewed under this heading of K fixation.

2.4.1. Alternate wetting and drying

When clays are wetted the crystal lattices expand and water enters into the interspaces of clay. Along with water K ions also gain entry into lattice spaces. When clays are dried causing contraction of lattices water comes out while K ions are being trapped between lattices (Shaviv et al., 1985).

Prasad et al. (1967) reported that alternate wetting and drying of alluvial soils of Bihar increased the K fixation from 23.0 to 47.6 per cent. Hasan and Velayutham (1971) stated that Delhi alluvial soil and Coimbatore black soil under wet condition recorded 15.2 and 11.6 per cent K fixation while the above soils under alternate wetting and drying recorded 23.9 and 16.4 per cent respectively. But later Hasan *et al.* (1972) found that for medium black soils of Uttar Pradesh the fixation under alternate wetting and drying conditions was less than that under wet condition. Similar results were also reported in soils of Dapoli, Poona by Kadrekar and Kibe (1973).

2.4.2. Soil reaction

In general, at lower pH the fixation is less and with increasing pH the fixation increases. A decrease in pH reduces the K fixation either as a result of competition of H_3O ions for the interlattice exchange positions or due to the destruction of the lattice structure. With increased pH the fixation of K increases (Misra, 1958; Grewal and Kanwar, 1967; Patil *et al.*, 1976 and Ranganathan and Satyanarayana, 1980).

2.4.3. Organic matter

The organic matter substances block the edge positions of expanded layers and thereby reduce the fixation as reported by Kuntse and Leisen (1970).

2.4.4. Mineralogy

The mineralogical make up of the soil decides the fixation of K to a larger extent and the amount and nature of clay mineral play a vital role in the fixation. Thus the intensity of fixation is zero with kaolinite, chlorite and micas; slight with montmorillonite and strong with vermiculite (Ramamoorthy and Velayutham, 1976).

The adsorption and fixation of K in soils containing bentonite are more (Misra, 1958). Illite alone does not fix K but releases K on drying (DeMumbrum and Hoover, 1958). Some eastern Ontario soils containing illite, mixed layer minerals and vermiculite fixed considerable portion of added K (McLean and Brydon, 1971). In Kenyan soils montmorillonite, amorphous clay, kaolinite fixed 53 to 80, 48 to 66 and 19 to 32 per cent of added K respectively (Barber, 1979). Soils with illite type of clay minerals had higher K fixing capacity than those with kaolinitic type minerals (Bagchi and Roy, 1975).

According to Bajwa (1980) soils with montmorillonite and beidellite fixed higher proportion of added K followed by vermiculite in wet land soils.

2.4.5. Soil type

Soils fix different quantities of added K depending upon initial K saturation. According to Verma and Verma (1970) deep black soils showed medium fixation and alluvial soils, the least.

Alluvial soils of Delhi fixed more K than black soils of Coimbatore (Hasan and Velayutham, 1971). The fixing capacity of Madhya Pradesh soils was more than that of Uttar Pradesh soils although the clay content of Madhya Pradesh soils was lower than that of Uttar Pradesh soils (Hasan *et al*., 1972 and Singh and Ram, 1975). Acid laterite soils showed comparatively less fixation than medium black calcareous soils (Patil *et al*., 1976).

2.4.6. Mechanical composition

Pathak (1954) studied the contribution of mechanical fractions of the soil and concluded that silt fractions showed greater K fixation. While Grewal and Kanwar (1967), Mehrotra *et al*. (1972), Ramanathan (1977), Nagarajan (1980) and Ranganathan and Satyanarayana (1980) opined that clay fraction of the soil was the main seat of K fixation.

2.4.7. Time of contact

The incubation time of added K with soil displays a significant role in K fixation. Nearly 90 per cent of the added K was fixed in one day and equilibrium was established in 7 days (Grewal and Kanwar, 1967). The K fixation increased significantly throughout the incubation period of 3 months (Ramanathan *et al*., 1975). Increasing fixation with time of contact of added K was also reported by Patil *et al*. (1976) and Valliappan (1984).

2.4.8. Complimentary ions

The cations like Ca^{2+}, NH_4^{+}, and companion anions like SO_4^{2-}, PO_4^{3-} etc. may decide the fixation to a larger extent by competing with K fixation sites.

Pathak (1954) stated that the soils showed greater K fixation when it was treated with KCl while Pathak and Sharma (1963) noted that K as phosphate showed greater fixation than sulphate or chloride. Thomas and Hipp (1968) reported that increased Ca ions promoted K fixation owing to an increase in pH and by the replacement of K from interlattice positions. Kar et al. (1975) showed in acid soils of West Bengal that about 25 to 40 per cent and 20 to 28 per cent of added K were fixed in the absence and presence of NH_4 ion respectively.

2.4.9. Concentration of added K

With increasing concentration of added K, the fixation increased but the percentage of fixation decreased (Prasad et al., 1967; Ramanathan, 1977; Barber, 1979; Subba Rao et al., 1982 and Valliappan, 1984).

2.4.10. Potassium saturation

Soils with low initial K saturation tend to fix more K. Joshi et al. (1978) found that low fixing capacity was related to high K saturation of soils. Hoveler and Spain (1980) concluded that relatively exhausted soils fixed high amounts of added K.

2.5. Degree and extent of K fixation

The K fixing capacity of Madhya Pradesh soils varied from zero to 2.95 me K/100 g of soil (Verma and Verma, 1970); 11.92 to 41.52 per cent of the added K in Uttar Pradesh soils (Misra and Shankar, 1971); 33.0 to 47.3 per cent in Bundelkhand soils (Mehrotra et al., 1972); 7.46 me K/100 g of soil in medium black soils of Rjasthan (Bhatnagar et al., 1973); 0.3 to 1.9 me/100 g of soils of arid zone (Joshi et al., 1978); 5.2 me/100 g of soil in Madukkur soil series of Vaigai-Periyar Command Area (Nagarajan, 1980); 1.60 to 2.00 me/100 g of soil in soils of Madurai (Valliappan, 1984) and 8.8 to 35.5 me/100 g of soil in alluvial soils of Agra region of Uttar Pradesh (Chandraprakash and Vinay Singh, 1985).

2.6. Correlation studies between K fixation and factors influencing K fixation

Verma and Verma (1970) established a negative relation between K fixation and organic carbon in red and yellow soils. Potassium fixation was positively related to clay, pH, $CaCO_3$, CEC of soils (Singh and Ram, 1975; Bagchi and Roy, 1975; Chandraprakash and Vinay Singh, 1985) and to silt (Ramanathan and Krishnamoorthy, 1976; and Joshi et al., 1978). Howeler and Spain (1980) obtained a negative relation between K fixation and Kex.

2.7. Potassium release and supplying power of soils

According to Ramanathan and Krishnamoorthy (1982), the K releasing power (KRP) of soil is the sum of Knex converted to Kex and Kex form into water-soluble form whereas supplying power (KSP) of soil is the amount of K supplied to growing plants from soil solution, Kex and Knex. KRP is affected by soil physical factors while KSP by plant factors. Almost the same factors influencing K fixation also influence the release of K.

2.7.1. Wetting and drying

Illite alone does not fix K but release K on drying (DeMumbrum and Hoover, 1958). Illite rich soil released more K than montmorillonitic one (Datta and Sastry, 1985). Potassium release on drying occurred only when the per cent K saturation was less than 1.11 ± 0.12 (Mathews and Sherrell, 1960). Wetting causes expansion of clay mineral lattices resulting in the replacement of interlattice K by other cations (Talibudeen and Weir, 1972). Under continuous moist conditions the release of K took place only at the end of 50-60 days. Wetting followed by air drying brought out early release of soil K from Knex. Lower moisture level of 50 per cent moisture equivalent was conducive to greater release of soil K (Kadrekar and Kibe, 1973). According to Datta and Sastry (1985) at higher saturation the influence of moisture on release of K in different soils was quite variable while at lower degree saturation (depleted soil) the effect was more pronounced. In the latter situation continuous submergence restricted the K release from Knex. Jixian Luo and Marlon L.Jackson (1985) stated that soil samples from China were higher in Kex after air drying and oven drying (60°C) than when wet.

2.7.2. Weathering

To weathering, the primary minerals are more susceptible than clay minerals (Rich, 1968). According to Davis (1972) the interlattice diffusion is the reason for K release during weathering.

2.7.3. Soil reaction

The soil reaction and K release are inversely related. The release of K is more at lower pH (Nemeth and Grimme, 1972). A rise in pH raises the CEC, thereby increases the Kex (Ranganathan and Satyanarayana, 1980).

2.7.4. Soil texture

The textural components of soils viz., clay, silt, fine sand and coarse sand fractions influence the K release. Generally clay fraction increases K than other components. More release of K occurred from coarse clay, less from medium clay and least from finer fractions of clay (Doll et al., 1965). The highest release of K was observed in clay fraction followed by silt and sand (Talibudeen and Weir, 1972). Sidhu and

Dhillon (1985) claimed that most of the released K originated from the silt fraction. According to Feigenbaum and Levy (1977) the K release depends on distribution of K between silt and clay fractions, total K and soil salinity. Silt fraction with a high K content released K at a higher rate than clay with similar K content. Joshi et al. (1978) opined that K release was due to low amount of clay and preponderance of K bearing minerals. Clay and loam soils released more K than clay loams and silty clay loam (Sailakshmiswari et al., 1985).

2.7.5. Complimentary ions

The effect of complimentary ions on K release was studied by Powell and Hutchensen (1965) and reported that the release of Knex was enhanced by lime application. Esakkimuthu et al. (1975) reported that application of $(NH_4)_2SO_4$ decreased the K release whereas Ranganathan and Satyanarayana (1980) observed that in slightly alkaline and neutral soils, the Ca ion is the dominating one which promotes the opening up of clay mineral pockets and consequently release the lattice K. While Sen Gupta (1982) upheld the view that Ca ion favoured K release. Beauchamp (1982) pointed out that the rate of release of K during successive periods were almost constant and not affected by the addition of NH_4 ion. Geetanjali Ghosh (1985) stated that sodium salts with divalent anions (CO_3^{2-} and SO_4^{2-}) brought more K in solution than the same cation in combination with monovalent anions (Cl^- and HCO_3^-).

As for divalent cations, Mg^{2+} was more effective than Ca^{2+} in releasing K. Further mineral acids release more K than organic acids.

2.7.6. <u>Mineral characteristics</u>

The primary source of K in soil is feldspars and micas (DeMumbrum and Hoover, 1958). The important minerals are orthoclase and microcline feldspars, biotite and muscovite micas and illite clays. The release of K varies depending upon nature of clay minerals, per cent K saturation, the protective residual layer, expansion of interlayer spacing, triootahedral or dioctahedral structures of clay minerals and degree of wetting.

Davis (1972) observed that biotite (triootahedral) released more K than muscovite (Dioctahedral). Sidhu and Dhillon (1985) reported that micas released more K than feldspar because of the presence of protective residual layer on their surface whereas more of K release by mica was due to the increase of interlayer spacing when cations like calcium replaces interlattice K. Ramanathan (1977) observed that a laterite soil with high Kex possibly held K with less tenacity released K rapidly whereas an alluvial K depleted soil could release only very little K and soils dominant with illite clay released K steadily and gradually indicating its highly buffered nature. Pal and Mandal (1980) indicated that the K release behaviours of illite dominant clay fractions of soils indicated a probable mechanism of K release through a diffusion controlled process which contributed a considerable amount of K probably through a process of dissolution. Xie Jian Chang *et al*. (1982) reported that K fixed on broken edges or in lattices of weathered hydrated micas was released in the course of continuous cropping.

2.7.7. Influence of crops on K release

According to Nath and Dey (1982) the K intensity values decreased progressively during the initial cropping period of rice when dry matter yield, K content and uptake in harvested material increased. Singh and Ghosh (1984) found that in the absence of applied K, its Knex contributed to a greater extent towards total K removal by crops, compared to K treated soils.

2.8. Potassium availability indices

Proper assessment of K availability in soil is a pre-requisite for soil fertility evaluation, correct interpretation and appropriate use of fertilizers. Nelson (1959) pointed out that limitations to the use of soil tests are due to the heterogeneity of soil population and differing colloidal characteristics. Tamhane *et al*. (1958) comparing many soil test methods on different types of soils showed that none of these methods is suitable for all types of soils because of the above reasons.

Gething (1962) attributed two reasons for obtaining any perfect method which gives better correlations. The relatively strong reagents which are used in practice extracted K ions held on the clay in positions where they are not truly exchangeable. Secondly the extraction of the whole of Kex grossly disturbed the equilibrium between this and the less easily available forms.

Balasundaram (1971) pointed out that of the biological methods, the Neubauer's method is very reliable one to predict the availability of K in soils. But considering the time and cost factors involved in biological assay methods, the empirical methods are preferred. Ramanathan (1975) revealed that in reality the actual amount of available K is truly reflected by plant uptake. Hence any simple chemical method of K availability index which approaches more closely the actual uptake by plant can be considered as a reliable and suitable method.

In attempting to choose a good and reliable extractant to estimate the available K of the soil, a number of extractants like water, mineral acids, neutral salt solutions, organic acids, buffer solutions of different concentrations with varying incubation time, soil : extractant ratios have been employed by different workers.

Datta and Kalbande (1967) reported that Hunter and Pratt method (1.32N H_2SO_4) appeared to be the best acid extractant. Swami and Lal (1970) comparing the efficiency of different extractants concluded that water-soluble K and Morgan's K are suitable solvents for predicting K availability while Pathak et al., (1975) stated that only Morgan's extractant was the best.

Neutral N NH_4OAC is the best extractant for apprising K availability in soils (Esakkimuthu, 1972; Talati *et al*., 1974; Quemener, 1979; Nagarajan, 1980; Wood and Burrows, 1980; Tahir Saleem *et al*., 1980; Sobulo, 1982; Chandrasekara Rao and Prasad Rao, 1983; Kalbande, 1983 and Bansal *et al*., 1985).

According to Panda (1971) and Ramanathan (1978) 0.1N HNO_3 soluble K was more closely correlated to plant uptake. Sobulo (1982) concluded that 0.13N HCl was the good extractant.

2.9. Q/I parameters as a measure of K status in soil

The K status as measured by chemical extractants has limited use as they would extract a large amount of nutrient from a volume of soil than plants would extract (Tamhane *et al*., 1958). Thus chemical potential was measured to overcome the soil heterogeneity. The above physico-chemical measurement has been developed by Beckett (1964) based on Schofield's ratio law (1947).

Beckett (1964a) concluded that AR_e^K had the same value for all solutions in equilibrium irrespective of Ca plus Mg up to 0.06M and is a measure of chemical potential of labile K in a soil provided it is not used to compare soils of widely different Ca and Mg status. Acquaye and MacLean (1966) stated that the AR_e^K was better correlated with portions of K derived from Kex, while the AR_e^K and the quantity of K released ($-\Delta K^o$) were much more indicative of total K uptake than AR_e^K alone.

The PBC^K was a good measure of K availability (Barrow, 1966; Pchelarova and Milcheva, 1983 and Gupta et al., 1983) while Ramanathan (1977) stated that it was a poor index of K availability.

Zandstra and Mackensie (1968) opined that the K potential correlated well with crop response than AR_e^K or PBC^K while Balasundaram (1971) and Oertli (1973) concluded that K potential alone could not be relied upon as a sole index of K availability. Rezk and Amer (1969) stated that the Q/I relation was a better index of K status but Ramanathan (1977) expressed that it was found to be an unsatisfactory measure of K availability. Nash (1971) and Ramanathan (1977) stated that labile K ($-\Delta K°$) was found to be the better index than PBC^K, AR_e^K and ΔG but Narayanan Nambiar (1972), Chandrasekar Rao and Prasad Rao (1983) opined that among Q/I parameters the AR_e^K was a better index.

Zandstra and Mackensie (1968), Wild et al. (1969), and Schuffelen (1972) stated that uptake of K is a function of Q and soils of equal I, the soil with higher b factor will have a higher Q resulting higher K uptake. Biddappa and Sarkunan (1981) found positive relationship between K_L with AR_e^K, PBC^K and K_X and in turn K_X with K uptake.

Low and high activity ratios being associated in red and black soils respectively and the decrease of AR_O^K by plant uptake or by leaching in acid than black soils was reported by Maji and Sen Gupta (1982). Chatterjee *et al.* (1983) proposed two new parameters viz., buffering capacity (BC_e^K) and unified solution Q/I factor (USQI) by taking concentration ratio of K in soil solution as intensity factor and K extracted by 1N NH_4OAC as quantity factor and these parameters have merit over Beckett's Q/I technique due to hydrophysical properties of the soil. According to Mahendra Singh *et al.* (1982) $pK-\frac{1}{2}p$ (Ca + Mg) parameter was found to be a better measure of K availability than $\triangle G$. Ganeshamurthy and Biswas (1984) observed a decrease in AR_e^K values in plots receiving no K fertilizer and change in AR_e^K was accompanied by change in labile pool of K (K_L). The depletion of K decreased the AR_e^K and K_L and increased the PBC^K while addition of K increased AR_e^K and K_L but decreased the PBC^K.

2.10. Effect of potassium on yield of rice

The influence of K on the performance of rice varieties, on different soils, in different seasons and the pattern of response are reviewed hereunder.

2.10.1. Effect of K on the yield of rice on different soils

Mann (1965) concluded that the response was the highest in mixed red and black soils and lowest in a coastal alluvial soil. Sundaram *et al.* (1969) found a general response to K application in cultivators field in Thanjavur. Mahapatra and Rajendra Prasad (1970) and Bansal *et al.* (1985) reported highest responses in red soils. Sadayappan *et al*. (1971) showed response of rice to K application in Manimuthar soils of Tirunelveli district. Goswami *et al*. (1972) observed response in red soils with medium and high K status. Hazra *et al*. (1974) concluded that the response to K was high in laterite soil. According to Ali *et al*. (1976) alluvial, red, laterite and coastal saline soils responded to K_2O. Similarly Goswami *et al*. (1976) found that of the major soil groups red, red and yellow, coastal and deltaic alluvium have responded to K application.

2.10.2. Influence of K on the yield of different varieties of rice

The beneficial effects of K application to rice varieties IR 8, TN 1 (Raheja *et al*., 1970); IR 5 (Dhanapalan Mosi *et al*., 1973); CO 33 and ADT 27 (Kalyanikutty and Morachan, 1974); IET 1991 (Agarwal, 1979); Bala and Sona varieties (Verma *et al*., 1979) and BR 3 and BR 4 (Haque *et al*., 1982); Pusa 33 (Barthakur *et al*., 1983) and IR 50 (Nannabatcha and Alagappan, 1985) were reported.

2.10.3. Influence of K levels on the yield of rice under different seasons

Mahapatra and Rajendra Prasad (1970) stated that although the yield levels were higher in rabi, the responses to K were higher in kharif season. Shyam Sundar Mondal *et al*. (1982) observed increased grain yield of rice in dry season than wet season.

2.10.4. Influence of graded levels of K on yield of rice

Varying doses of K have been reported to be essential for rice under different situations. 84 kg K_2O (Ali *et al.*, 1976); 200 kg K_2O (Ramanathan, 1977); 80 kg K_2O (Von Uexkull, 1978); 60 kg K_2O (Agarwal, 1979); 75 kg K O (Varma *et al.*, 1979); 80 kg K O (Mahapatra *et al.*, 1981); 120 kg K_2O (Haque *et al.*, 1982; Shyam Sundar Mondal *et al.*, 1982); 140 kg K_2O (Barthakur *et al.*, 1983); 60 kg K_2O (Bhargava *et al.*, 1985) and 93.8 kg K_2O/ha (Nannabatcha and Alagappan, 1985).

2.10.5. Absence of response of rice to added K

There are quite a number of reports to show that rice did not respond to application of K and the factors contributing for such situations are summarised.

Ramankutty (1971) found a negative response of grain yield in Taichung native 1 to added K but a significant linear increase of straw yield. Similar instances of lack of response were also made by Krishnasamy *et al.* (1974) and Ramasamy and Palaniappan (1974).

The reasons for lack of response may be based on the fact that rice requirement of K was supplied from plant residues turned under and from K in irrigation water (Desai *et al.*, 1958).

Later workers like Mehta (1976); Ramanathan (1977) and Deol *et al*. (1985) claimed that sufficiency of K in soils, release of K from Knex and low responsive varieties were other possible reasons for lack of response.

2.11. Influence of K on the availability of K

Application of 80 kg K_2O/ha increased the availability of K in the soil over 40 kg K_2O/ha (Loganathan and Raj, 1973). According to Esakkimuthu *et al*. (1974) K addition increased the water-soluble NH_4, K and NH_4ex and Kex in soil. Similar results of added K increasing water soluble K and Kex were also reported by Talati *et al*. (1974); Varadarajan (1976); Ramanathan (1977); Nagarajan (1980); Negi *et al*. (1981) and Valliappan (1984).

Added K increased the Knex in soil (Pandey, 1967; Nagarajan, 1980 and Valliappan, 1984). According to Ekambaram and Kothandaraman (1983) water-soluble K and Kex were high during initial stages and the same decreased with ageing of the crop whereas Knex was high during initial and final stages of crop growth. Total K continuously declined as the crop matured. In all the stages black soil registered more amounts of water-soluble K, Kex, Knex and total K followed by alluvial and red soil.

2.12. <u>Influence of added K on the content and uptake of nutrients</u>

The content and uptake of K significantly increased with higher dose of K fertilisation in rice and the highest uptake of K was observed at flowering stage (Sadanandan *et al.*, 1969). An increased uptake of K resulted in the enhanced uptake of N, P, Ca, Mg but a decline in Fe uptake (Kim and Park, 1973; and Agarwal, 1979). Increased K levels had an antagonistic effect on Fe uptake (Ramanathan, 1977).

According to Esakkimuthu *et al.* (1975) the highest level of K promoted the N uptake and N content in straw. Uptake of K was increased with increasing levels of K (Singh and Sinha, 1975 and Raju and Verma, 1983). According to Sethi *et al.* (1976) to produce 100 kg of grain, the requirement of K was 3.22 kg in dwarf rice while 4.52 kg in the case of tall rice and the content of K in straw was 10 times that in grain in dwarf rice whereas it was 15 times in tall rice. The K requirement per unit of grain increased as the accumulation of K in straw increases. Ramanathan (1977) and Bansal *et al.* (1985) pointed out that the uptake of K in grain was not influenced by K fertilization but uptake in straw was enhanced.

Nagarajan (1980) revealed that with increasing levels of K, the grain and straw content and uptake of N, P and K increased. The leaf K content at 3 months old rice plant was increased from 0.39 to 1.23 per cent with K addition (Howeler and Spain, 1980). Potassium content of rice was high at initial stages and the same gradually declined at later stages from 2.56 to 1.71 per cent (Raju and Verma, 1982).

Xie Jian-Chang et al. (1982) observed that rice obtains part of its K uptake from readily available source and greater part from slowly available sources and total K uptake was better correlated with slowly available K than readily available K.

According to Mandal and Dasmahapatra (1982) increased levels of added K enhanced the uptake of K and N whereas Park et al. (1971) observed that the amount of N absorbed tended to decrease with increasing levels of K_2O and K_2O/N ratio also increased with K addition. Simonis and Nemeth (1985) concluded that the K uptake was low despite high K availability in soils.

Plant analysis has been found useful in diagnosing the potassium status of the soil and for recommending potassium fertiliser to rice. Ishizuka and Tanaka (1951) stated that if the K_2O content of straw at harvest is less than one per cent a potassium deficiency is likely to exist. Kinchi and Ishizuka (1961) also found that two per cent potassium in straw at booting stage and heading stage is required for a high number of grains.

Tanaka and Yoshida (1970) found that the critical percentage of K in the leaf blade at the tillering stage and in the straw at harvest is one per cent. Calibrations made in Taiwan (Sheng _et al_., 1964), based on 20 field experiments on latosols, indicated that the percentage of K in straw corresponding to 90 per cent and 98 per cent of the maximum rice yield were one per cent and 1.8 per cent respectively. According to Mikkelsen (1971) the critical percentage of K in the most mature leaf of a rice plant was 1.8 per cent at the mid-tillering stage, 1.0 per cent at maximum tillering and 0.8 per cent at panicle initiation. The percentage of adequate K at the same stages were 1.4 to 2.8 per cent, 1.2 to 2.4 per cent and 1.0 to 2.2 per cent respectively.

Von Uexkull (1976) found that the critical percentage in straw depends on the N and P status of the soil. He proposed the ratio of K percentage (control) to K percentage (with NP) as the criterion for diagnosing the K requirements of rice crop. When the ratio exceeds 1, there will be a response to K. If the percentage of K in rice straw, at or before harvest is lower than one per cent, a significant response to K is most likely; no significant response is likely if this level is above two per cent. Beringer (1985) showed that under low N and P (control) the percentage of K in straw was rather constant inspite of different responses to applied K.

2.13. Interaction of K with other ions in soil and plant

The latest trends in fertiliser recommendation signifying balanced nutrition envisage nutrient interactions. Mutual antagonistic effects of heavy doses of nutrients or otherwise its high availability consequent of the uptake of other nutrients in crop species is well documented. Thus interaction is a mutual effect either in favouring or off-setting the availability of one ion by the other. Interactions of nutrients ions occur in soil and plant due to differences in electrovalency, precipitations reactions, blocking effect, excessive absorption of one nutrient ion and dilution effect of one ion promoting the biomass.

2.13.1. Interaction of K with N

Application of NH_4^+ before addition of K increased K and N uptake (Singh and Sinha, 1975). Prior addition of K by six hours resulted in depression of NH_4 fixation to a larger extent (Badhe *et al.*, 1976). Ammonium fixation was very low under H^+ saturated condition. A 10.0 per cent saturation of CEC by K increased the NH_4^+ fixation whereas above 10 per cent reduced the fixation (Raju and Mukhopadhyay, 1976). About 40 and 28 per cent of added K was fixed in absence and presence of NH_4^+ respectively (Singh and Singh, 1979).

Uptake of K was depressed by NH_4^+ due to root media acidulation (Baker *et al.*, 1967). Potassium uptake was significantly increased by applied N levels (Roy and Wright, 1974 and Durairaj Muthiah, 1978).

2.13.2. Interaction of K with P

Phosphorus had a depressive effect on K availability (Roy and Wright, 1974 and Durairaj Muthiah, 1978).

2.13.3. Interaction of K with Ca

Potassium interacts with Ca antagonistically both in soil and plant. Ethrenberg (1919) attributed the decreased K uptake on limed soils to an antagonistic effect of Ca upon K. He formulated the lime-potash law which means that when Ca concentration is relatively high, the plants may not be able to absorb their required K at an adequate rate. Narrower the ratio (1 : 4) the more K the plants accumulate (Berry and Ulrich, 1970) Randhawa and Pasricha (1976) reported that the decrease in Ca content was more in the above ground portion with increasing K addition.

2.13.4. Interaction of K with Mg

Magnesium also exhibits antagonistic effect on K. Low Mg/K ratio causes a slower absorption of K and causes Mg deficiency (Ramamoorthy and Velayutham, 1976). Heavy application of K affects Mg absorption and Mg deficiency was accentuated by higher levels of K (Nightingale, 1937 and Hovland and Caldwell, 1960).

2.13.5. <u>Interaction of K with Fe</u>

With regard to Fe-K interaction it is concluded that excess K addition causes Fe deficiency and low level of K causes Fe toxicity. According to Bolle-Jones (1955) iron chloresis was cured by addition of high levels of K. Tanaka and Tadano (1972) concluded that good status of K in plants depressed iron uptake and high levels of Fe in soil depressed the K uptake.

Oertli and Opoku (1974) reported that the uptake of Fe was increased from 0 to 2.5 g/pot. When the K level was further increased there was a decrease in Fe uptake. Such reduction of Fe uptake at low and high levels of K was also reported by Hernando and Sanfluents (1976).

EXPERIMENTAL DETAILS

CHATPER 3

EXPERIMENTAL DETAILS

Details regarding the soils used for the study, laboratory incubation, pot and field experiments conducted, the collection of soil and plant samples, the analytical methods followed in the present investigations are presented in this chapter.

3.1. Details of the soils included for the study

Thanjavur district, the rice bowel of Tamil Nadu was chosen for a detailed study relating to the topic of investigation. It has an area of about 9700 Sq.km and lies between 9° 50' and 11° 50' north latitudes and between 78° 50' and 80° east longitudes. It includes old delta commanded by the river Cauvery and Vennar and new delta served by the Grand Anicut Canal (Cauvery Mettur Project). The district enjoys a tropical hot monsoonic climate with an average rainfall ranging from 900 mm to 1300 mm.

The geological formation of Thanjavur district comprises of cretaceous, tertiary and alluvial deposits. However the major area is occupied by the alluvial and tertiary deposits (Dhanapalan Mosi *et al*., 1974).

The cretaceous formations occur as a small patch in West and South-west of Vallam. These exposures are only a part of the long narrow strip, occurring in a NE-SW direction, from

Thanjavur on the north of Pudukkottai and Karaikudi on the south. These formations have a very thick lateritic cap. They consist of impure lime stones and sandstones of silt, clay, calcareous and argillaceous varieties. In the coast, these formations are overlaid by Cuddalore sandstones of tertiary origin.

The Cuddalore sandstones of tertiary age are well developed in this district and occupy nearly an area of 3625 Sq.km. The best exposures are seen west of the Grand Anicut Canal and also near Orathanad. These tertiary sandstones are covered by a thin layer of wind-blown sands near Pattukkottai and Mannargudi. The formations mainly consist of sandy clays, unconsolidated sands, clay bound sands, mottled clays with thin lignitic seems at various horizons. Invariably the tertiary formations are capped by laterites.

Overlying the tertiary in the east, the alluvial deposits of river Cauvery and its distributaries occur over an area of about 5700 Sq.km. They consist of mainly medium to fine sands, gravelly sands, clays and sandy clays. The thickness of the formation ranges from about 30 metres in the inland to 400 metres near the coast. The alluvial formations bear the important filter point aquifers of the Cauvery delta.

Twenty two soil series have been identified in Thanjavur district as per soil taxonomy and described. These twenty two soil series occupy an area of 766,888 ha. Out of these, 10 soil series occupy an area of 637,839 ha and hence these 10 soil major series alone have been chosen for the present study.

The details of the ten major soil series and the location of soil samples collected are furnished in Table 1 and Figure 1. Also the profile descriptions of the ten soil series based on soil survey report of Thanjavur (Dhanapalan Mosi *et al.*, 1973) are presented in Figures 2, 2a and 2b.

3.2. Description of the major soil series

3.2.1. Adanur series

Adanur series comprises dark greyish brown to dark yellowish brown clay loam soils. The soils are very deep, non-calcareous throughout having sand met with below 100 to 120 cm. The typifying pedon is Adanur clay loam cultivated. The colour notation in 0-20 cm depth is 10 YR 4/2. The texture ranges from clay loam to sandy loam in the top layers. The associated soil series are Kalathur and Kivalur of which the former is calcareous in sub-soil and the latter is fine textured on the surface.

3.2.2. Alathur series

These are greyish brown to grey and deep soils occurring at the bottom of very gentle slopes of the Cauvery delta. The soils are derived mainly from the alluvial parent material rich in bases. They are sandy clay in the surface changing to clay loam below. Lime concretions are present in the lower depths. The typifying pedon is Alathur sandy clay cultivated. The

TABLE 1

DETAILS OF THE TEN MAJOR SOIL SERIES OF THANJAVUR DISTRICT

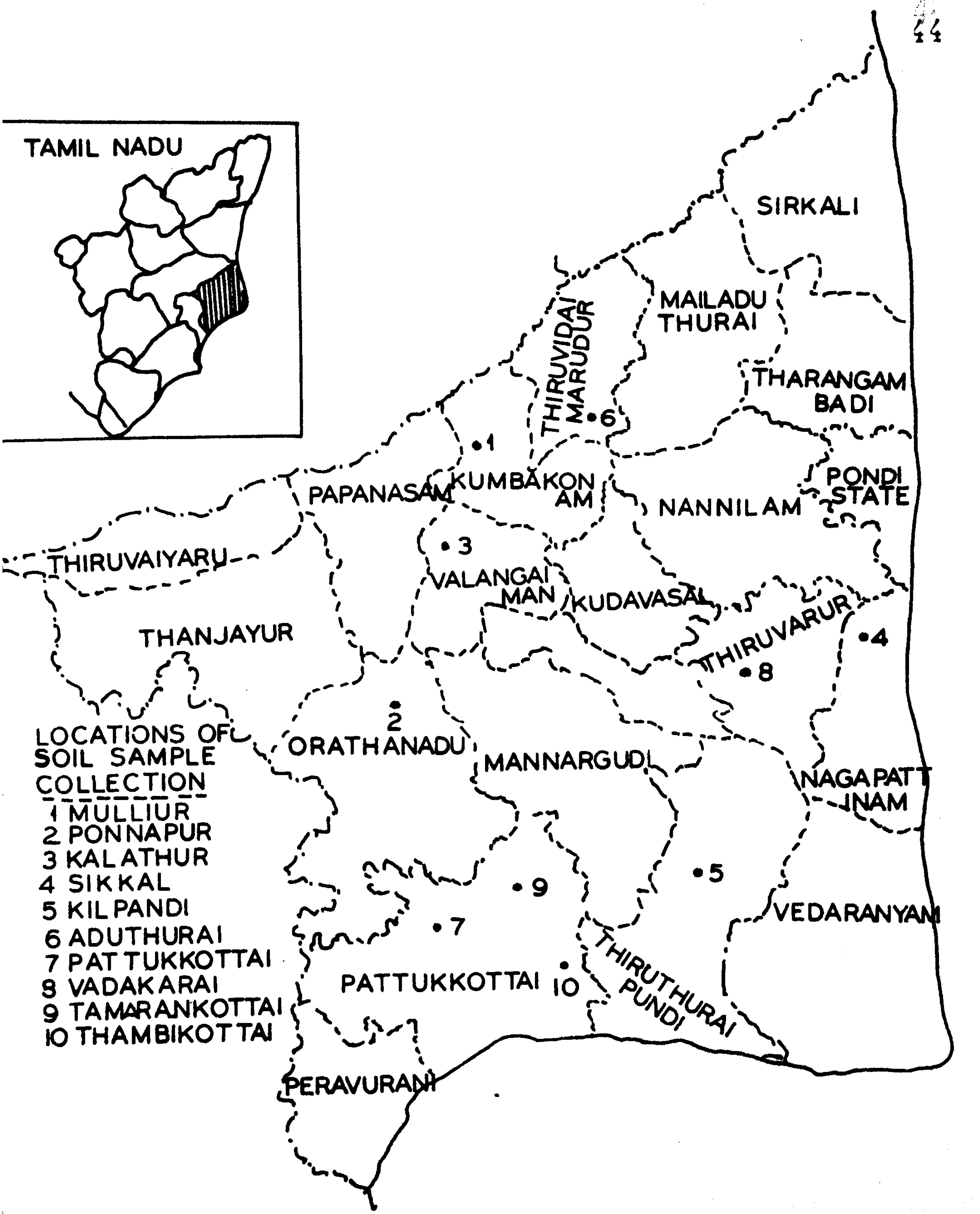
Soil No.	Name of soil series	Soil series symbol	Taluks where they occur	Extent of occurrence (ha)	Location of soil sample collection	Soil sub-group level classification
1.	Adanur	Adn	Nannilam Papanasam Mayuram Kumbakonam Sirkali and Thanjavur	82732	Mulliyur village in Kumbakonam	Entic Chromusterts
2.	Alathur	Alt	Mannargudi Orathanad Pattukkottai Thanjavur and Thiruthuraipoondi	46509	Ponnappur in Orathanad	Entic Chromusterts
3.	Kalathur	Klt	Mannargudi Nannilam Papanasam Kumbakonam and Thanjavur	126632	Kalathur in Papanasam	Udic pellusterts
4.	Kivalur	Kvr	Nagapattinam	28533	Sikkal State Seed Farm in Nagappattinam	Entic chromusterts
5.	Nedumbalam	Ndb	Thiruthuraipoondi	31907	Kilpandi in Thiruthuraipoondi	Entic chromusterts
6.	Padugai	Pdg	Mannargudi Nannilam Papanasam Mayuram Kumbakonam and Thanjavur	51863	Banana Research Station, Aduthurai	Typic Ustic fluents

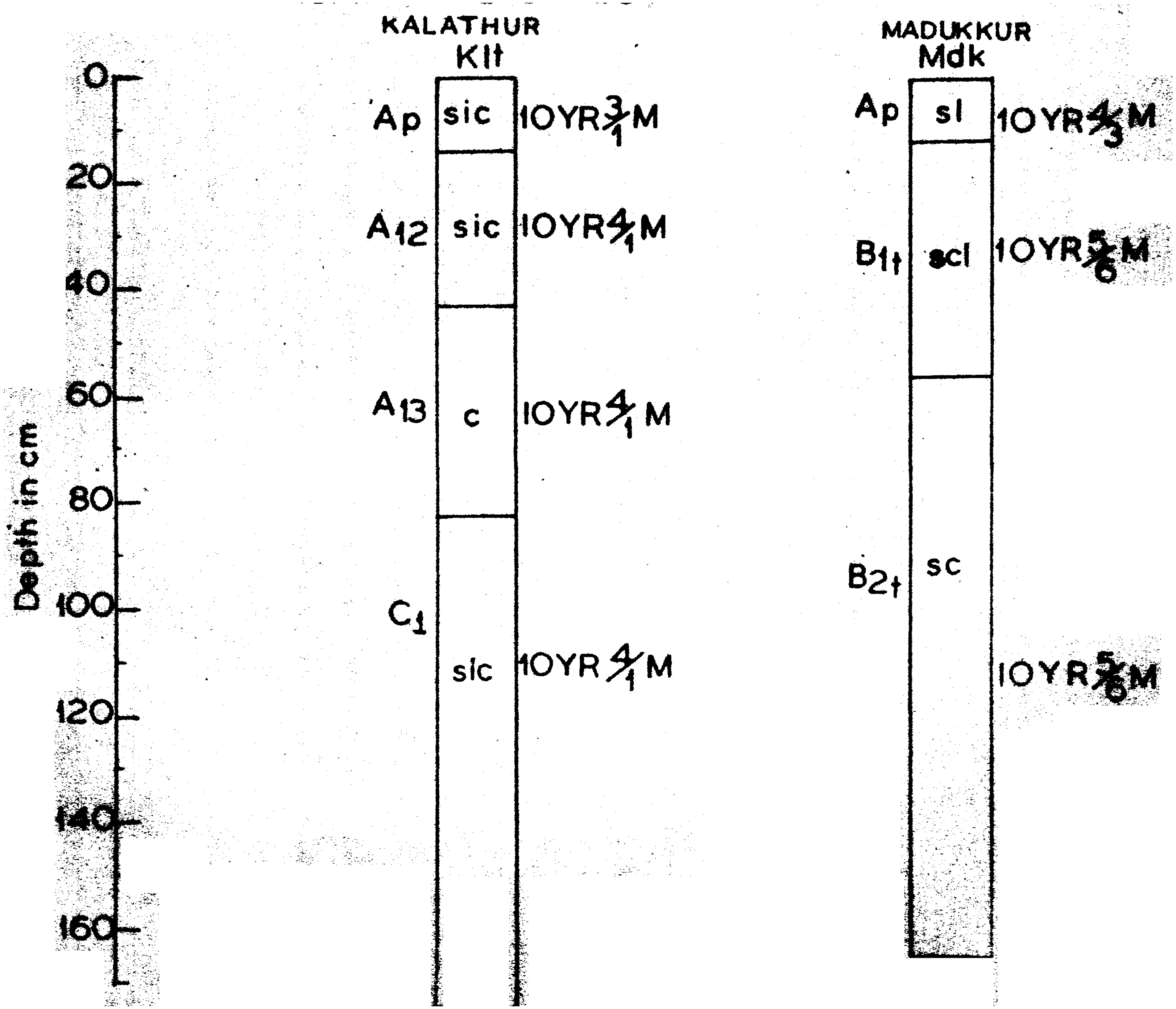
Contd...

TABLE 1 (CONTINUED)

Soil No.	Name of soil series	Soil series symbol	Taluks where they occur	Extent of occurrence (ha)	Location of soil sample collection	Soil sub-group level classification
7.	Pattukkottai	Pkt	Mannargudi Papanasam Orathanad Pattukkottai and Thanjavur	74788	State Seed Farm, Pattukkottai	Ultic Haplustalfs
8.	Sikar	Skr	Nagapattinam	19560	Vadagari village in Nagapattinam	Typic Chromusterts
9.	Madukkur	Mdk	Pattukkttai Orathanad Thanjavur and Thiruthuraipoondi	135143	Thamaramkottai in Pattukkottai	Typic Haplustalfs
10.	Melakadu	Mlk	Pattukkottai and Thiruthuraipoondi	40172	Thambikottai in Pattukkottai	Aquic Udifluents

FIG.4 MAP OF THANJAVUR DISTRICT INDICATING LOCATIONS OF SOIL SAMPLES COLLECTION





KALATHUR
Klt
MADUKKUR
Mdk
Depth in cm
0
20
40
60
80
100
120
140
160
Ap
sic
10YR 3/1 M
A12
sic
10YR 4/1 M
A13
c
10YR 4/1 M
C1
sic
10YR 4/1 M
Ap
sl
10YR 4/3 M
B1t
scl
10YR 5/6 M
B2t
sc
10YR 5/6 M

colour in 0-20 cm is 10 YR 4/2. The top soil ranges from sandy clay to silty in texture. The closely related soil series are Madukkur and Pattukkottai without lime concretions in the profile.

3.2.3. Kalathur series

It is a very dark greyish brown soil mainly formed due to the process of sedimentation by the river Cauvery. It is a very deep, silty clay soil with sub-soil underlined by sand below 175 cm. Lime concretions are met with in sub-soil. The typifying pedon is Kalathur silty clay cultivated. The colour in 0-14 cm depth is 10 YR 3/1. The related series is Adanur series which is clay loam textured on the top and sand is met within 100 to 120 cm.

3.2.4. Kivalur series

This series is greyish brown to dark greyish brown; very deep, non-calcareous alluvial soil. Texture of the top soil ranges from silty clay to silty clay loam. The typifying pedon is Kivalur silty clay. The soil colour in 0-31 cm depth is 10 YR 4/2. The competing series is Kalathur having lime concretions in the lower depths.

3.2.5. Nedumbalam series

This series consists of very deep, very heavy clayey greyish brown soils laid over lateritic base. The typifying pedon is Nedumbalam clay cultivated. The colour in 0-25 cm depth of soil is 10 YR 3/2. The related series is Madukkur which is medium textured.

3.2.6. Padugai series

It consists of deep, dark greyish brown sandy loam soils lying very near to the rivers and streams. They are conspicuous, by their stratified layers. The typifying pedon is Padugai sandy loam cultivated. The colour in 0-50 cm depth is 10 YR 4/2.

3.2.7. Pattukkottai series

Pattukkottai series comprises very deep sandy loam, brown soils with sandy clay loam sub-soil. They occupy the top portions of the gently sloping Cauvery-Mettur Project Area and are developed from lateritic parent materials. The soils are non-calcareous. Iron concretions and kaolin are met with at lower depth. The soil colour notation in 0-19 cm depth is 7.5 YR 3/2. The related series is Madukkur occupying the gentle sloping mid-lands.

3.2.8. Sikar series

The Sikar series consists of very dark greyish brown to dark brown, clayey soils developed from alluvial deposits of river Vennar, Vettar etc. The soil is free from gravel except small lime concretion distributed throughout the profile. The typifying pedon is Sikar silty clay. The colour in 0-22 cm depth of soil is 10 YR 3/2. The closely related soil is Kalathur series having lime concretions in the lower layers.

3.2.9. Madukkur series

These are very deep brown soils, derived from lateritic parent materials. They occupy the gentle-sloping middle portion of the Cauvery-Mettur Project Area. They are sandyloam on the top grading to sandy clay loam below. They are non-calcareous. The soil colour in 0-12 cm depth is 10 YR 4/3. The related soil series is Pattukkottai series.

3.2.10. Melakadu series

These are occurring near the coastal lines. They are light textured throughout the profile. The soil colour in 0-13 cm depth is 10 YR 3/3, grading to lighter colour with depth. The solum depth ranges from 60 to 75 cm grouped as moderately deep to deep. The surface texture ranges from loamy sand to sandy loam. In the typifying pedon, the plough layer texture is sandy loam. These are derived from granitic alluvium.

3.3. Soil analysis

3.3.1. Collection and analysis of initial soil sample

The surface-bulk samples (0-15 cm) representing the ten major soil series (Map Fig.1) of Thanjavur district were collected, dried in shade, powdered and sieved through a 2 mm sieve and used for mechanical and chemical analyses.

The heads of mechanical and chemical analyses carried out, the methodology adopted and the references are furnished below.

Sl. No.	Head of analysis	Method adopted	Reference
1.	Textural analysis	International pipette method	Piper (1966)
2.	Soil reaction	Soil-water suspension 1:2 ratio	Jackson (1973)
3.	E.C.	Soil-water suspension 1:2 ratio	Jackson (1973
4.	Organic carbon	Wet chromic acid digestion	Walkley and Black (1934)
5.	$CaCO_3$	Titration method	Piper (1966)
6.	Total Ca and Mg	Versenate titration	Piper (1966)
7.	Total N	Macro Kjeldahl's method	Jackson (1967)
8.	Total P	Pemberton's Method (1945)	Jackson (1973)
9.	Total K	Digestion and flame photometry	Pratt (1965)
10.	Available N	Alkaline permanganate	Subbiah and Asija (1956)
11.	Available P	0.5M $NaHCO_3$	Olsen *et al.* (1954)
12.	Available K	1N NH_4OAC (pH 7.0)	Stanford and English (1949)
13.	Available Ca and Mg	Versenate titration	Jackson (1967)
14.	Available Fe	0.005M DTPA + 0.01M $CaCl_2$ + 0.1M TEA (pH 7.3) in AAS	Lindsay and Norvell (1978)

Contd...

Sl. No.	Head of analysis	Method adopted	Reference
15.	CEC	1N NH_4OAC (pH 7.0)	Schollenberger and Dreibelbis (1930)
16.	NH_4N	Extraction with KCl and by stem distillation-Macro Kjeldahl	Jackson (1967)
17.	NO_3N	Extraction with KCl and by colorimetry	Sims and Jackson (1971)

3.4. Soil analysis for different forms of K

3.4.1. Water-soluble K

A ten gram sample of soil was weighed into a shaking bottle and 20 ml of distilled water was added. The contents were shaken in a mechanical shaker for two hours, kept overnight and filtered. From the filtrate, the water-soluble K was estimated by flame photometry (MacLean, 1960).

3.4.2. Exchangeable K (N NH_4OAC extractable K)

Five grams of soil was shaken with 25 ml of neutral N NH_4OAC for 5 minutes and filtered. Potassium was determined in the filtrate by flame photometry (Stanford and English, 1949 and Hanway and Heidal, 1952).

3.4.3. Boiling N HNO_3 soluble K

A two gram soil sample was boiled exactly for 10 minutes with 20 ml of N HNO_3 over a hot plate. After dilution and allowing to cool, the contents were filtered into a 100 ml volumetric flask. The soil residue was washed thrice and the washings were also collected and made up to a known volume. An aliquot was neutralised with NH_4OH and K was determined by flame photometry (Wood and DeTurk, 1940).

3.4.4. Non-exchangeable K

This was the K not extracted by N NH_4OAC. Hence Knex was got by subtracting the N NH_4OAC soluble K from the boiling N HNO_3 soluble K value.

3.5. Potassium extracted by different extractants

The K extracted by various extractants of different concentrations like mineral acids, neutral salt solutions and organic acid was estimated. The different extractant solutions used, the soil solution ratios together with time of shaking are furnished below:

Extractants	Soil solution ratio	Period of shaking	Reference
0.1N HCl	1:5	5 minutes	Ramanathan (1977)
0.5N HCl	1:5	5 minutes	Ramanathan (1977)
0.1N HNO_3	1:5	5 minutes	Ramanathan (1977)
0.5N HNO_3	1:5	5 minutes	Ramanathan (1977)
0.5N EDTA	1:5	5 minutes	Ramanathan (1977)
0.5N NaCl	1:5	5 minutes	Ramanathan (1977)
Citric acid 1 per cent	1:10	5 minutes	Ramanathan (1977)
0.01M $CaCl_2$	1:10	1 hour	Ramanathan (1977)
Morgan's reagent	1:10	1 hour	Nagarajan (1980)

3.6. Determination of K potential

The method developed by Beckett (1964a) and as adopted by Palaniappan (1972) and Ramanathan (1977) was employed for the determination of K potential. To a series of 5 g soil samples (passing through 50 mesh sieve) in a 100 ml shaking bottles, 40 ml of 0.0125M $CaCl_2$ solution was added. In addition, 10 ml portions each of varying KCl concentrations were added to make up the final concentrations of $CaCl_2$ to 0.01M. The concentrations of KCl used were 0, 0.25, 0.5, 1.0, 2.0, 3.0 and 5.0 millimoles. Another sample of 0.5 g was also weighed into the centrifuge bottle and 50 ml of 0.01M $CaCl_2$ solution was added. The bottles with contents were shaken for one hour, kept overnight and centrifuged at 2000 rpm for 10 minutes. The supernatant solution was filtered and analysed for K using flame photometer and for Ca and Mg, the versenate titration was used.

From the concentrations of K, Ca and Mg, the activity ratio $^{a}K/a\sqrt{Ca + Mg}$ was calculated using the Debye-Huckel formula as proposed by Beckett (1964a and 1965) as detailed below:

Ionic strength (μ) $= \sum \frac{1}{2} m\, Z^2$

Activity coefficient (γ) = log $= -0.509\, Z^2 \sqrt{\mu}$

Where, m = Molar concentration

Z = Valency of ions

0.509 = Constant

$$\text{Activity ratio} = \frac{M\ K}{\sqrt{M\ (Ca + Mg)}} \times \text{Activity coefficient}$$

ΔK (gain or loss of K) the difference between the amount of K added and recovered in the extracted solution in me/100 g soil was also calculated. The AR^K was then plotted against ΔK. The Q/I curve resolves into a lower curved part and the upper linear part. The difference between the lower curved part and the upper linear part represents the K held at specific sites (K_X) at zero activity ratio. Further an extension of the lower curved part to the ΔK axis gives the total amount of K in labile pool (K_L). The linear part of the curve was interpolated to the X-axis and this X-intercept would represent the equilibrium activity ratio (AR_e^K) when ΔK is zero. The linear part was also interpolated to intersect the Y-axis and this Y-intercept would represent the amount of K held in the soil on sites or surfaces of which the exchange equilibrium is described by the linear part of Q/I relation ($-\Delta K°$). The other Q/I parameters calculated are as follows:

$$PBC^K = \frac{-\Delta K°}{AR_e^K}$$

Where, PBC^K = Potential buffering capacity

$-\Delta K°$ = Labile K (Quantity of K released or the part of labile K that is located on the planar surface)

AR_e^K = Equilibrium activity ratio of K.

The K potential values are got by taking the product of labile K ($-\Delta K^{\circ}$) and PBC^K as per Zandstra and Mackenzie (1968).

Free energy change (ΔG) in calories was calculated as proposed by Woodruff and McIntosh (1960) using the formula

$$-\Delta G = RT\ l_n\ (AR_e^K)$$

Where,

R is the gas constant (1.987 calories/degree/millimole)

T is absolute temperature (273° + room temperature)

$l_n = \log_e = 2.303$

$l_n\ AR_e^K = 2.303 \times \log_{10}\ (AR_e^K)$

3.7. Potassium fixing capacity of soil

The method described by Verma and Verma (1970) and as adopted by Ramanathan (1977) was followed. To a series of 5 g soil samples in 100 ml shaking bottles varying concentrations of KCl solutions to supply 0, 1, 2, 5 and 10 me K/100 g soil were added and kept at room temperature for equilibration for 24 hours, 72 hours, 7 and 14 days. At the end of equilibration period, 25 ml of N NH_4OAC was added, shaken for 5 minutes, filtered and K was determined by flame photometry.

The K fixed was calculated using the formula

$$\text{K fixed} = \left[\text{Original exchangeable K} + \text{K added} \right] - \left[\text{Exchangeable K after equilibration} \right]$$

3.8. Potassium supplying power of soils

The following procedures were used to study the above parameter.

3.8.1. Chemical method

The K releasing pattern of soils are evaluated by successive extractions with 0.01N HCl. It is also known as step K.

3.8.1.1. Chemical cumulative releasing power

The method proposed by Garman's (1957) and modification as adopted by Ramanathan (1977) was followed. To a 5 gram soil sample in a centrifuge tube, 50 ml of 0.01N HCl was added, shaken for 15 minutes, centrifuged for 10 minutes at 2000 rpm and K was estimated in the supernatant liquid. To the same soil, another 50 ml of 0.01N HCl was added and the same procedure was repeated for 15 times or till such time that the released K was constant or nil. The cumulative K releasing power of the soil was computed by adding the values of K by successive extractions. As against the values of cumulative release of K, the curves were drawn.

3.8.2. Bio-assay method

The K supplying power of soil was studied by exhaustive cropping technique using minipots.

3.8.2.1. Bio-assay - K supplying power of soils by exhaustive cropping technique

The procedure adopted by Ramanathan (1977) was followed to evaluate the above parameter.

A minipot experiment was conducted with ADT 31 rice as test crop with 4 levels of K (0, 25, 50 and 75 ppm of K as KCl) replicated two times. The same 10 major soil series described in section 3.2 were used for this study. Thus there were 80 pots in total. Common dose of N and P were added at 50 ppm and 25 ppm respectively for every crop to promote growth of the crop.

Six hundred grams of soil sample passing through a 2 mm sieve was transferred to well cleaned and wax lined plastic pots. The calculated quantities of the nutrient solutions were added to each pot and mixed well with hand after adding sufficient quantities of de-ionised water. Fifty well sprouted ADT 31 rice seeds were sown and allowed to grow for 30 days. De-ionised water was added every day to maintain uniform level of submergence.

The plants were pulled out carefully after 30 days of growth, the roots were washed and the adhering soil returned back to the pots. The above ground portions of the plants were dried and yield of dry matter was recorded. Again the nutrient solutions were added as in the previous experiment and the second crop was raised. Following the same procedure, six crops of ADT 31 rice were raised totally and the yield of dry matter was recorded. The plant material after each harvest were analysed for K content following standard procedure (Jackson, 1973). The cumulative dry matter yield and the cumulative K uptake values were calculated.

From the analysis of the soil sample (before and after cropping) and plant samples, the extent of non-exchangeable K used, was computed from the following formula

$$\text{Amount of K from non-exchangeable form} = \left[\text{Total K taken by plant}\right] - \left[\text{Exchangeable K before cropping} - \text{Exchangeable K after cropping}\right]$$

(Acquaye, 1973; Biswas, 1974 and Ramanathan, 1977)

3.9. Plant analysis

The plant materials collected for analysis were dried in a hot air oven at 65-70°C, powdered in a Wiley mill and the materials passing through one mm sieve was analysed for the following constituents as detailed below.

Heads of analysis	Method adopted	Reference
N content	Micro-Kjeldahl	Jackson (1973)
P content	Vanadomolybdate	Jackson (1967)
K content	Flame photometry	Jackson (1973)
Ca and Mg content	Versenate titration	Jackson (1967)
Fe content	Triple acid extract in AAS	Jackson (1967)

3.10. Pot culture experiment to study the response of ADT 31 rice under graded levels of K

All the ten major soil series chosen (The details are given in Table I) were used for this experiment. The treatments consisted of 5 levels of K (0, 50, 100, 150 and 200 kg K_2O/ha) with common dose of N and P at the rate of 100 and 50 kg/ha respectively. The test crop used was ADT 31 rice and the experiment was replicated twice.

Ten kg of the soil was used for each pot. The entire quantity of P and K and 50 per cent of N were added basally and the soil was mixed thoroughly and brought to a puddled condition. After allowing for a period of 24 hours for equilibration, soil samples representing pre-planting stage were drawn from each pot for analysis of K.

Twenty one days old ADT 31 seedlings were transplanted at the rate of 10 seedlings per pot in 5 hills. Watering was done periodically to maintain a continuous submergence of 5 cm of water. The remaining half of N was applied on 30th day after transplanting.

When the crop attained maturity, the grain and straw yields were recorded. Simultaneously post-harvest soil samples were drawn for analysis. The grain and straw samples were analysed individually for K following the standard procedures described earlier and the total uptake of K by grain and straw was computed.

3.10.1. Response functions

To evaluate the performance of ADT 31 rice under different soils for added K levels, response curves along with response equations were worked out. In each soil series, the yield responses to the added K were tested by using three different response functions viz., linear: $Y = a + bx$, Quadratic: $Y = a + bx + cx^2$, and Cubic: $Y = a + bx + cx^2 + dx^3$ in orthogonal polynomial model (Snedecor and Cochran, 1967). For each response function, R^2 value was calculated and the function for which the largest R^2 value obtained was selected as the best fit. The best fit response equations are profitably used to predict the grain yield of ADT 31 rice for a particular level of applied K.

For working out physical and economic optimum levels, the cubic polynomial response function fitted to soils S_1, S_2, and S_9 is of the form

$$Y = a + bx + cx^2 + dx^3$$

Where,

Y = Grain yield in g/pot (Transformed to kg/ha)

x = K levels kg/ha

The optimum level of K which gives the highest grain yield is obtained by using the first and second order conditions.

$$\frac{dy}{dx} = 0 \text{ and}$$

$$\frac{d^2Y}{dx^2} < 0$$

The first order condition gives

$$\frac{dy}{dx} = 3\,dx^2 + 2\,ex + b = 0$$

This equation gives two values for x. The level of K for which Y is maximum is then found out by using the second order condition $\frac{d^2Y}{dx^2} < 0$.

3.10.2. Correlation studies

Simple correlations were worked out between different K availability parameters and the yield and uptake values to predict the best method of K determination.

3.11. Field experiment

A field experiment was conducted with graded levels of K to study the performance of ADT 31 rice to confirm the results of the pot experiment. The experiment was laid out on the Madukkur soil series of Thamarankottai village in Thanjavur district in randomised blocks design with four replications. The following were the treatments adopted.

3.11.1. Treatments

K levels

K_0 - No potassium

K_1 - 50 kg K_2O/ha

K_2 - 100 kg K_2O/ha

K_3 - 150 kg K_2O/ha

K_4 - 200 kg K_2O/ha

A common dosage of N and P_2O_5 at the rate of 100 kg and 50 kg respectively, were applied to all plots.

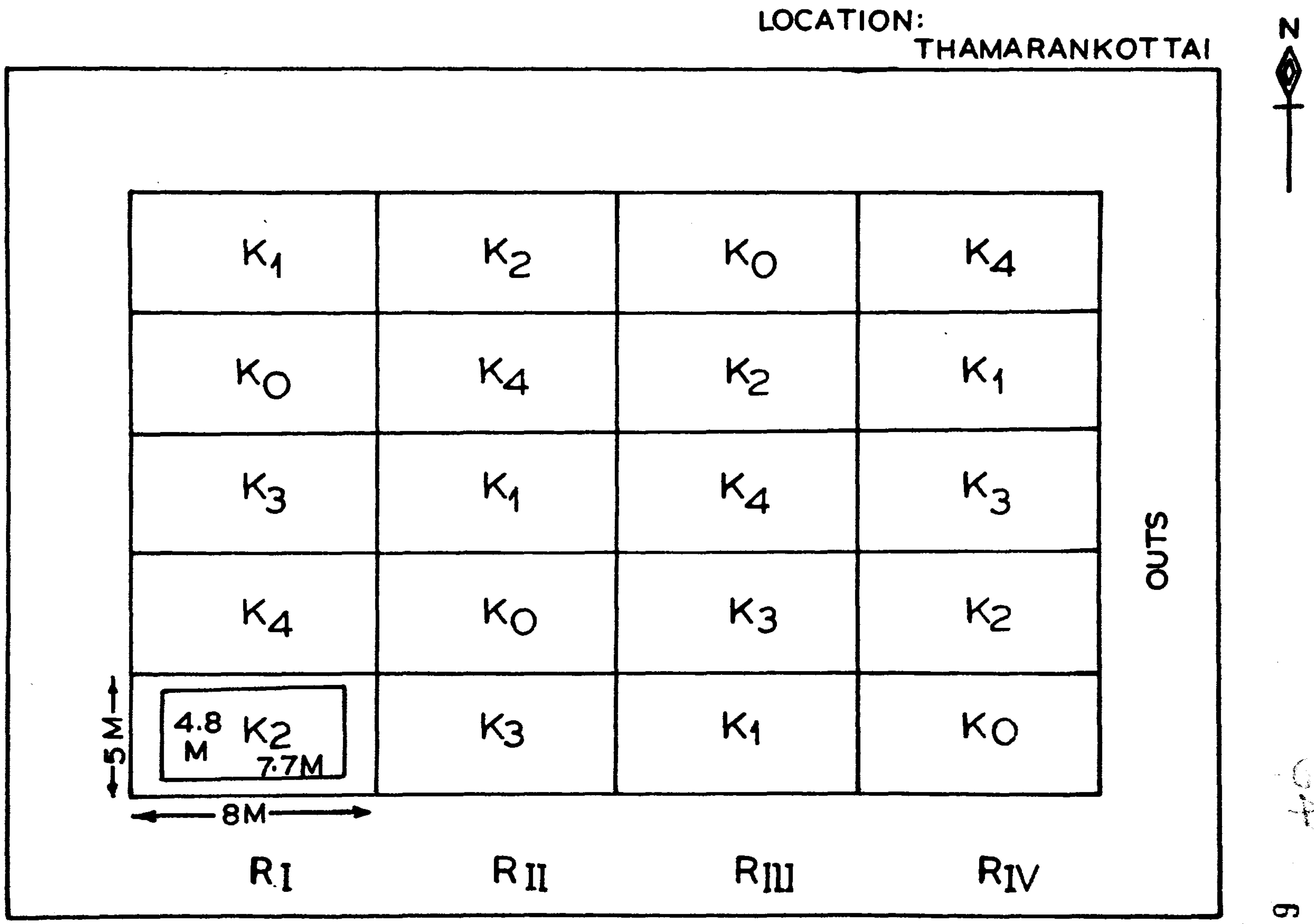
3.11.2. Size of the plot

A gross plot size of 8 x 5 m with a net plot of 7.7 x 4.8 m was adopted. Totally there were 20 plots in the experiment and the field experiment plan is shown in Fig.3.

3.11.3. Spacing and time of fertilization

Rice seedlings of ADT 31 raised in a separate nursery for 21 days without any manure were transplanted adopting a spacing of 15 x 10 cm. The entire quantity of potassium, phosphorus and half of the nitrogen were applied as basal dressing. The remaining quantity of nitrogen was top dressed on 45th day after transplanting. Routine cultural and plant protection operations were carried out regularly.

FIG. 3 LAYOUT PLAN OF FIELD EXPERIMENT



3.11.4. Sampling

Plant samples were collected at tillering (30 days after transplanting) and flowering (55th day after planting) stages by pulling out 3 hills from each plot to record dry matter yield and for analysis. Simultaneously index leaves (3rd leaf from top) were also collected at random from 15 hills from each plot at the above stages for analysis. On maturity, the crop was harvested and the yield of grain and straw were recorded. At the corresponding stages of plant sampling, soil samples were also drawn and analysed for available N, P, K, Ca, Mg, Fe, N NH_4OAC extractable K and different Q/I parameters. The plant samples drawn at various stages of crop growth including grain and straw were analysed for N, P, K, Ca, Mg and Fe and the uptake of these nutrients was calculated. The index leaves samples drawn at different stages were analysed for K content. Nutrient ratios of the above nutrient ions on equivalent basis were worked out at different stages both in soil and plant. Appropriate relationships among various K availability parameters with that of yield and uptake values were worked out.

3.11.5. Response functions

The physical optimum K level in field experiment was determined following the procedure furnished in section 3.10.1. The economic optimum level which denotes the level of K for which the profit is maximum is calculated as follows:

$$P = P_y\, y - P_x\, x$$

Where,

P = Profit

P_x = Price of unit kg of fertiliser nutrient

P_y = Price of unit kg of produce

In order to get the maximum profit, the first and second conditions are

$$\frac{dP}{dx} = 0 \quad \text{and} \quad \frac{d^2P}{dx^2} < 0$$

These conditions were used to calculate the economic optimum levels of K for soil S_9 under field trial.

3.12. <u>Statistical analysis</u>

The yield and uptake data obtained were subjected to statistical scrutiny (Snedecor and Cochran, 1967) to determine the effect of various treatments as well as the inter-relationships among the various parameters studied.

RESULTS

RESULTS

CHAPTER 4

RESULTS

The results of the experiments conducted and described under Chapter 3 are presented below.

4.1. General properties of the soils used for the study (Table 2)

The ten major soil series of Thanjavur district used for the study varied from loamy sand to clay with clay content ranging from 8.6 to 70.6 per cent. The CEC of soils ranged from 5.8 to 7.7 and EC varied from 0.1 to 0.9 m.mhos/cm. The percentage of organic carbon ranged from 0.21 to 0.74. The calcium carbonate content of soils varied from 0.10 to 1.43 per cent. With regard to nutrient status, all these soils fell under low N status and in respect of P, the soils had medium and high levels and for K these soils fell under low, medium and high status.

4.2. Laboratory studies on the forms, status and availability indices of K in soils

4.2.1. Forms and status of K

The K status of soils as determined by extraction with different extractants is presented in Table 3. The correlations among different K availability indices are furnished in Table 4. The simple correlation between K availability indices with clay percentage and CEC and other soil characteristics

TABLE 2

PHYSICO-CHEMICAL PROPERTIES OF THE MAJOR SOIL SERIES OF THANJAVUR DISTRICT

Soil No.	Name of soil series	Mechanical analysis %					EC m.mhos/cm	pH	Organic carbon %	Free $CaCO_3$ %	Total nutrients %					Available nutrients (kg/ha)			CEC me/100 g
		Course sand	Fine sand	Silt	Clay	Textural class					N	P	K	CaO	MgO	N	P (Olsen's)	K	
1.	Adanur	25.7	21.0	18.3	34.8	scl	0.1	7.4	0.74	0.46	0.350	0.226	0.675	0.400	0.740	139	9.2	403	34.4
2.	Alathur	54.0	10.8	6.7	27.7	scl	0.1	7.4	0.39	0.82	0.300	0.172	1.02	0.270	0.190	129	11.6	383	42.5
3.	Kalathur	10.6	5.1	41.1	43.3	sic	0.2	7.1	0.57	1.08	0.350	0.330	0.768	1.320	0.640	184	14.8	383	54.3
4.	Kivalur	8.8	40.7	10.9	37.8	sc	0.3	7.2	0.27	0.82	0.280	0.012	1.120	0.810	0.430	157	14.8	376	38.1
5.	Nedumbalam	6.0	2.2	21.4	70.6	c	0.4	7.0	0.67	1.43	0.375	0.076	1.440	[illegible]	0.390	197	17.3	538	49.6
6.	Padugai	17.1	31.5	13.4	37.6	sc	0.3	7.7	0.54	0.87	0.275	0.630	0.790	0.920	0.460	157	22.4	448	41.1
7.	Pattukkottai	45.5	41.1	4.3	8.6	ls	0.2	6.0	0.21	Tr	0.280	0.185	0.554	0.580	0.520	136	[illegible]	147	10.4
8.	Sikar	24.1	30.2	20.4	25.1	scl	0.9	7.1	0.57	0.10	0.300	0.026	0.890	0.420	0.210	197	18.8	363	41.0
9.	Madukkur	46.5	40.2	3.3	9.9	ls	0.1	5.8	0.30	Tr	0.490	0.270	0.970	0.140	0.030	169	27.6	179	12.1
10.	Melakadu	59.8	24.5	2.4	13.0	ls	0.3	7.5	0.21	0.10	0.220	0.1	0.280	0.250	0.120	113	11.6	80	7.5

TABLE 3

POTASSIUM EXTRACTED BY DIFFERENT EXTRACTANTS (ppm)

Soil No.	Name of soil series	H_2O-K	Neutral N NH_4OAc-K	0.1N HNO_3-K	0.5N HNO_3-K	N HNO_3 (boiling)-K	0.1N HCl-K	0.5N HCl-K	1 per cent citric acid-K	0.5N EDTA-K	Morgan-K	0.01M $CaCl_2$-K	Knex	Total K (per cent)
1.	Adanur	8	110	90	125	1120	80	80	70	75	120	70	1010	1.86
2.	Alathur	6	165	55	75	800	45	45	50	45	70	40	635	2.06
3.	Kalathur	8	165	65	90	1160	60	55	60	45	80	50	995	0.89
4.	Kivalur	12	175	70	85	1080	65	50	50	45	90	50	905	1.47
5.	Nedumbalam	10	290	130	170	1360	120	110	90	80	130	70	1070	1.38
6.	Padugai	6	180	70	90	1360	65	65	60	50	90	50	1180	1.12
7.	Pattukkottai	8	105	35	40	660	35	45	50	35	70	50	570	1.15
8.	Sikar	8	130	105	140	1480	95	90	70	75	110	50	1350	1.33
9.	Madukkur	12	70	45	45	720	35	35	40	45	60	50	650	1.05
10.	Melakadu	4	30	30	35	200	30	25	30	45	50	30	190	1.00
	Percentage to the total K	0.06	1.07	0.523	0.672	7.470	0.473	0.451	0.428	0.406	0.654	0.383	6.49	100.00

TABLE 4

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN DIFFERENT K AVAILABILITY INDICES (n = 10)

Sl. No.	Variables X	Variables Y	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	0.1N HNO_3-K	N NH_4OAc-K	0.739*	Y = 25.94 + 1.67x
2.	0.5N HNO_3-K	N NH_4OAc-K	0.729*	Y = 37.81 + 1.66x
3.	1N HNO_3-K	N NH_4OAc-K	0.714*	Y = 14.17 + 0.13x
4.	0.1N HCl-K	N NH_4OAc-K	0.748*	Y = 26.04 + 1.84x
5.	0.5N HCl-K	N NH_4OAc-K	0.714*	Y = 26.07 + 1.93x
6.	1% citric acid-K	N NH_4OAc-K	0.788**	Y = 124.16 + 4.67x
7.	Morgan-K	N NH_4OAc-K	0.677*	Y = 17.82 + 1.84x
8.	0.5N HNO_3-K	0.1N HNO_3-K	0.992**	Y = 6.84 + 0.70x
9.	1N HNO_3-K	0.1N HNO_3-K	0.837**	Y = 3.31 + 0.07x
10.	0.1N HCl-K	0.1N HNO_3-K	0.994**	Y = 1.44 + 1.08x
11.	0.5N HCl-K	0.1N HNO_3-K	0.971**	Y = 0.10 + 1.66x
12.	1% citric acid-K	0.1N HNO_3-K	0.939**	Y = -70.67 + 2.46x
13.	0.5N EDTA-K	0.1N HNO_3-K	0.907**	Y = -26.18 + 1.77x
14.	Morgan-K	0.1N HNO_3-K	0.958**	Y = -30.98 + 1.15x
15.	0.01M $CaCl_2$-K	0.1N HNO_3-K	0.753*	Y = -26.18 + 1.88x
16.	0.5N NaCl-K	0.1N HNO_3-K	0.959**	Y = -27.47 + 2.55x
17.	Non-exchangeable-K	0.1N HNO_3-K	0.799**	Y = 6.66 + 0.07x
18.	Cumulative K release	0.1N HNO_3-K	0.852**	Y = -49.87 + 0.48x
19.	1N HNO_3-K	0.5N HNO_3-K	0.828**	Y = -4.39 + 0.09x
20.	0.1N HCl-K	0.5N HNO_3-K	0.987**	Y = -6.25 + 1.52x
21.	0.5N HCl-K	0.5N HNO_3-K	0.971**	Y = -9.13 + 1.64x
22.	1% citric acid-K	0.5N HNO_3-K	0.948**	Y = -110.97 + 3.52x
23.	0.5N EDTA-K	0.5N HNO_3-K	0.910**	Y = -46.56 + 2.52x
24.	Morgan-K	0.5N HNO_3-K	0.956**	Y = -51.75 + 1.62x
25.	0.01M $CaCl_2$-K	0.5N HNO_3-K	0.739*	Y = -51.05 + 2.76x

Contd...

TABLE 4 (CONTINUED)

Sl. No.	Variables X	Variables Y	Correlation coefficient (r)	Regression equation (Y = a + bx)
26.	0.5N NaCl-K	0.5N HNO_3-K	0.934**	Y = -44.41 + 3.52x
27.	Non-exchange-able-K	0.5N HNO_3-K	0.803**	Y = 0.08 + 0.10x
28.	Cumulative K release	0.5N HNO_3-K	0.865**	Y = 50.92 + 0.69x
29.	0.1N HCl-K	1N HNO_3-K	0.830**	Y = 279.98 + 11.33x
30.	0.5N HCl-K	1N HNO_3-K	0.832**	Y = 244.21 + 12.49x
31.	1% citric acid-K	1N HNO_3-K	0.838**	Y = -577.89 + 27.56x
32.	0.5N EDTA-K	1N HNO_3-K	0.633*	Y = 154.84 + 15.54x
33.	Morgan-K	1N HNO_3-K	0.823**	Y = -84.80 + 12.40x
34.	0.01M $CaCl_2$-K	1N HNO_3-K	0.648*	Y = -99.44 + 21.44x
35.	0.5N NaCl-K	1N HNO_3-K	0.752*	Y = 38.30 + 25.15x
36.	Non-exchange-able-K	1N HNO_3-K	0.989**	Y = 18.73 + 1.14x
37.	Cumulative K release	1N HNO_3-K	0.760*	Y = -344.98 + 5.41x
38.	0.5N HCl-K	0.1N HCl-K	0.975**	Y = -1.2 + 1.07x
39.	1% citric acid-K	0.1N HCl-K	0.943**	Y = -66.39 + 2.27x
40.	0.5N EDTA-K	0.01N HCl-K	0.893**	Y = -23.67 + 1.61x
41.	Morgan-K	0.1N HCl-K	0.955**	Y = -28.35 + 1.05x
42.	0.01M $CaCl_2$-K	0.1N HCl-K	0.743*	Y = -28.29 + 1.79x
43.	0.5N NaCl-K	0.1N HCl-K	0.959**	Y = -26.30 + 2.35x
44.	Non-exchange-able-K	0.1 HCl-K	0.791**	Y = 3.12 + 0.07x
45.	Cumulative K release	0.1N HCl-K	0.832**	Y =-43.43 + 0.43x
46.	1% citric acid-K	0.5N HCl-K	0.978**	Y = -61.98 + 2.14x
47.	0.5N EDTA-K	0.5N HCl-K	0.896**	Y = -18.84 + 1.46x
48.	Morgan-K	0.5N HCl-K	0.963**	Y = -24.39 + 0.97x
49.	0.01M $CaCl_2$-K	0.5N HCl-K	0.792**	Y = -14.97 + 1.74x
50.	0.5N NaCl-K	0.5N HCl-K	0.944**	Y = -19.80 + 2.10x

Contd...

TABLE 4 (CONTINUED)

Sl. No.	Variables X	Variables X	Correlation coefficient (r)	Regression equation (Y = a + bx)
51.	Non-exchange-able-K	0.5N HCl-K	0.809**	Y = 6.95 + 0.06x
52.	Cumulative K release	0.5N HCl-K	0.849**	Y = -39.0 + 0.40x
53.	Morgan-K	1% citric acid-K	0.946**	Y = 19.59 + 0.43x
54.	0.01M $CaCl_2$-K	1% citric acid-K	0.834**	Y = 14.26 + 0.84x
55.	0.5N NaCl-K	1% citric acid-K	0.876**	Y = 23.10 + 0.89x
56.	Non-exchange-able-K	1% citric acid-K	0.791**	Y = 33.05 + 0.03x
57.	Cumulative K release	1% citric acid-K	0.786**	Y = 15.17 + 0.17x
58.	Morgan-K	0.5N EDTA-K	0.884**	Y = 6.85 + 0.54x
59.	0.01M $CaCl_2$-K	0.5N EDTA-K	0.696**	Y = 6.16 + 0.94x
60.	0.5N NaCl-K	0.5N EDTA-K	0.906**	Y = 7.11 + 1.23x
61.	Non-exchange-able-K	0.5N EDTA-K	0.633*	Y = 28.34 + 0.03x
62.	Cumulative K release	0.5N EDTA-K	0.814**	Y = -4.41 + 0.24x
63.	0.01M $CaCl_2$-K	Morgan-K	0.859**	Y = -9.08 + 1.88x
64.	0.5N NaCl-K	Morgan-K	0.926**	Y = 8.91 + 2.06x
65.	Non-exchange-able-K	Morgan-K	0.798**	Y = 34.82 + 0.061x
66.	Cumulative K release	Morgan-K	0.824**	Y = -9.53 + 0.39x
67.	0.5N NaCl-K	0.01M $CaCl_2$-K	0.722*	Y = 23.26 + 0.73x
68.	Non-exchange-able-K	0.01M $CaCl_2$-K	0.728*	Y = 16.61 + 0.025x
69.	Cumulative K release	0.01M $CaCl_2$-K	0.882**	Y = -8.53 + 0.188x
70.	Cumulative K release	Non-exchange-able-K	0.762*	Y = -307.01 + 4.69x

Contd...

TABLE 4 (CONTINUED)

Sl. No.	Variables X	Variables Y	Correlation coefficient (r)	Regression equation (Y = a + bx)
71.	PBC^k	AR_e^k	0.695*	Y = 0.00369 + 0.00005x
72.	G	AR_e^k	0.691*	Y =-0.00805 + 0.0000049 x
73.	PBC^k	$-K^o$	-0.936**	Y = -0.07 - 0.00528x
74.	K-potential	$-K^o$	-0.978**	Y = -0.192 - 0.0069x
75.	K-potential	PBC^k	0.942**	Y = 27.19 + 1.185x
76.	Total K	G	0.646*	Y = 2309 + 582.11x

* - Significant at 5 per cent; ** - Significant at 1 per cent level

are presented in Table 4a and 4b respectively. The efficiency of different reagents in extracting K varied considerably and the results of the same are summarised below.

4.2.1.1. Water-soluble K

This form varied from 4 (S_{10}) to 12 ppm (S_4) with a mean value of 8.2 ppm accounting for 5.63 per cent of the Kex and 0.06 per cent of the total K. The water-soluble K was not correlated with other forms of K.

4.2.1.2. Neutral N NH_4OAc K

The values ranged from 30 (S_{10}) to 290 ppm (S_5) with a mean value of 142 ppm amounting to 1.07 per cent to the total K. These values were closely correlated with K extracted by 0.1N HNO_3, 0.5N HNO_3, 1N HNO_3, 0.1N HCl, 0.5 N HCl, 1 per cent citric acid and Morgan's reagent. It had the highest correlation coefficient (r = 0.788**) with 1 per cent citric acid K.

4.2.1.3. 0.1N HNO_3 K

The K extracted by 0.1N HNO_3 varied from 30 (S_{10}) to 130 ppm (S_5) with a mean of 69.5 ppm and it was 0.523 per cent of the total K, having significant correlation with K extracted by 0.5N HNO_3, 1N HNO_3, 0.1N HCl, 0.5N HCl, 1 per cent citric acid, 0.5N EDTA, Morgan's reagent, 0.01M $CaCl_2$ and 0.5N NaCl and Knex and cumulative K release. Among these, 0.1N HCl was closely correlated with 0.1N HNO_3 (r = 0.994**).

TABLE 4a

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN CLAY PER CENT (X) AND K AVAILABILITY INDICES AND OTHER SOIL CHARACTERISTICS (Y)
(n = 10)

Sl. No.	Y variables	Correlation coefficient (r)	Regression equation ($\hat{Y}$ = a + bx)
1.	H_2O-K	0.360	N.S.
2.	Neutral N NH_4OAc-K	0.842**	Y = 31.6 + 3.5x
3.	0.1N HNO_3-K	0.771**	Y = 24.9 + 1.4x
4.	0.5N HNO_3-K	0.755*	Y = 27.6 + 1.9x
5.	1N HNO_3-K	0.636*	Y = 535.4 + 14.5x
6.	0.1N HCl-K	0.762*	Y = 22.4 + 1.3x
7.	0.5N HCl-K	0.706*	Y = 25.8 + 1.1x
8.	1% citric acid-K	0.767**	Y = 32.9 + 0.76x
9.	0.5N EDTA-K	0.586	N.S.
10.	Morgan-K	0.677*	Y = 54.3 + 1.0x
11.	0.01M $CaCl_2$-K	0.671*	Y = 36.2 + 0.47x
12.	0.5N NaCl-K	0.611	N.S.
13.	Knex	0.539	N.S.
14.	Cumulative release K	0.375	N.S.
15.	AR_e^k	-0.073	N.S.
16.	-_ K^o	-0.219	N.S.
17.	PBC^k	0.175	N.S.
18.	_G	0.027	N.S.
19.	Total-K	0.095	N.S.
20.	Potash potential	0.148	N.S.
21.	CEC	0.718*	Y = 18.6 + 0.57x
22.	Organic carbon	0.541	N.S.
23.	pH	0.165	N.S.
24.	$CaCO_3$	0.108	N.S.

* - Significant at 5 per cent level   N.S. - Not significant

**- Significant at 1 per cent level

TABLE 4b

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN CEC (X) AND K AVAILABILITY INDICES AND OTHER SOIL CHARACTERISTICS (Y)
(n = 10)

Sl. No.	Y variables	Correlation coefficient (r)	Regression equation ($\hat{Y}$ = a + bx)
1.	H_2O-K	0.217	N.S.
2.	Neutral N NH_4OAc-K	0.805**	Y = 12.1 + 4.2x
3.	0.1N HNO_3-K	0.659*	Y = 13.81 + 1.5x
4.	0.5N HNO_3-K	0.686*	Y = 7.3 + 2.2x
5.	1N HNO_3-K	0.767**	Y = 179.8 + 22.2x
6.	0.1N HCl-K	0.654*	Y = 12.1 + 1.4x
7.	0.5N HCl-K	0.565	N.S.
8.	1% citric acid-K	0.636*	Y = 27.9 + 0.79x
9.	0.5N EDTA-K	0.366	N.S.
10.	Morgan-K	0.583	N.S.
11.	0.01M $CaCl_2$-K	0.583	N.S.
12.	0.5N NaCl-K	0.480	N.S.
13.	Knex	0.702*	Y = 210.4 + 17.6x
14.	Cumulative release K	0.511	N.S.
15.	AR_e^k	-0.569	N.S.
16.	- _ K^o	-0.514	N.S.
17.	PBC^k	0.642*	Y = 9.4 + 1.5x
18.	_ G	0.413	N.S.
19.	Total-K	0.234	N.S.
20.	Potash potential	0.521	N.S.
21.	Clay %	0.718*	Y = -1.5 + 9.1x
22.	Organic carbon	0.267	N.S.
23.	pH	0.122	N.S.
24.	$CaCO_3$	0.932**	Y = -4.5 + 0.03x

* - Significant at 5 per cent level
** - Significant at 1 per cent level
NS - Not significant

4.2.1.4. $0.5N\ HNO_3$ K

The values of this form ranged from 35 (S_{10}) to 170 ppm (S_5) with a mean of 89.5 ppm, which worked out to 0.672 per cent of the total K. The 0.5N HNO_3 K had a close correlation with 0.1N HCl K (r = 0.987**).

4.2.1.5. Boiling 1N HNO_3 K

This form varied from 200 (S_{10}) to 1480 ppm (S_8) with a mean of 994 ppm accounting for 7.47 per cent of the total K, and was closely correlated to the values of other forms of K (HCl K, 1 per cent citric acid K, 0.5N EDTA K, Morgan K, 0.01M $CaCl_2$ K, 0.5N NaCl K, Knex and cumulative K release). The Knex was highly correlated with boiling 1N HNO_3 K (r = 0.989**).

4.2.1.6. 0.1N HCl K

This fraction ranged from 30 (S_{10}) to 120 ppm (S_5) with a mean value of 63 ppm and it was 0.473 per cent to the total K. The 0.5N HCl K was highly correlated with 0.1N HCl K (r = 0.975**).

4.2.1.7. 0.5N HCl K

The K estimated by this extractant ranged from 25 ppm (S_{10}) to 110 ppm (S_5) with a mean value of 62 ppm and was equal to 0.451 per cent of the total K. The 1 per cent citric acid K was highly correlated with 0.5N HCl K (r = 0.978**).

4.2.1.8. One per cent citric acid K

This constituent ranged from 30 ppm (S_{10}) to 90 ppm (S_5) with a mean of 57 ppm, accounting for 0.428 per cent of total K. It was significantly correlated with Morgan K, 0.01M $CaCl_2$ K, 0.5N NaCl K, Knex and cumulative K release.

4.2.1.9. 0.5N EDTA K

This form varied from 35 (S_7) to 80 ppm (S_5) with a mean of 54 ppm which represented 0.406 per cent of the total K. Among the different forms, 0.5N NaCl K was highly correlated with 0.5N EDTA K (r = 0.906**).

4.2.1.10. Morgan K

This component varied from 50 ppm (S_{10}) to 130 ppm (S_5) with a mean of 87 ppm which was equal to 0.654 per cent of the total K. There existed significant correlations between this form and 0.01M $CaCl_2$ K, 0.5N NaCl K, Knex and cumulative K release.

4.2.1.11. 0.01M $CaCl_2$ K

The K extracted by this reagent ranged from 30 ppm (S_{10}) to 70 ppm (S_1 and S_5) with a mean value of 51 ppm which formed 0.383 per cent of the total K. This form was highly correlated with cumulative K release (r = 0.882**) followed by Knex and 0.5N NaCl K.

4.2.1.12. Non-exchangeable K (Knex)

This fraction of K varied from 190 (S_{10}) to 1350 ppm (S_8) with a mean value of 865 ppm which worked out to 6.49 per cent of the total K. The Knex fraction displayed a significant correlation with cumulative K release (r=0.762**).

4.2.1.13. Total K

The total K content of soils varied from 0.89 (S_3) to 2.06 per cent (S_2) with a mean of 1.33 per cent. In general, of the ten soil samples studied for various forms of K, the soil S_5 (Nedumbalam series) recorded the highest values of all forms of K except boiling N HNO_3 K, Knex and total K. The soil S_{10} (Melakadu series) registered the lowest values of Knex and total K and also K extracted by water, N NH_4OAc, 0.1N HNO_3, 0.5N HNO_3, boiling N HNO_3, 0.1N HCl, 0.5N HCl, 0.5N EDTA, 1 per cent citric acid, Morgan's reagent, 0.01M $CaCl_2$.

The clay content of these soils were correlated significantly with neutral N NH_4OAc K (r = 0.842**), 0.1N HNO_3 K (r = 0.771**), 1 per cent citric acid K (r = 0.767**), Morgan K (r = 0.677*) and 0.01M $CaCl_2$ K (r = 0.671*) (Table 4a).

The simple correlations worked out between CEC and other K parameters (Table 4b) revealed that the CEC was correlated significantly with neutral N NH_4OAc K (r = 0.805**) and boiling 1N HNO_3 K (r = 0.767**). It also displayed significant relation with 0.1N HNO_3 K (r = 0.659*), 0.5N HNO_3 K (r=0.686*), one per cent citric acid K ($r = 0.636^*$), Knex ($r = 0.702^*$) and PBC^k ($r = 0.642^*$).

4.2.2. Potassium potential parameters (Table 5; Figs.4, 4a and 4b)

4.2.2.1. Equilibrium activity ratio (AR_e^k)

This parameter ranged from 4.8×10^{-3} (S_8) to 7.6×10^{-3} $(m/l)^{1/2}$ (S_7) with a mean of 7.1×10^{-3} $(m/l)^{1/2}$. There were positive correlations between AR_e^k and other K parameters like PBC^k, ΔG.

4.2.2.2. $-\Delta K^o$ (Amount of K released or labile K)

The values ranged from 0.15 (S_9) to 0.73 me/100 g soil (S_6) with a mean value of 0.42 me/100 g soil, having negative relationship to PBC^k and K potential.

4.2.2.3. Potential buffering capacity (PBC^k)

The PBC^k values varied from 11.19 (S_9) to 113.0 (S_5) with a mean value of 66.23. This value was correlated with K potential only ($r = 0.942^{**}$).

4.2.2.4. Free energy change (ΔG)

The free energy change values ranged from -2596 (S_9) to -3938 calories (S_2) with a mean of -3085 calories. The correlation coefficient attained the level of significance only with total K.

TABLE 5

POTASSIUM POTENTIAL PARAMETERS OF SOILS

Soil No.	Name of soil series	$AR_e^k \times 10^{-3}$ $(m/l)^{1/2}$	PBC^k	$\Delta - K^o$ me/100 g	ΔG (- Cal)	K potential	K_L me/100 g	K_x me/100 g
1.	Adanur	7.1	39.4	0.28	-2979	10.0	0.78	0.50
2.	Alathur	5.2	62.9	0.34	-3938	21.4	0.65	0.31
3.	Kalathur	5.4	81.5	0.44	-3144	35.8	0.66	0.22
4.	Kivalur	7.0	61.4	0.43	-2988	26.4	0.77	0.34
5.	Nedumbalam	6.0	113.0	0.68	-3081	77.1	0.90	0.22
6.	Padugai	7.1	102.8	0.73	-2979	75.1	1.00	0.27
7.	Pattukkottai	7.6	27.6	0.21	-2938	5.8	0.33	0.11
8.	Sikar	4.8	93.8	0.45	-3215	42.2	0.64	0.19
9.	Madukkur	13.4	11.2	0.15	-2596	1.7	0.35	0.20
10.	Melakadu	7.0	68.6	0.48	-2988	32.9	0.60	0.12

FIG. 4 Q/I RELATIONSHIP CURVES OF SOILS

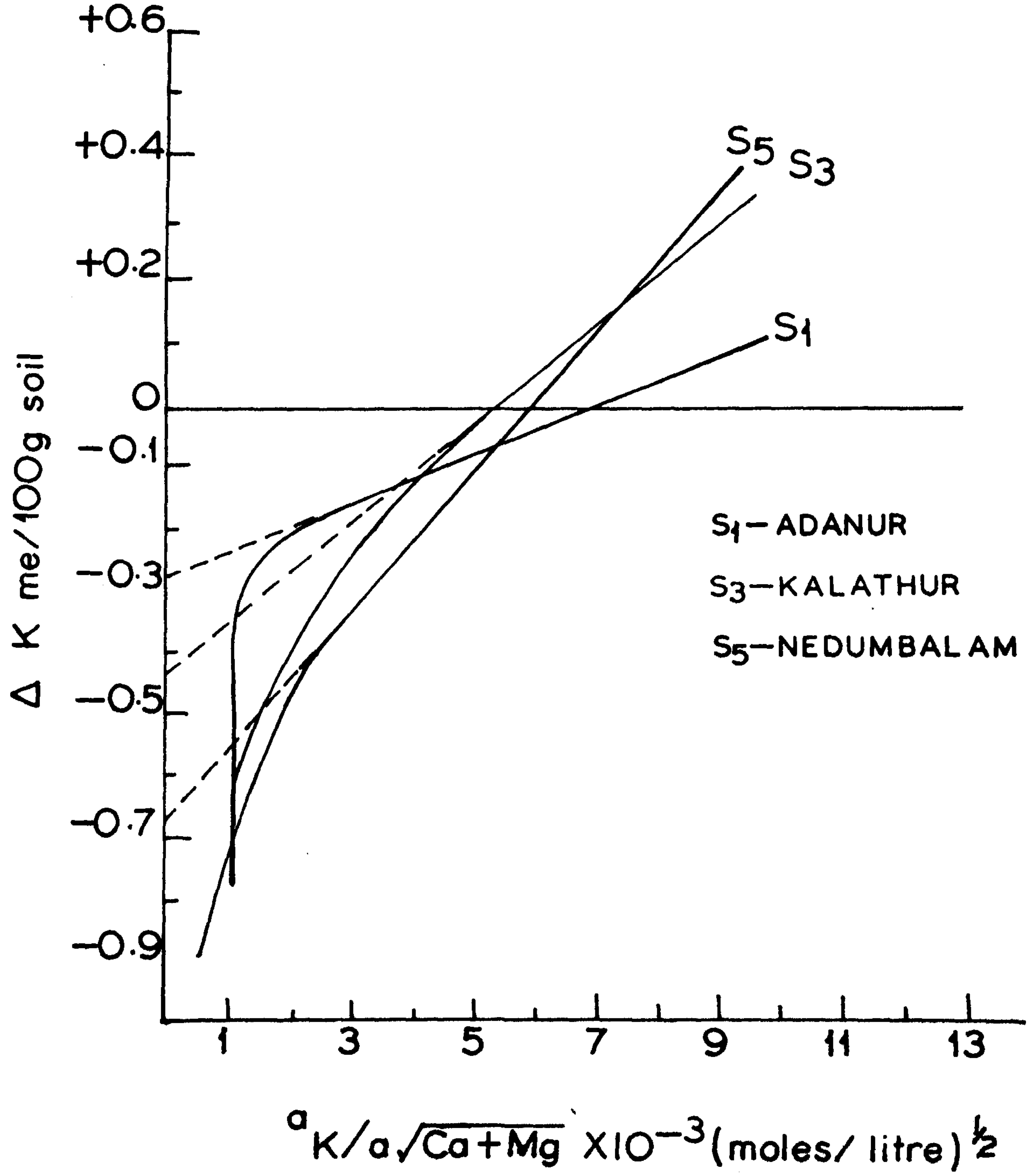


FIG. 4a Q/I RELATIONSHIP CURVES OF SOILS

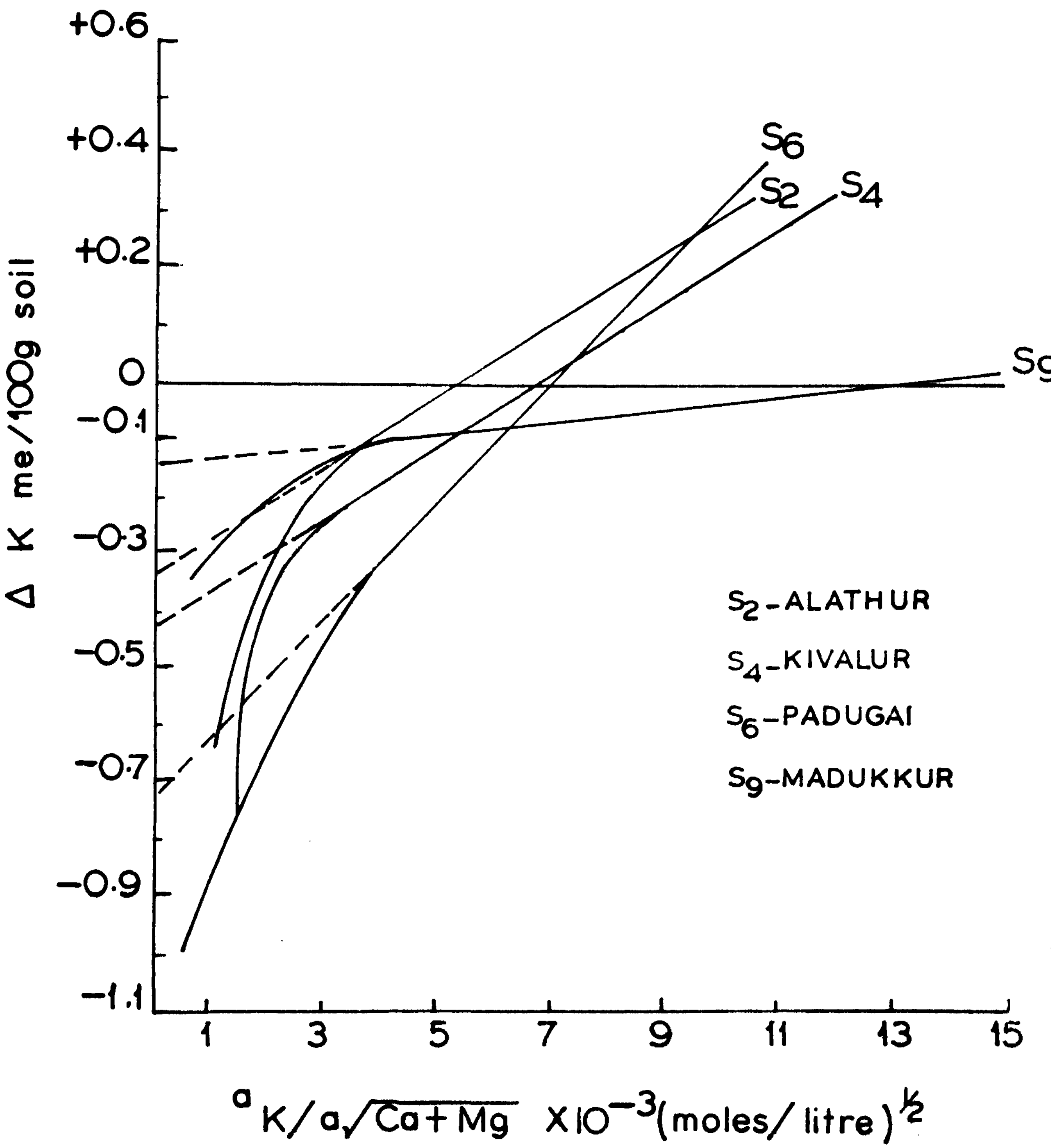
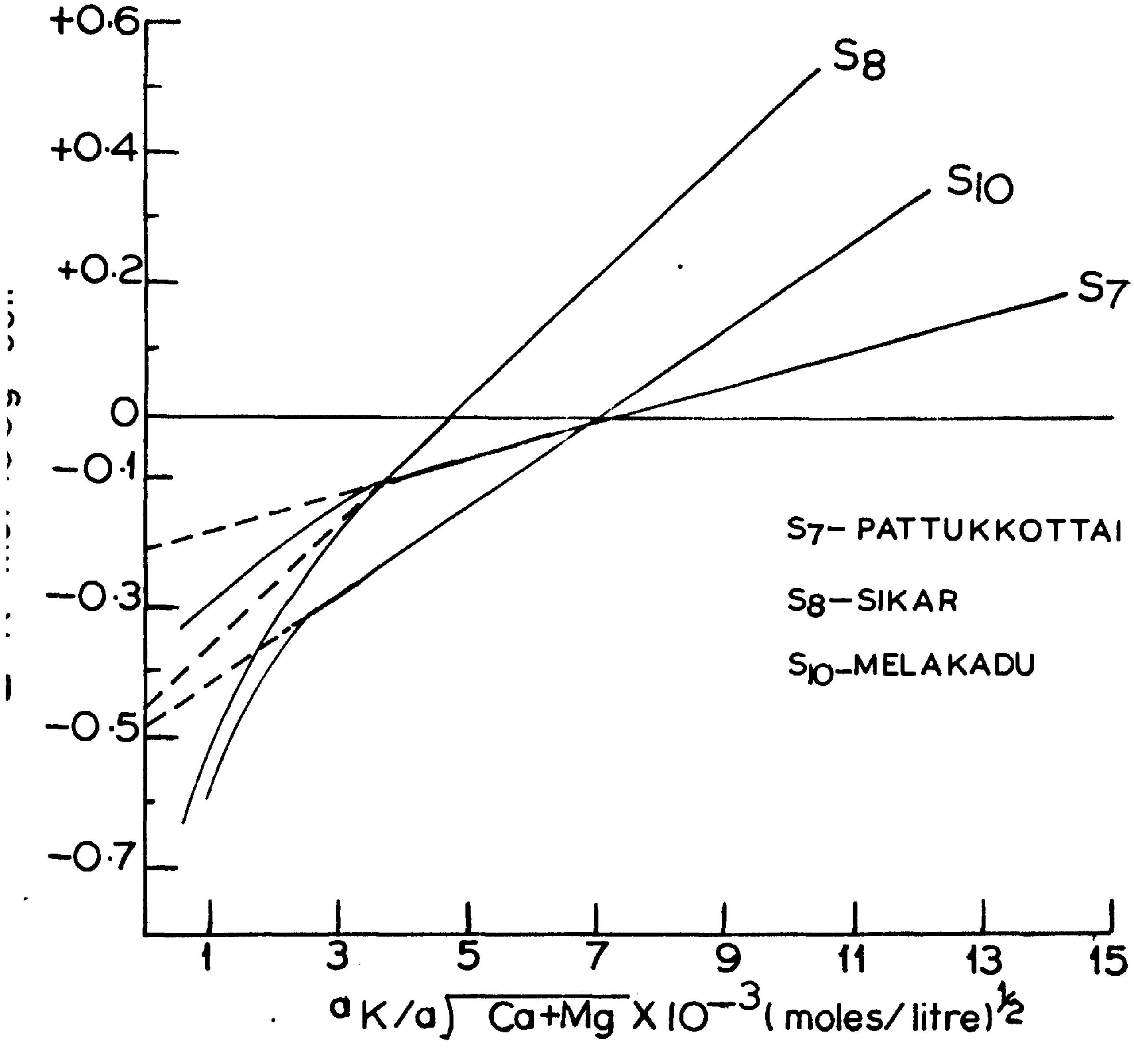


FIG. 4b Q/I RELATIONSHIP CURVES OF SOILS



4.2.2.5. Potash potential

These values ranged from 1.68 (S_9) to 77.1 (S_5) with a mean of 32.94.

4.2.2.6. K_L (Total amount of K in labile pool)

The K_L values of soils varied from 0.33 (S_7) to 1.00 me/100 g soil (S_6) with a mean of 0.67 me/100 g soil.

4.2.2.7. K_X (K held at specific sites)

The above values ranged from 0.11 (S_7) to 0.50 me/100 g soil (S_1) with a mean of 0.25 me/100 g soil.

4.3. Potassium fixing capacity of soils

The extent of K fixation at different levels of added K under varying incubation periods and the percentage of K fixed to that of added K are presented in Table 6. The K fixation trend of soils are presented in Figs. 5, 5a, and 5b.

The added K levels resulted in significant variations in K fixation. From the data it was revealed that there was progressive increase in the K fixation as the concentration of added K increased irrespective of soils. When the per cent K fixation was considered, it decreased with increase in K levels in all soils.

Among the incubation periods, the fixation was the lowest during the first day and the same increased when the

TABLE 6

POTASSIUM FIXING CAPACITY OF SOILS

Soil No.	Name of soil series	K Levels	Incubation period								Mean of % K fixed
			1 day		3 days		7 days		14 days		
			K fixed me/100g	% K fixed	K fixed me/100g	% K fixed	K fixed me/100g	% K fixed	K fixed me/100g	% K fixed	
1.	Adanur	K_1	0.200	20.0	0.325	32.5	0.345	34.5	0.350	35.0	30.6
		K_2	0.400	20.0	0.454	22.7	0.460	23.0	0.460	23.0	22.2
		K_3	0.830	16.6	1.000	20.0	1.100	22.0	1.150	23.0	20.4
		K_4	1.500	15.0	1.960	19.6	1.900	19.0	2.000	20.0	18.4
2.	Alathur	K_1	0.246	24.6	0.282	28.2	0.282	28.2	0.290	29.0	27.5
		K_2	0.470	23.5	0.526	26.3	0.521	26.1	0.538	26.9	25.7
		K_3	0.833	16.7	1.080	21.6	1.120	22.4	1.140	22.8	20.9
		K_4	1.650	16.5	1.750	17.5	2.090	20.9	2.090	20.9	18.5
3.	Kalathur	K_1	0.268	26.8	0.388	38.8	0.390	39.0	0.391	39.1	35.9
		K_2	0.366	18.3	0.528	26.4	0.530	26.5	0.533	26.6	24.5
		K_3	0.760	15.2	1.080	21.6	1.120	22.4	1.240	24.8	21.0
		K_4	1.510	15.1	2.080	20.8	2.100	21.0	2.250	22.5	19.9
4.	Kivalur	K_1	0.180	18.0	0.452	45.2	0.456	45.6	0.488	48.8	39.4
		K_2	0.244	12.2	0.484	24.2	0.488	24.4	0.500	25.0	21.5
		K_3	0.584	11.7	1.230	24.6	1.240	24.8	1.220	24.4	21.4
		K_4	1.010	10.1	1.900	19.0	1.920	19.2	1.940	19.4	16.9

Contd...

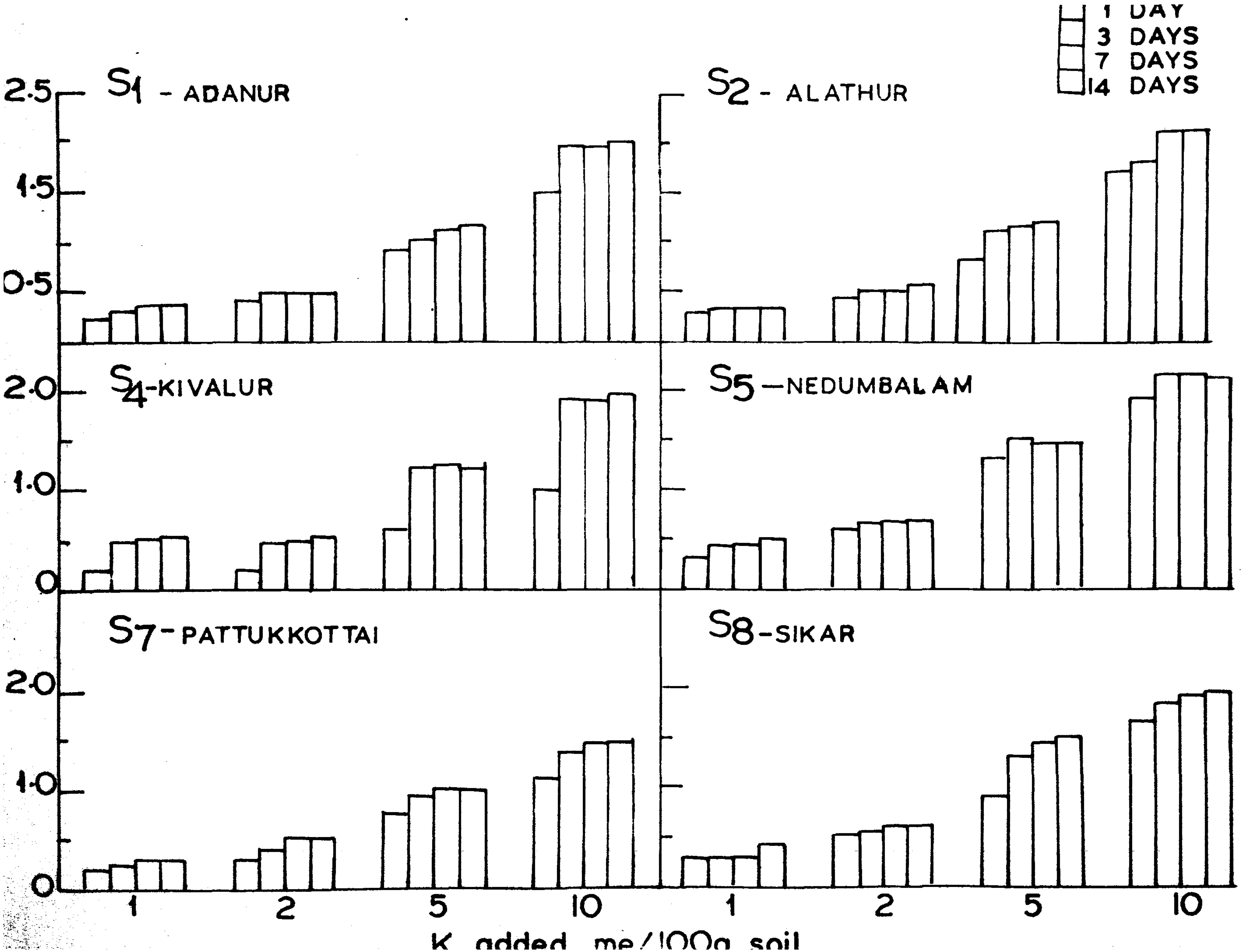
TABLE 6 (CONTINUED)

Soil No.	Name of soil series	K levels	Incubation period								Mean of % K fi[xed]
			1 day		3 days		7 days		14 days		
			K fixed me/100g	% K fixed	K fixed me/100g	% K fixed	K fixed me/100g	% K fixed	K fixed me/100g	% K fixed	
5.	Nedumbalam	K_1	0.306	30.6	0.386	38.6	0.390	39.0	0.391	39.1	36.8
		K_2	0.601	30.2	0.666	33.3	0.671	33.5	0.668	33.4	32.6
		K_3	1.320	26.4	1.520	30.4	1.470	29.4	1.430	28.6	28.7
		K_4	1.910	19.1	2.150	21.5	2.150	21.5	2.080	20.8	20.7
6.	Padugai	K_1	0.506	50.6	0.520	52.0	0.521	52.1	0.521	52.1	51.7
		K_2	0.800	40.0	0.920	46.0	0.930	46.5	0.940	47.0	44.8
		K_3	1.640	32.8	1.710	34.4	1.730	34.6	1.740	34.8	34.2
		K_4	2.560	25.6	3.130	31.3	3.150	31.5	3.150	31.5	30.0
7.	Pattukkottai	K_1	0.202	20.2	0.244	24.4	0.256	25.6	0.256	25.8	24.0
		K_2	0.308	15.4	0.408	20.4	0.472	23.6	0.480	24.0	20.8
		K_3	0.721	14.2	0.901	18.0	0.910	18.2	0.920	18.4	17.3
		K_4	1.060	10.6	1.370	13.7	1.430	14.3	1.430	14.3	13.3
8.	Sikar	K_1	0.296	29.6	0.320	32.0	0.311	31.1	0.404	40.4	33.3
		K_2	0.526	26.3	0.596	29.8	0.600	30.0	0.602	30.1	29.1
		K_3	0.896	17.9	1.320	26.4	1.410	28.2	1.490	29.8	25.6
		K_4	1.650	16.5	1.870	18.7	1.910	19.1	1.960	19.6	18.5

Contd...

Soil No.	Name of soil series	K levels	Incubation period								Mean of % K fixed
			1 day		3 days		7 days		14 days		
			K fixed me/100g	% K fixed	K fixed me/100g	% K fixed	K fixed me/100g	% K fixed	K fixed me/100g	% K fixed	
9.	Madukkur	K_1	0.192	19.2	0.225	22.5	0.298	29.8	0.298	29.8	25.3
		K_2	0.270	13.5	0.410	20.5	0.417	20.8	0.427	21.3	19.3
		K_3	0.600	12.0	1.010	20.2	1.000	20.0	1.000	20.0	18.1
		K_4	1.010	10.1	1.560	15.6	1.530	15.3	1.600	16.0	14.3
10.	Melakadu	K_1	0.220	22.0	0.308	30.8	0.305	30.5	0.306	30.6	28.5
		K_2	0.400	20.0	0.518	25.9	0.520	26.0	0.500	25.0	24.2
		K_3	0.980	19.6	1.220	24.4	1.250	25.0	1.210	24.2	23.3
		K_4	1.740	17.4	2.120	21.2	2.120	21.2	2.200	22.0	20.5

	Particulars	Mean values										S.E.	C.D.(0.05)
i)	K levels	K_1	K_2	K_3	K_4								
		0.333	0.529	1.13	1.92							0.025	0.068
ii)	Incubation period	T_1	T_2	T_3	T_4								
		0.804	1.02	1.05	1.06							0.025	0.068
iii)	Soils	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}		
		0.902	0.931	0.958	0.921	1.132	1.529	0.711	1.010	0.740	0.995	0.038	0.107



1 DAY
3 DAYS
7 DAYS
14 DAYS
S1 - ADANUR
S2 - ALATHUR
S4-KIVALUR
S5 -NEDUMBALAM
S7-PATTUKKOTTAI
S8-SIKAR
2.5
1.5
0.5
2.0
1.0
0
2.0
1.0
0
1
2
5
10
1
2
5
10
K added me/100g soil

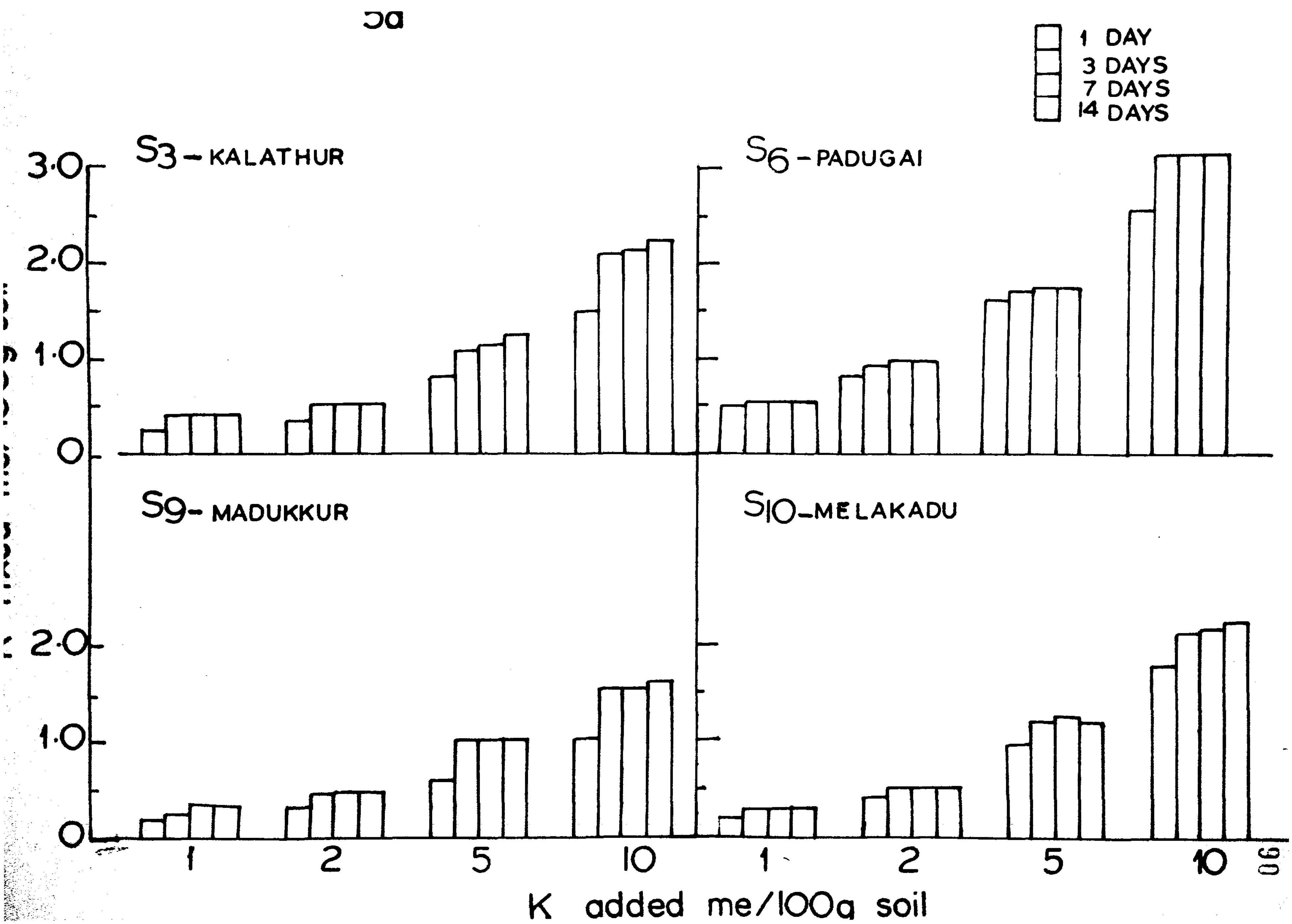
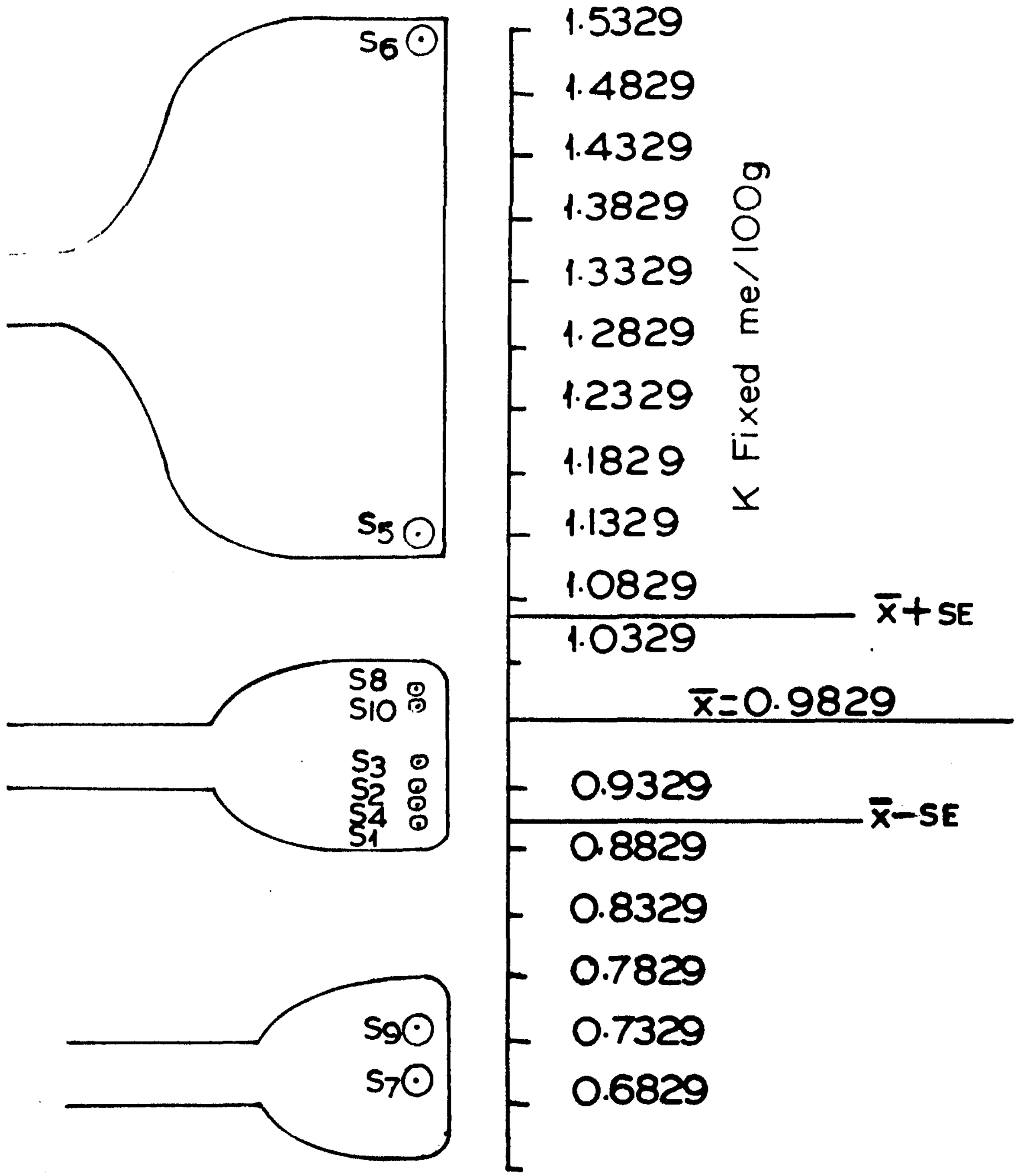

5a
1 DAY
3 DAYS
7 DAYS
14 DAYS
S3 - KALATHUR
S6 - PADUGAI
S9 - MADUKKUR
S10 - MELAKADU
3.0
2.0
1.0
0
1
2
5
10
K added me/100g soil
90

FIG. 5b POTASSIUM FIXATION (me/100g soil)
GROUPING OF SOILS BASED ON $\bar{X} \pm SE$



incubation period was extended to 72 hours beyond which there was no conspicuous increase in K fixation.

Among the soils, the fixation ranged from 0.71 (S_7) to 1.53 me/100 g (S_6). The soil S_6 followed by S_5 recorded the highest value of K fixation. On the other hand, the soils S_8, S_{10}, S_3, S_2, S_4 and S_1 exhibiting similar trend in fixing the added K recorded higher values of K fixation than S_9 and S_7 between which there was no conspicuous difference.

The simple correlations worked out between K fixation and different K availability indices and other soil characteristics (Table 7) revealed that the K fixation was positively influenced by CEC (r = 0.636*), clay content (r = 0.648*), potash potential (r = 0.765**) and $CaCO_3$ (r = 0.642*) while it was negatively correlated with $-\Delta K^o$ (r = 0.719*).

4.4. <u>Potassium supplying power of soils</u>

4.4.1. <u>Chemical - The cumulative K releasing power of soils - step-K</u>

The amount of K extracted by stepwise extraction with 0.01N HCl and the cumulative K releasing power of soils are presented in Table 8; and Fig.6.

The results indicated that there was considerable variation in K releasing power of soils. Generally, the quantity of K extracted from soils studied gradually decreased from 1st extraction to 15th extraction. In the 1st extraction, soils S_5

TABLE 7

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN K FIXATION (X) AND K AVAILABILITY INDICES AND OTHER SOIL CHARACTERISTICS (Y) (n = 10)

Sl. No.	Y variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	H_2O-K	0.009	NS
2.	N NH_4OAc-K	0.289	NS
3.	0.1N HNO_3-K	0.119	NS
4.	0.5N HNO_3-K	0.094	NS
5.	1N HNO_3-K	0.511	NS
6.	0.1N HCl-K	0.136	NS
7.	0.5N HCl-K	0.116	NS
8.	1% citric acid-K	0.097	NS
9.	0.5N EDTA-K	-0.087	NS
10.	Morgan-K	0.082	NS
11.	0.01M $CaCl_2$-K	-0.057	NS
12.	0.5N NaCl-K	-0.107	NS
13.	Knex	0.523	NS
14.	Cumulative release-K	0.023	NS
15.	AR_e^k	-0.055	NS
16.	-_ K^o	-0.719*	Y = 0.0968 - 1.25x
17.	PBC^k	0.664*	Y = 17.53 + 188.91x
18.	_ G	-0.125	NS
19.	Total-K	0.326	NS
20.	Potash potential	0.765**	Y = -15.19 + 186.71x
21.	Clay %	0.648*	Y = 25.12 + 25.34x
22.	CEC	0.636*	Y = 25.62 + 42.88x
23.	Organic carbon	-0.010	NS
24.	pH	-0.236	NS
25.	$CaCO_3$	0.642*	Y = 3.05 + 1.44x

* - Significant at 5 per cent level

** - Significant at 1 per cent level

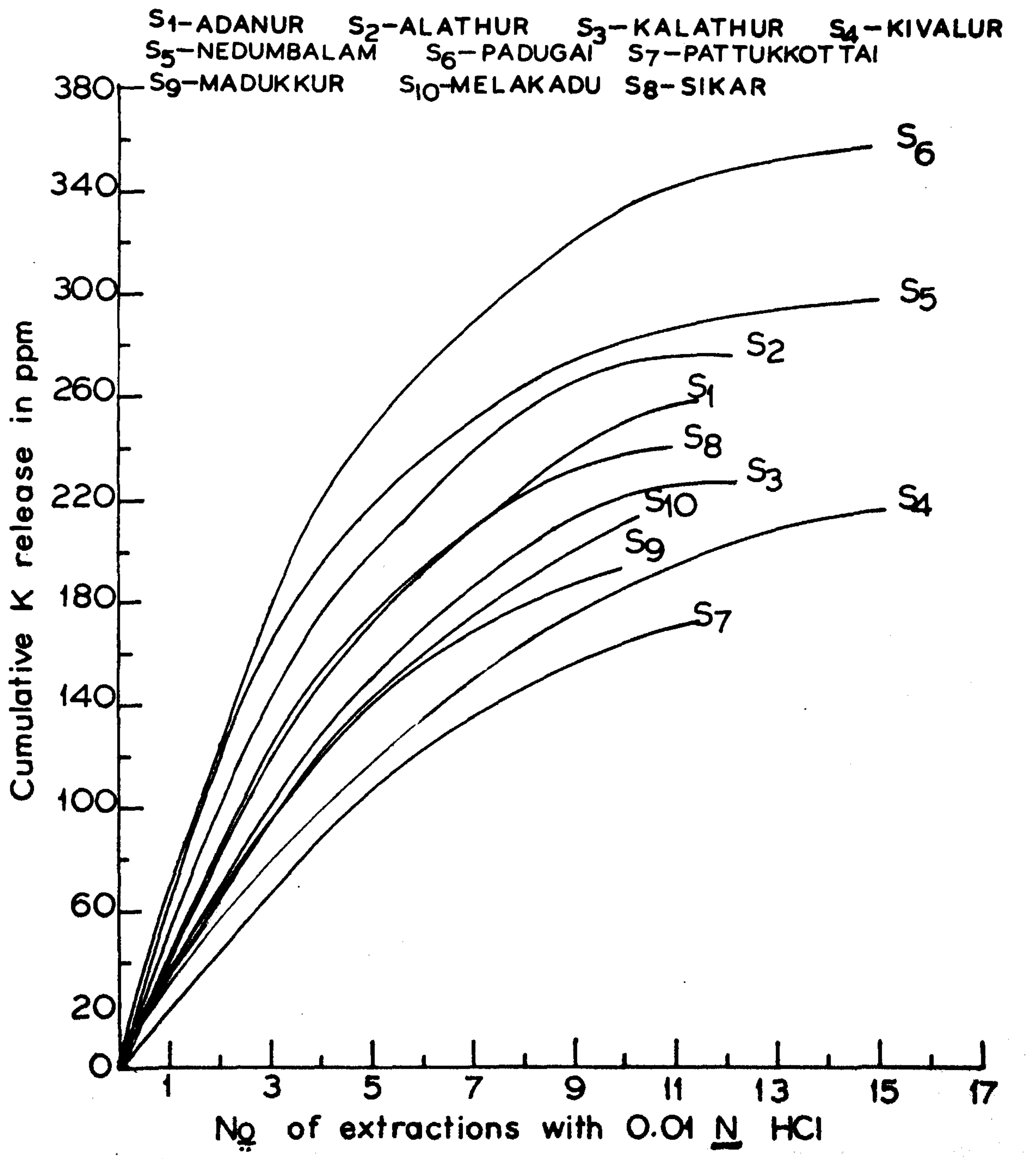
NS - Not significant

TABLE 8

POTASSIUM EXTRACTED BY STEPWISE EXTRACTION WITH 0.01N HCl (ppm)

Soil No.	Name of soil series	Number of extractions															Cumulative K-release
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1.	**Adanur**	42.3	37.5	31.9	26.4	26.4	23.9	20.0	17.5	15.9	12.5	5.0	-	-	-	-	259
2.	**Alathur**	55.9	42.5	37.5	37.5	25.0	22.5	22.5	16.9	10.0	7.9	2.5	2.5	-	-	-	283
3.	**Kalathur**	39.9	31.9	26.4	25.0	21.4	20.0	18.3	17.5	15.9	8.5	2.5	2.5	-	-	-	230
4.	**Kivalur**	33.4	25.8	22.5	20.0	15.9	15.9	14.0	15.9	14.0	12.5	7.9	6.8	5.5	4.5	3.5	218
5.	**Nedumbalam**	71.6	55.9	40.4	31.9	21.4	18.3	14.3	12.5	10.0	7.9	5.5	4.5	2.5	2.5	2.5	302
6.	**Padugai**	62.4	55.9	55.9	42.3	33.4	21.4	20.0	18.3	14.0	10.0	6.8	5.0	5.0	5.0	5.0	360
7.	**Pattukkottai**	24.3	21.4	20.0	20.0	18.3	17.5	15.9	14.0	10.0	6.8	5.0	-	-	-	-	173
8.	**Sikar**	40.2	39.9	33.4	33.4	23.9	18.3	17.5	17.5	10.0	5.0	3.5	-	-	-	-	243
9.	**Madukkur**	31.9	32.5	26.4	25.0	20.0	18.3	17.5	10.0	7.9	4.5	-	-	-	-	-	194
10.	**Melakadu**	32.5	31.9	26.9	25.0	24.0	21.4	20.0	15.9	10.0	5.0	-	-	-	-	-	21[illegible]

FIG. 6 CUMULATIVE K RELEASE CURVES OF SOILS
STEP-K



and S_7 released the highest (71.6 ppm) and lowest (24.3 ppm) K respectively. Soils S_9 and S_{10} released K up to tenth extraction while soils S_1, S_7 and S_8 released K up to eleventh extraction and S_2 and S_3 released K up to twelfth extraction. By about twelfth extraction, most of the soils released a considerable quantity of K and thereafter the quantity of K released was low.

The soils S_4, S_5 and S_6 continued to release K up to 15th extraction.

In respect of cumulative K release power of soils it was observed that the highest release was recorded in soil S_6 followed by S_5, S_2, S_1, S_8, S_3, S_4, S_{10}, S_9 and S_7 in decreasing order. Besides, the cumulative release curves were of Cobb-Douglas functions showing a good fit with $Y = ax^b$ (Table 8a).

Simple correlation studies between cumulative K release and other K availability indices (Table 4) revealed that there were positive correlations with almost all K parameters excepting PBC^k and potash potential where a negative relationship existed.

4.4.2. Biological-K supplying power of soils by exhaustive cropping-Mini pot experiment

The dry matter yield produced, the K concentration and the K uptake values for six successive short term (30 days) crops of ADT 31 rice are presented in Tables 9, 10 and 11.

TABLE 8a

COBB-DOUGLAS EXPONENTIAL EQUATIONS FOR THE CUMULATIVE K RELEASE OF SOILS

Soil No.	Name of soil series	Exponential equation $Y = ax^b$
1.	Adanur	$Y = 48.0\ X^{1.77}$
2.	Alathur	$Y = 54.5\ X^{1.83}$
3.	Kalathur	$Y = 43.6\ X^{1.75}$
4.	Kivalur	$Y = 40.9\ X^{1.72}$
5.	Nedumbalam	$Y = 60.6\ X^{1.86}$
6.	Padugai	$Y = 63.9\ X^{1.68}$
7.	Pattukkottai	$Y = 35.0\ X^{1.66}$
8.	Sikar	$Y = 47.4\ X^{1.78}$
9.	Madukkur	$Y = 38.4\ X^{1.69}$
10.	Melakadu	$Y = 39.7\ X^{1.72}$

The values of these yield parameters in general decreased gradually for every successive crop both in control as well as in the K treated plots for all the soils. The results indicated that the levels of K, effect of soils and crops and the interaction effects were significant.

4.4.2.1. Effect of K levels and soils on dry matter yield of rice (Table 9)

The level K_3 caused the highest dry matter yield (3.39 g/pot) of ADT 31 rice while the pot receiving no K recorded the lowest yield (2.29 g/pot). Among the soils, soil S_7 produced the highest yield (3.93 g/pot) while S_{10} recorded the lowest yield (1.74 g/pot). The dry matter yield recorded from 1st crop to 6th crop reduced significantly. The reduction of such dry matter from 1st to 6th crop was to a tune of 37.2 per cent.

The interaction between crops and K levels revealed that at all levels of applied K, the 1st and 6th crop produced the highest and lowest dry matter yield respectively. On the other hand, irrespective of crops K_3 and K_0 levels resulted in the highest and lowest dry matter yields respectively.

The interaction between soils and K levels favoured the dry matter yield in all the soils except in soils S_1 and S_2 in which K_2 level resulted an increase in yield. Irrespective of added K levels soils S_7 and S_{10} produced the highest and lowest dry matter yields respectively.

TABLE 9

DRY MATTER YIELD OF RICE PLANT (g/pot) - EXHAUSTIVE CROPPING

(Mean of two replications)

Soil No.	Name of soil series	K levels	Crop I	Crop II	Crop III	Crop IV	Crop V	Crop VI	Cumulative yield
1.	Adanur	K_0	3.14	3.05	2.95	2.83	2.68	2.15	16.80
		K_1	3.82	3.70	3.78	3.25	2.68	2.35	19.58
		K_2	5.95	5.60	4.93	4.25	3.70	2.45	26.88
		K_3	3.52	3.45	3.25	3.00	2.83	2.58	18.63
2.	Alathur	K_0	2.06	1.98	1.95	2.08	1.98	1.78	11.83
		K_1	2.55	2.38	2.40	2.25	2.13	1.90	13.61
		K_2	4.83	4.19	4.05	3.25	3.10	2.63	22.05
		K_3	3.68	2.56	2.58	2.50	2.43	2.40	16.15
3.	Kalathur	K_0	2.66	2.61	2.40	2.50	2.38	2.13	14.68
		K_1	2.76	2.61	2.55	2.38	2.45	2.43	15.18
		K_2	3.34	3.38	3.48	3.26	3.33	3.28	20.07
		K_3	4.59	4.34	4.13	3.88	3.50	3.38	23.82
4.	Kivalur	K_0	2.68	2.54	2.48	2.44	2.18	1.98	14.26
		K_1	3.01	2.66	2.48	2.50	2.33	2.05	15.03
		K_2	3.23	3.27	3.16	3.00	2.53	2.25	17.44
		K_3	3.78	4.24	4.17	3.75	3.13	2.53	21.60
5.	Nedumbalam	K_0	2.58	2.66	2.42	2.50	2.18	1.73	14.07
		K_1	3.15	2.93	2.78	2.51	2.30	1.98	15.65
		K_2	4.06	3.93	3.75	3.63	2.98	2.18	20.53
		K_3	3.98	3.85	3.59	3.50	3.20	2.38	20.50
6.	Padugai	K_0	2.69	2.86	2.88	2.75	2.45	2.08	15.71
		K_1	3.61	3.41	3.22	3.00	2.73	2.30	18.27
		K_2	3.99	3.75	3.69	3.50	2.98	2.58	20.49
		K_3	4.60	4.42	4.51	4.08	3.38	2.83	23.82

Contd...

TABLE 9 (CONTINUED)

Soil No.	Name of soil series	K levels	Crop I	Crop II	Crop III	Crop IV	Crop V	Crop VI	Cumulative yield
7.	Pattukkottai	K_0	3.55	3.49	3.39	3.15	2.98	2.10	18.66
		K_1	4.46	4.36	4.21	3.88	3.13	2.38	22.42
		K_2	5.29	5.05	4.79	4.63	3.88	2.75	26.39
		K_3	5.99	5.38	4.74	4.11	3.88	3.25	26.85
8.	Sikar	K_0	2.47	2.60	2.38	2.13	2.00	1.78	13.36
		K_1	3.71	3.54	3.28	3.06	2.38	2.07	18.04
		K_2	4.71	4.54	4.31	4.13	3.20	2.58	23.47
		K_3	4.96	4.85	4.64	4.25	3.45	2.98	25.13
9.	Madukkur	K_0	1.63	1.11	1.09	1.59	1.64	1.24	8.30
		K_1	2.49	2.24	1.48	1.62	1.53	1.64	11.00
		K_2	2.75	1.82	1.65	1.96	1.55	1.47	11.20
		K_3	2.81	1.84	2.04	1.84	1.61	1.42	11.56
10.	Melakadu	K_0	2.11	1.80	1.37	1.67	1.28	1.32	9.55
		K_1	2.30	1.88	1.38	1.70	1.44	1.20	9.90
		K_2	2.45	2.07	1.55	1.74	1.54	1.28	10.63
		K_3	2.92	2.22	1.65	1.76	1.72	1.36	11.63

(Contd...)

Particulars		Mean values										S.E.	C.D.(0.05)
i) K levels		K_0	K_1	K_2	K_3								
		2.29	2.65	3.32	3.39							0.02	0.05
ii) Soils		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}		
		3.41	2.65	3.08	2.85	2.95	3.26	3.93	3.33	1.75	1.74	0.03	0.08
iii) Crops		C_1	C_2	C_3	C_4	C_5	C_6						
		3.47	3.23	3.04	3.00	2.56	2.18					0.02	0.06
iv) Interaction													
Crops x K levels		C_1	C_2	C_3	C_4	C_5	C_6						
	K_0	2.56	2.47	2.33	2.39	2.18	1.83					0.04	0.12
	K_1	3.19	2.97	2.76	2.62	2.31	2.03						
	K_2	4.06	3.76	3.54	3.34	2.88	2.35						
	K_3	4.08	3.72	3.53	3.63	2.86	2.51						
v) Soils x K levels		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}		
	K_0	2.80	1.97	2.45	2.38	2.35	2.62	3.11	2.23	1.38	1.59	0.06	0.15
	K_1	3.26	2.27	2.53	2.51	2.61	3.05	3.74	3.01	1.83	1.65		
	K_2	4.48	3.68	3.35	2.91	3.42	3.42	4.40	3.91	1.87	1.77		
	K_3	3.11	2.69	3.97	3.60	3.42	3.97	4.48	4.19	1.93	1.94		
vi) Soils x Crops		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}		
	C_1	4.11	3.28	3.34	3.18	3.44	3.72	4.82	3.96	2.42	2.45	0.07	0.19
	C_2	3.95	2.78	3.24	3.18	3.34	3.61	4.57	3.88	1.75	1.99		
	C_3	3.73	2.75	3.14	3.07	3.14	3.58	4.28	3.65	1.57	1.49		
	C_4	3.33	2.52	3.01	2.91	3.03	3.33	3.94	3.39	1.75	1.72		
	C_5	2.97	2.41	2.92	2.54	2.67	2.89	3.34	2.76	1.58	1.50		
	C_6	2.38	2.18	2.81	2.20	2.07	2.45	2.62	2.35	1.44	1.29		

The significant interaction displayed between soils and crops revealed that under all soils, the 1st crop produced the highest yield and irrespective of crops, the soils S_7 continued to register higher dry matter yield than the other soils.

4.4.2.2. <u>Potassium content of rice-exhaustive cropping</u> (Table 10)

The K content in rice due to added K levels did not vary appreciably among levels. However, the level K_3 and K_0 numerically recorded the highest (1.78 per cent) and lowest (1.43 per cent) K content respectively. Similarly there was no striking difference of K content among soils. Soils S_4 and S_6 recorded marginally the highest and lowest values respectively.

In the case of crops, the K content in 1st three crops was significantly higher than the later three crops. In general, the K content decreased from 1st to 6th crop similar to dry matter yield although the trend and magnitude of such decrease varied in different soils.

4.4.2.3. <u>Potassium uptake by rice-exhaustive cropping</u> (Table 11)

Application of K increased the K uptake. However, the levels K_3 and K_2 were on par. Among the soils, soil S_7 recorded the highest uptake (72.7 mg/pot) accounting for 165 per cent increase in uptake over S_{10} (27.4 mg/pot).

TABLE 10

POTASSIUM CONTENT OF RICE PLANT (PER CENT) - EXHAUSTIVE CROPPING

(Mean of two replications)

Soil No.	Name of soil series	K levels	Crop I	Crop II	Crop III	Crop IV	Crop V	Crop VI
1.	Adanur	K_0	1.94	2.03	1.68	1.21	1.05	0.91
		K_1	2.01	1.98	1.88	1.28	1.11	1.01
		K_2	2.03	1.96	1.89	1.29	1.18	1.04
		K_3	2.30	2.08	2.00	1.36	1.23	1.14
2.	Alathur	K_0	2.14	2.01	1.90	1.25	1.20	0.98
		K_1	2.25	2.13	2.04	1.31	1.24	1.01
		K_2	2.31	2.21	2.10	1.40	1.28	1.09
		K_3	2.40	2.28	2.15	1.56	1.30	1.13
3.	Kalathur	K_0	2.03	1.95	1.75	1.23	1.16	0.91
		K_1	2.15	2.09	1.88	1.38	1.20	0.98
		K_2	2.15	2.09	1.94	1.43	1.29	1.09
		K_3	2.40	2.31	2.13	1.51	1.36	1.20
4.	Kivalur	K_0	2.18	2.09	1.84	1.26	1.01	0.86
		K_1	2.26	2.23	2.05	1.45	1.24	1.01
		K_2	2.36	2.29	2.18	1.48	1.36	1.16
		K_3	2.49	2.36	2.20	1.56	1.39	1.25
5.	Nedumbalam	K_0	2.09	2.03	1.94	1.19	1.10	0.79
		K_1	2.19	2.08	2.00	1.36	1.16	0.93
		K_2	2.33	2.21	2.10	1.40	1.25	1.04
		K_3	2.46	2.31	2.21	1.50	1.30	1.14
6.	Padugai	K_0	1.86	1.73	1.60	1.25	1.15	0.69
		K_1	1.89	1.83	1.78	1.33	1.20	0.84
		K_2	1.90	1.84	1.78	1.38	1.25	0.88
		K_3	2.06	1.98	1.98	1.53	1.29	1.01
7.	Pattukkottai	K_0	2.11	2.03	1.79	1.16	1.01	0.79
		K_1	2.31	2.23	2.01	1.31	1.21	0.93
		K_2	2.46	2.34	2.19	1.56	1.29	1.15
		K_3	2.51	2.43	2.28	1.86	1.35	1.23

Contd...

TABLE 10 (CONTINUED)

Soil No.	Name of soil series	K levels	Crop I	Crop II	Crop III	Crop IV	Crop V	Crop VI
8.	Sikar	K_0	1.39	1.28	1.18	1.04	1.00	0.83
		K_1	2.01	1.94	1.71	1.29	1.11	0.93
		K_2	2.35	2.15	2.00	1.44	1.21	1.09
		K_3	2.19	2.04	1.94	1.48	1.28	1.19
9.	Madukkur	K_0	1.98	1.88	1.80	1.10	1.01	0.81
		K_1	2.34	2.10	2.04	1.30	1.19	0.93
		K_2	2.40	2.30	2.18	1.48	1.29	1.15
		K_3	2.45	2.37	1.86	1.63	1.36	1.26
10.	Melakadu	K_0	1.70	1.66	1.53	1.01	1.01	0.69
		K_1	1.91	1.80	1.80	1.11	1.04	0.91
		K_2	2.04	1.98	1.93	1.26	1.16	1.01
		K_3	2.29	2.16	2.05	1.36	1.28	1.18

	Particulars			Mean values				S.E.	C.D. (0.05)
i)	K levels	K_0	K_1	K_2	K_3				
		1.425	1.581	1.688	1.780			0.284	0.583
ii)	Crops	C_1	C_2	C_3	C_4	C_5	C_6		
		2.115	2.114	1.930	1.355	1.123	0.998	0.243	0.489
iii)	Soils	S_1	S_2	S_3	S_4	S_5			
		1.564	1.693	1.649	1.731	1.657		0.179	0.368
		S_6	S_7	S_8	S_9	S_{10}			
		1.490	1.724	1.507	1.674	1.494			

TABLE 11

POTASSIUM UPTAKE BY RICE PLANT (mg/pot) - EXHAUSTIVE CROPPING
(Mean of two replications)

Soil No.	Name of soil series	K level	Crop I	Crop II	Crop III	Crop IV	Crop V	Crop VI	Cumulative K uptake	Mean
1.	Adanur	K_0	59.1	61.9	49.4	34.3	28.1	19.6	252.3	42.1
		K_1	76.9	73.2	70.8	41.5	29.8	23.8	315.8	52.7
		K_2	80.8	71.6	65.0	40.9	34.6	29.3	322.1	55.4
		K_3	85.4	78.0	69.0	42.8	36.5	25.4	338.0	56.3
2.	Alathur	K_0	43.9	39.8	37.1	26.0	23.7	17.3	187.0	31.3
		K_1	57.4	50.6	48.9	29.4	26.4	19.3	232.0	38.7
		K_2	88.2	58.2	55.3	39.6	31.5	26.9	299.2	49.9
		K_3	90.8	62.9	58.9	43.8	37.6	28.0	322.0	53.7
3.	Kalathur	K_0	53.9	50.9	42.1	30.6	27.6	19.4	224.6	37.4
		K_1	57.4	50.6	48.9	29.4	26.4	19.3	232.0	38.7
		K_2	88.2	58.2	55.3	39.6	31.5	26.9	299.2	49.9
		K_3	90.8	62.9	58.9	43.8	37.6	28.0	322.0	53.7
4.	Kivalur	K_0	58.2	52.9	45.5	30.2	22.0	17.0	225.9	37.7
		K_1	58.4	52.7	45.8	30.3	21.6	17.1	226.0	37.7
		K_2	65.7	55.0	47.9	34.8	25.8	20.8	250.0	41.7
		K_3	67.5	57.2	50.9	38.7	28.9	21.8	265.0	44.2
5.	Nedumbalam	K_0	53.6	54.1	46.9	29.7	23.9	13.6	221.9	37.0
		K_1	66.6	58.7	52.8	32.2	25.6	17.2	253.0	42.2
		K_2	83.0	67.6	57.0	45.8	31.0	22.6	309.0	51.5
		K_3	90.9	74.0	66.0	47.1	26.0	23.0	327.0	54.5

Contd...

Soil No.	Name of soil series	K level	Crop I	Crop II	Crop III	Crop IV	Crop V	Crop VI	Cumulative K uptake	Mean
6.	Padugai	K_0	50.3	49.4	46.0	33.4	28.2	14.3	221.5	36.9
		K_1	64.1	54.0	51.1	33.8	30.7	15.3	249.0	41.5
		K_2	66.1	63.0	54.3	41.2	35.8	17.6	278.0	46.3
		K_3	79.8	70.3	55.5	44.0	36.4	20.0	306.0	51.0
7.	Pattukkottai	K_0	75.1	70.5	60.5	36.6	30.1	16.6	289.6	48.2
		K_1	90.4	70.0	66.8	38.9	32.9	17.0	316.0	52.7
		K_2	100.0	85.0	73.1	43.3	36.9	22.8	361.0	60.2
		K_3	105.5	86.6	74.9	44.6	39.6	26.8	380.0	63.3
8.	Sikar	K_0	34.2	33.0	27.9	22.1	20.0	14.7	151.8	25.3
		K_1	48.6	42.6	30.2	25.0	23.4	15.2	185.0	30.8
		K_2	55.6	48.6	36.2	32.1	25.3	17.0	215.0	35.8
		K_3	60.6	54.6	49.2	40.0	33.6	27.0	260.0	43.3
9.	Madukkur	K_0	32.2	20.8	19.6	17.5	16.6	10.1	114.0	19.0
		K_1	58.2	47.0	30.2	21.1	18.2	15.2	190.0	31.6
		K_2	66.2	41.8	35.9	28.9	20.0	16.9	209.8	35.0
		K_3	68.9	43.6	38.0	29.9	21.9	17.9	220.2	36.7
10.	Melakadu	K_0	35.9	29.9	20.9	16.9	13.0	9.1	125.6	20.9
		K_1	44.0	33.8	24.8	18.9	14.9	10.9	147.4	24.6
		K_2	49.9	40.9	29.8	22.0	17.9	13.0	173.4	28.9
		K_3	66.8	48.0	33.8	24.0	21.9	16.0	210.5	35.1

Contd...

TABLE [illegible] (CONTINUED)

Particulars	Mean values										S.E.	C.D.(0.05)
i) K levels	K_0	K_1	K_2	K_3							2.1	5.8
	33.6	43.7	58.2	61.7								
ii) Soils	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}		
	55.3	46.7	52.1	51.6	51.7	51.0	72.7	54.0	30.7	27.4	3.3	9.1
iii) Crops	C_1	C_2	C_3	C_4	C_5	C_6						
	76.1	67.2	59.3	40.1	31.0	22.2					2.6	7.1
iv) Interaction												
Crops x K levels	C_1	C_2	C_3	C_4	C_5	C_6						
K_0	49.7	46.3	39.6	27.7	23.3	15.2					5.1	14.2
K_1	67.8	60.7	52.6	34.7	27.1	19.2						
K_2	90.6	79.0	71.4	47.3	36.1	25.1						
K_3	96.1	82.7	73.8	50.5	37.6	29.3						

As regards the number of crops and uptake of K, the 1st crop recorded the highest uptake (76.1 mg/pot) working out to 243 per cent increase over 6th crop (22.2 mg/pot).

In general, the uptake of K gradually declined from 1st to 6th crop. This followed the similar trend as that of the dry matter yield.

The results of interaction between crops and K levels revealed that the uptake values decreased marginally with number of crops harvested. The difference among 1st three crops and later three crops was almost becoming same. Similarly, irrespective of crops, the uptake values increased marginally with increased levels of added K.

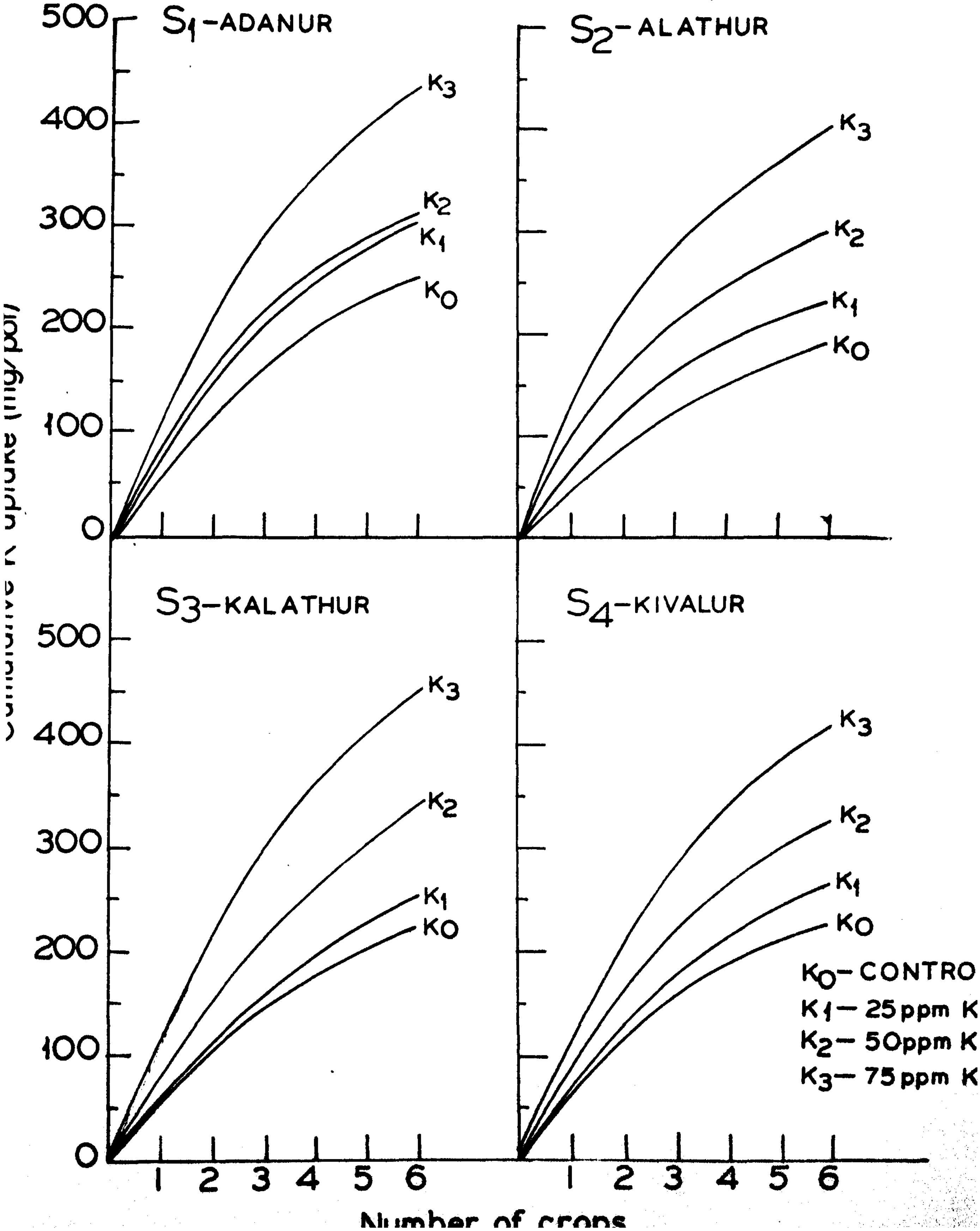
4.4.2.4. Cumulative uptake curves

The cumulative K uptake curves for the ten soils are presented in Fig.7, 7a and 7b. Cobb-Douglas exponential equations for the cumulative K uptake by successive cropping with rice for K_0 treatments only are presented in Table 12.

4.4.3. Extent of Kex and Knex used-exhausitive cropping (Table 13)

In all the soils, application of K promoted the total uptake of K. The highest and lowest values of K uptake were observed in soil S_8 (288 mg/pot) and soil S_{10} (85 mg/pot) respectively.

G. CUMULATIVE K UPTAKE BY SUCCESSIVE CROPPING OF RICE (mg/pot)



CUMULATIVE K UPTAKE BY SUCCESSIVE CROPPING OF RICE (mg/pot)

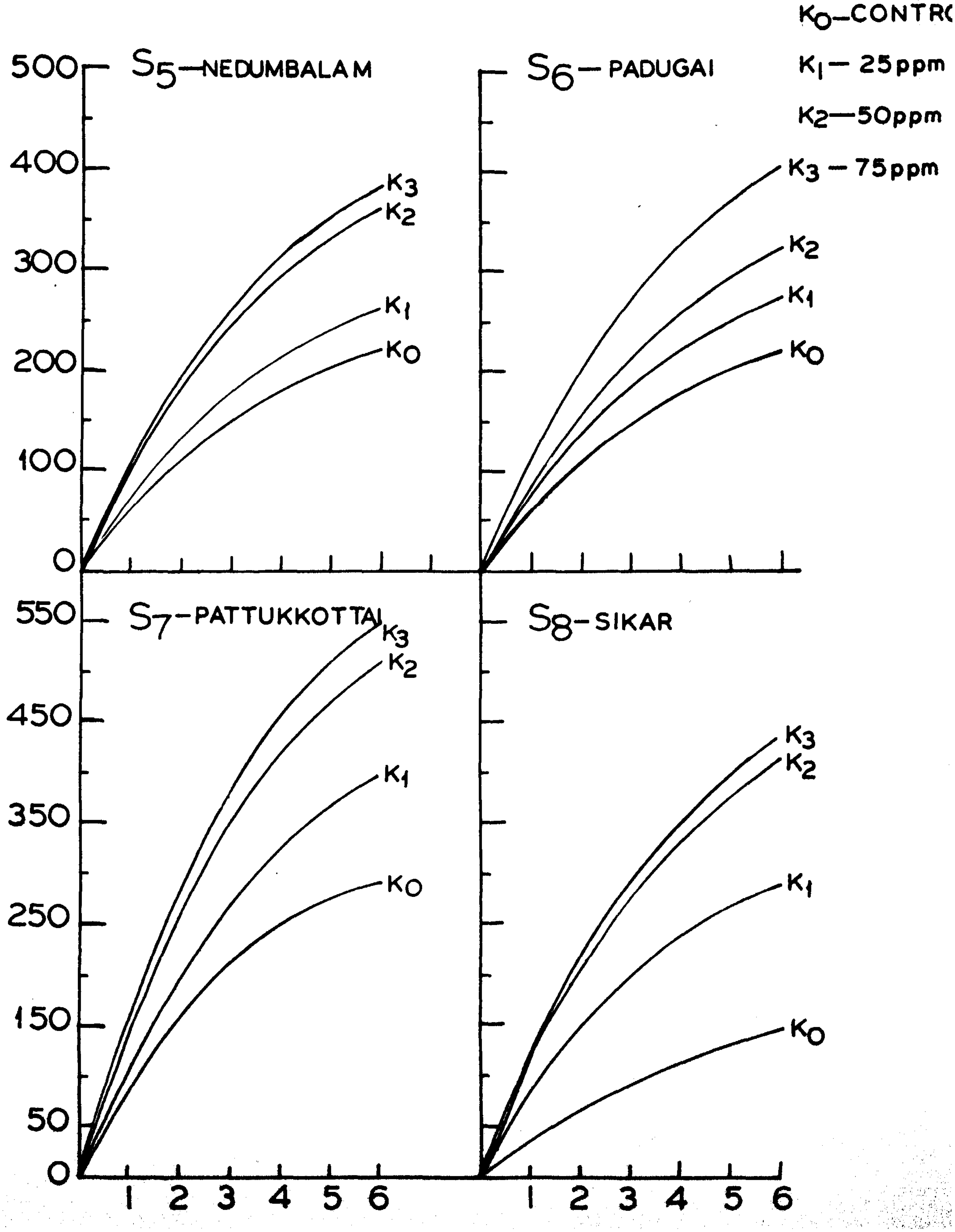


FIG. 7b CUMULATIVE K UPTAKE BY SUCCESSIVE CROPPING OF RICE (mg/pot)

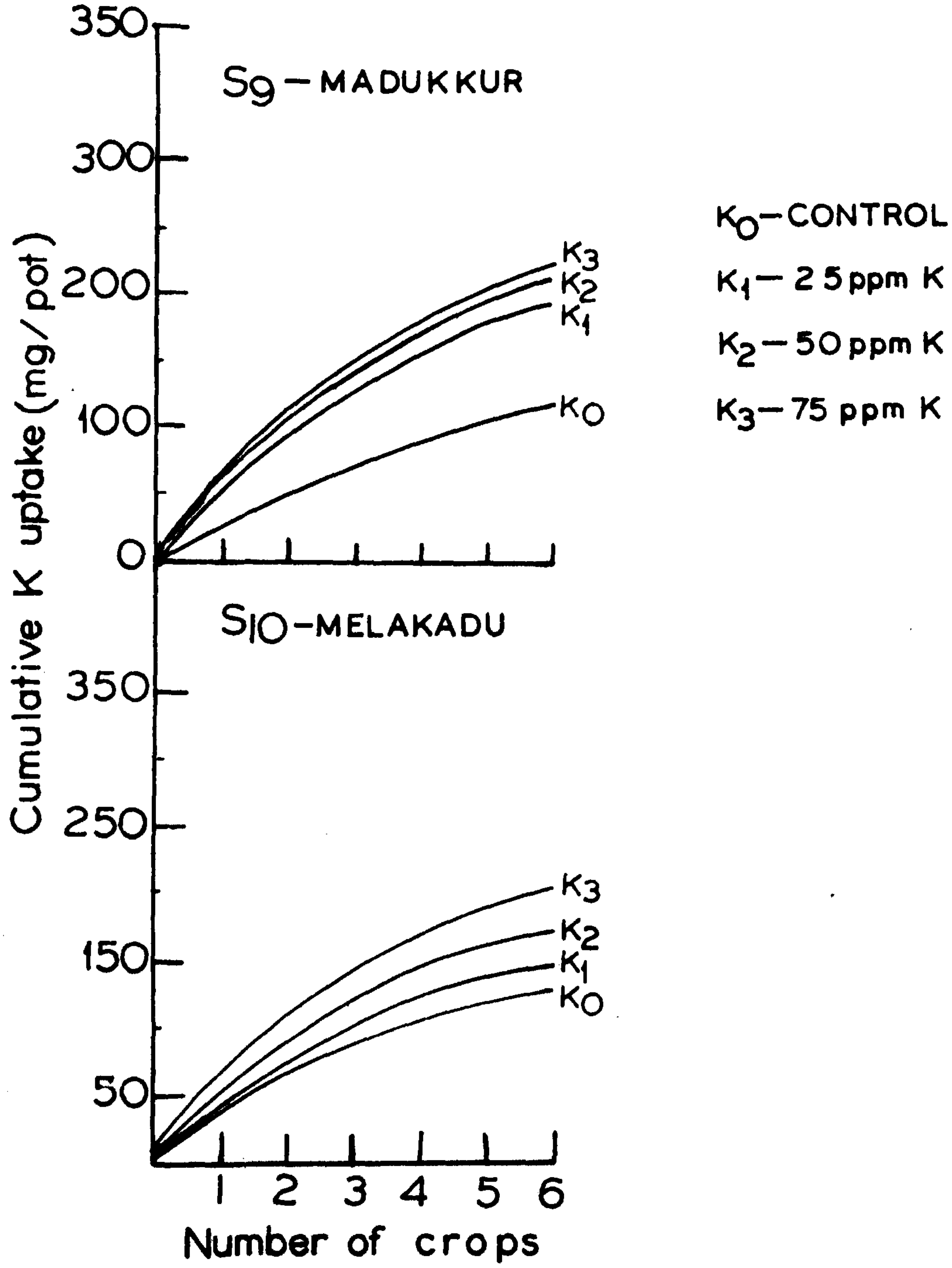


TABLE 12

COBB-DOUGLAS EXPONENTIAL EQUATIONS FOR THE CUMULATIVE K UPTAKE BY SUCCESSIVE CROPPING WITH RICE (Control pots only)

Soil No.	Name of soil series	Exponential equation ($Y = ax^b$)
1.	Adanur	$Y = 64.7\ X^{0.807}$
2.	Alathur	$Y = 38.2\ X^{0.703}$
3.	Kalathur	$Y = 58.2\ X^{0.795}$
4.	Kivalur	$Y = 53.6\ X^{0.842}$
5.	Nedumbalam	$Y = 58.2\ X^{0.804}$
6.	Padugai	$Y = 49.9\ X^{0.829}$
7.	Pattukkottai	$Y = 81.2\ X^{0.764}$
8.	Sikar	$Y = 61.1\ X^{0.760}$
9.	Madukkur	$Y = 36.5\ X^{0.829}$
10.	Melakadu	$Y = 32.4\ X^{0.734}$

TABLE 13

EXTENT OF Kex REDUCTION IN SOILS AFTER SIX EXHAUSTIVE CROPPING OF RICE
(Values for control pots only)

Soils	Kex initial mg/pot	Mean Kex after six crops mg/pot	Kex reduction	
			mg/pot	Per cent
Adanur	66.0	16.0	50.0	75.8
Alathur	99.0	37.0	62.0	62.6
Kalathur	99.0	31.0	68.0	68.7
Kivalur	105.0	61.0	44.0	41.9
Nedumbalam	174.0	95.0	79.0	45.1
Padugai	108.0	72.0	36.0	33.3
Pattukkottai	63.0	57.0	6.0	9.5
Sikar	78.0	48.0	30.0	38.5
Madukkur	42.0	30.0	12.0	28.6
Melakadu	18.0	12.0	6.0	33.3

TABLE 13(a)

EXTENT OF Kex AND Knex USED BY SUCCESSIVE CROPPING OF RICE - EXHAUSTIVE CROPPING
(Mean of two replications)

Soils	K levels	Total-K uptake mg/pot	Kex after six crops mg/pot	K added to all six crops mg/pot	Kex used mg/pot	Knex used mg/pot	Percentage of Knex used
Adanur	K_0	252	16	-	50	202	80.2
	K_1	316	36	90	120	196	62.0
	K_2	332	86	180	160	172	51.8
	K_3	338	116	270	220	118	34.9
Alathur	K_0	187	37	-	62	125	66.8
	K_1	232	57	90	132	100	43.1
	K_2	299	75	180	204	95	31.8
	K_3	322	117	270	252	70	21.7

Contd...

TABLE 13(a) (CONTINUED)

Soils	K levels	Total-K uptake mg/pot	Kex after six crops mg/pot	K added to all six crops mg/pot	Kex used mg/pot	Knex used mg/pot	Percentage of Knex used
Kalathur	K_0	225	31	-	68	157	69.7
	K_1	247	88	90	101	146	59.1
	K_2	333	91	180	188	145	43.5
	K_3	350	121	270	248	102	29.1
Kivalur	K_0	226	61	-	44	182	80.5
	K_1	226	114	90	81	145	64.2
	K_2	250	139	180	146	104	41.6
	K_3	265	194	270	181	84	31.7
Nedumbalam	K_0	222	95	-	79	143	64.4
	K_1	253	152	90	112	141	55.7
	K_2	309	173	180	181	128	41.4
	K_3	327	214	270	230	97	29.7
Padugai	K_0	222	72	-	36	186	83.8
	K_1	249	122	90	76	173	69.5
	K_2	272	168	180	120	158	56.8
	K_3	306	182	270	196	110	35.9
Pattukkottai	K_0	290	57	-	6	284	97.9
	K_1	316	67	90	86	230	72.8
	K_2	361	91	180	152	209	57.9
	K_3	380	133	270	200	180	47.4
Sikkur	K_0	152	48	-	30	122	80.3
	K_1	185	88	90	80	105	56.8
	K_2	215	136	180	122	93	43.3
	K_3	260	166	270	182	78	30.0
Madukkur	K_0	114	30	-	12	102	89.5
	K_1	190	36	90	96	94	49.5
	K_2	210	96	180	126	84	40.0
	K_3	220	168	270	144	76	34.5
Melakadu	K_0	126	12	-	6	120	95.2
	K_1	148	66	90	42	106	71.6
	K_2	174	114	180	84	90	51.7
	K_3	211	156	270	132	79	37.4

It was also observed that without added K (K_0), the Kex used by the crop ranged from 6 mg/pot in soil S_{10} to 36 mg/pot in soil S_6. The above parameter increased with increasing levels of added K. The highest and lowest values were recorded in S_8 (336 mg/pot) and in S_{10} (126 mg/pot) respectively.

In contrast to Kex, the extent of Knex used decreased as the K levels increased in all the soils. The decrease of Knex with increase of K levels was the highest in soil S_5 (135 mg/pot) and lowest in soil S_9 (26 mg/pot).

4.4.4. Correlation studies

The results of simple correlations between cumulative dry matter yield and cumulative K uptake values on one hand and the various K availability indices on the other hand are furnished in Tables 14, 14a and 14b. With the cumulative dry matter yield, the Kex used gave the highest positive correlation (r = 0.717**), while per cent Knex used was negatively correlated (r = -0.504**). With cumulative K uptake also, Kex (r = 0.865**) and per cent Knex used (r = -0.632**) were correlated positively and negatively respectively.

4.5. Pot experiment to study the response of rice to added K in different soils

The data regarding the yield, content and uptake of K, correlation studies between different extractants for K and

TABLE 14

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN CUMULATIVE DRY MATTER YIELD (Y) AND DIFFERENT K AVAILABILITY INDICES (X) EXHAUSTIVE CROPPING
(n = 10)

Sl. No.	Y variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	H_2O-K	0.014	NS
2.	Neutral N NH_4OAc-K	0.379	NS
3.	0.1N HCl-K	0.391	NS
4.	0.5N HCl-K	0.511	NS
5.	0.1N HNO_3-K	0.354	NS
6.	0.5N HNO_3-K	0.396	NS
7.	0.5N EDTA-K	0.216	NS
8.	0.5N NaCl-K	0.368	NS
9.	1 per cent citric acid-K	0.571	NS
10.	0.01M $CaCl_2$-K	0.492	NS
11.	N HNO_3-K	0.586	NS
12.	Knex	0.563	NS
13.	Cumulative release-K	0.479	NS
14.	AR_e^k	0.479	NS
15.	$-\Delta K^o$	0.072	NS
16.	PBC^k	0.156	NS
17.	ΔG	0.128	NS
18.	K potential	0.099	NS
19.	Total-K	0.188	NS

TABLE 14a

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN CUMULATIVE K UPTAKE AND DIFFERENT K AVAILABILITY INDICES - EXHAUSTIVE CROPPING (n = 10)

Sl. No.	Variables	Correlation coefficient (r)	Regression equatin (Y = a + bx)
1.	H_2O-K	0.071	NS
2.	Neutral N NH_4OAc-K	0.381	NS
3.	0.1N HCl-K	0.311	NS
4.	0.5N HCl-K	0.431	NS
5.	0.1N HNO_3-K	0.274	NS
6.	0.5N HNO_3-K	0.307	NS
7.	0.5N EDTA-K	0.113	NS
8.	0.5N NaCl-K	0.309	NS
9.	1 per cent citric acid-K	0.511	NS
10.	0.01M $CaCl_2$-K	0.466	NS
11.	N HNO_3-K	0.447	NS
12.	Knex	0.435	NS
13.	Cumulative release-K	0.404	NS
14.	AR_e^k	-0.418	NS
15.	$-\Delta K^o$	0.043	NS
16.	PBC^k	0.045	NS
17.	ΔG	0.137	NS
18.	K potential	0.007	NS
19.	Total-K	0.194	NS

TABLE 14b

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN CUMULATIVE DRY MATTER YIELD AND Kex, Knex USED AND PERCENTAGE OF Knex - EXHAUSTIVE CROPPING (n = 40)

Sl. No.	Variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	Kex used	0.717**	Y = 12.2 + 0.03x
2.	Knex used	0.226	NS
3.	% of Knex	-0.504**	Y = 22.7 - 0.10x

TABLE 14c

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN CUMULATIVE K UPTAKE AND Kex, Knex USED AND PERCENTAGE OF Knex - EXHAUSTIVE CROPPING (n = 40)

Sl. No.	Variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	Kex used	0.865**	Y = 164.5 + 0.82x
2.	Knex used	0.121	NS
3.	% of Knex	-0.632**	Y = 427.9 - 2.57x

** - Significant at 1 per cent level

NS - Not significant

grain and straw yield besides K uptake are presented in Tables 15, 15a, 15b, 16, 17, 18, 19, 20, 20a, 20b, 20c and 20d.

4.5.1. Grain and straw yields

4.5.1.1. Grain yield (Table 15)

Application of K_2 and K_4 levels being on par registered higher grain yield than the rest. The treatment K_0 recording numerically lower yield was on par with K_1 level. With respect to grain yield, the ten soils tended to be in three different groups. The series of soils - S_9, S_7 and S_8 recorded the highest yield followed by series of soils - S_{10}, S_5, S_3, S_1 and S_6 and the series - S_4 and S_2 in decreasing order.

The results of interaction between soils and K levels on grain yield revealed that, soil S_9 under K_1, K_2 and K_4 levels; soil S_7 under K_3 level performed better than other soils. On the other hand, added K levels did not increase the grain yield in soils S_5 and S_6. However, the level K_2 in soils S_1 and S_2; K_3 level in soils S_4, S_8 and S_{10}; K_4 level in soils S_3, S_7 and S_9 favoured the grain yield in general.

4.5.1.1.1. Response functions

The performance of ADT 31 rice under varying K levels along with response functions, equations, R^2 values, actual and predicted yields in different soils are presented in Tables 15a and 15b and the response curves for the above soils are depicted in Figs. 8 and 8a.

TABLE 15

GRAIN YIELD OF ADT 31 RICE IN g/pot - POT CULTURE

(Mean of two replications)

Soil No.	Name of soil series \ K levels	K_0	K_1	K_2	K_3	K_4	Mean
1.	Adanur	29.3	35.4	47.5	21.5	37.1	34.2
2.	Alathur	13.0	21.4	35.7	16.0	33.9	24.0
3.	Kalathur	30.0	20.0	41.9	26.6	44.7	34.6
4.	Kivalur	18.5	13.6	30.5	34.0	32.7	25.9
5.	Nedumbalam	36.4	39.6	30.3	31.6	37.1	35.0
6.	Padugai	32.1	37.6	38.4	26.7	32.5	33.4
7.	Pattukkottai	29.1	34.7	44.0	51.4	63.1	44.5
8.	Sikar	28.9	30.1	47.4	50.9	50.6	41.6
9.	Madukkur	29.7	43.1	58.9	31.5	70.2	46.7
10.	Melakadu	35.6	24.8	35.4	41.7	39.2	35.3
	Mean	28.3	31.0	41.0	33.2	44.1	

	Particulars	S.E.	C.D.(0.05)
i)	K levels	1.3	3.7
ii)	Soils	1.9	5.3
iii)	Interaction		
	Soils x K levels	4.1	11.8

RESPONSE OF ADT 31 RICE TO K APPLICATION IN THE MAJOR SOIL SERIES OF THANJAVUR DISTRICT

(Pot culture)

Soil No.	Name of soil series	Response functions: Linear	Quadratic	Cubic	Best fit	Response equation	R^2	Grain yield: Actual	Predicted
1.	Adanur	NS	NS	Sig**	Cubic	$Y = 27.524 + 31.2098x - 19.2164x^2 + 2.9758x^3$	0.699	K_0 = 29.30	27.52
								K_1 = 35.39	39.62
								K_2 = 47.54	36.88
								K_3 = 21.45	28.55
								K_4 = 37.13	35.35
2.	Alathur	Sig.**	NS	Sig.**	Cubic	$Y = 11.425 + 30.5139x - 16.8228x^2 + 2.6224x^3$	0.727	K_0 = 13.02	11.43
								K_1 = 21.36	27.74
								K_2 = 35.71	26.14
								K_3 = 15.99	22.37
								K_4 = 33.75	32.15
3.	Kalathur	Sig.**	NS	Sig.**	Linear	$Y = 25.43+3.594x$	0.599	K_0 = 29.99	25.43
								K_1 = 20.00	29.02
								K_2 = 41.85	32.21
								K_3 = 26.58	36.21
								K_4 = 44.67	39.81
4.	Kivalur	Sig.**	NS	Sig.	Linear	$Y = 16.128+ 0.0973x$	0.689	K_0 = 18.53	16.13
								K_1 = 13.58	20.09
								K_2 = 30.54	25.86
								K_3 = 34.00	30.73
								K_4 = 32.68	35.59

Contd...

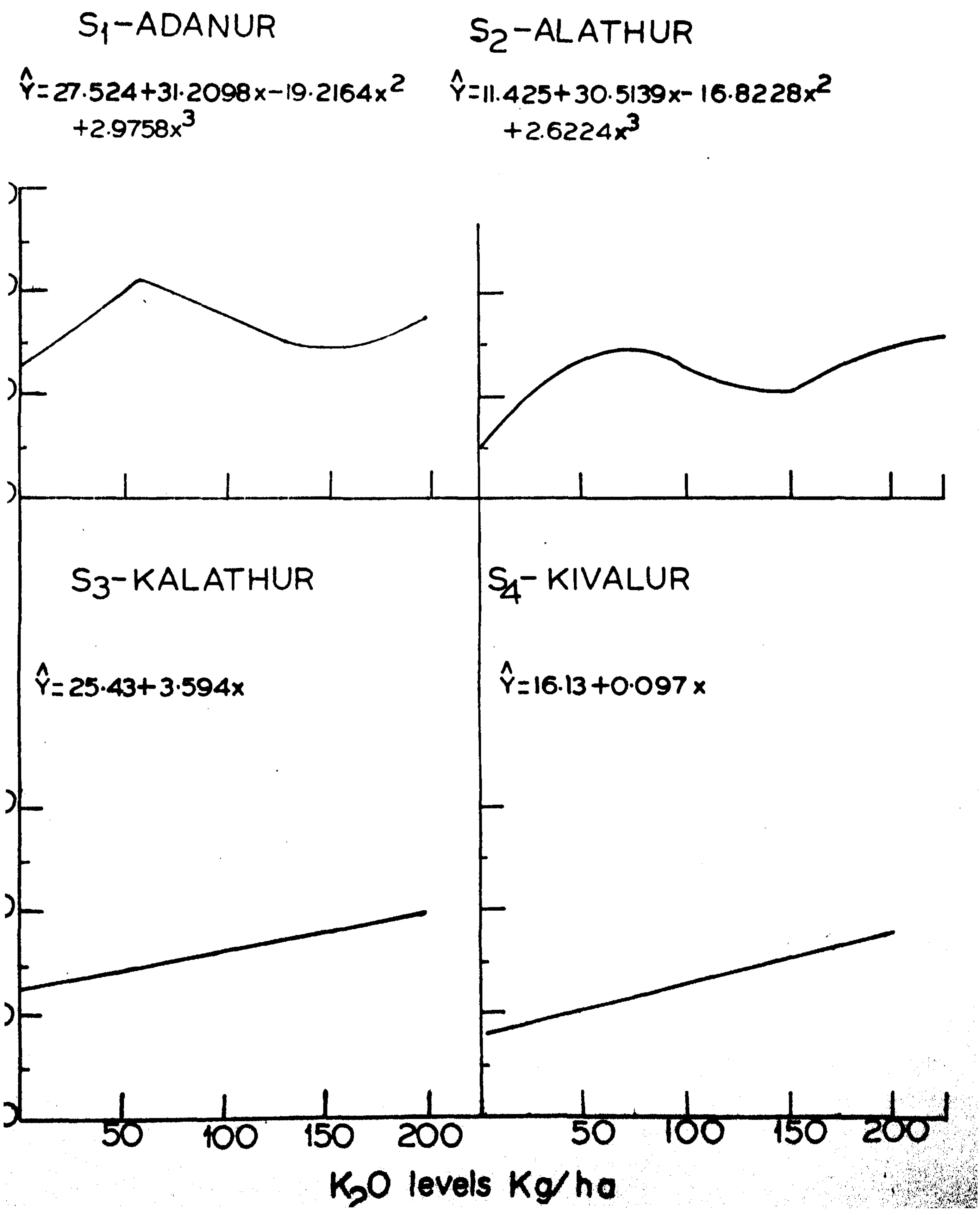
Soil No.	Name of soil series	Response functions: Linear	Response functions: Quadratic	Response functions: Cubic	Best fit	Response equation	R^2	Grain yield: Actual	Grain yield: Predicted
5.	Nedumbalam	NS	NS	NS	-	-	-	-	-
6.	Padugai	NS	NS	NS	-	-	-	-	-
7.	Pattukkottai	Sig.**	NS	NS	Linear	$Y = 27.494 + 0.1696x$	0.880	K_0 = 29.10	27.49
								K_1 = 34.65	35.97
								K_2 = 44.65	44.45
								K_3 = 51.36	52.93
								K_4 = 63.14	61.41
8.	Sikar	Sig.**	NS	NS	Linear	$Y = 28.774 + 0.1293x$	0.722	K_0 = 28.96	28.77
								K_1 = 30.10	35.19
								K_2 = 47.42	41.68
								K_3 = 50.93	48.03
								K_4 = 50.63	54.44
9.	Madukkur	Sig.**	Sig.**	Sig.**	Cubic	$Y = 27.5 + 1.00936x - 0.01252x^2 + 0.00004246x^3$	0.723	K_0 = 29.72	27.51
								K_1 = 43.13	51.97
								K_2 = 58.90	45.64
								K_3 = 31.54	40.38
								K_4 = 70.24	68.03
10.	Melakadu	Sig.**	NS	NS	Linear	$Y = 30.47 + 0.0485x$	0.352	K_0 = 35.56	30.47
								K_1 = 24.75	32.90
								K_2 = 33.41	35.32
								K_3 = 41.65	37.75
								K_4 = 39.24	40.17

TABLE 13b

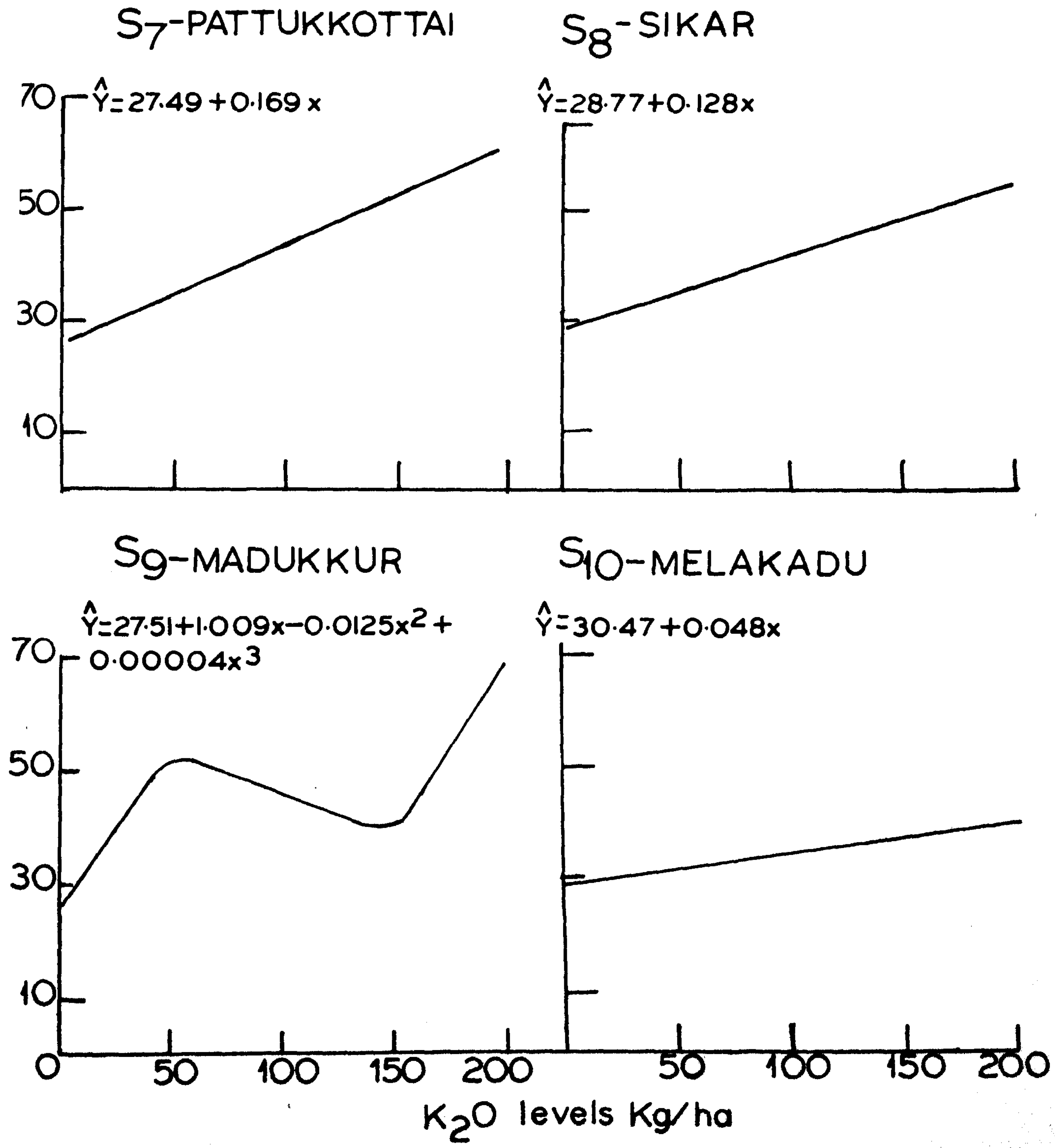
OPTIMUM LEVELS OF K AND THE CORRESPONDING YIELDS IN DIFFERENT SOIL SERIES (POT CULTURE)

Soil No.	Name of soil series	Physical optimum level of K (kg/ha)	Maximum grain yield	
			g/pot	kg/ha
1.	Adanur	54.18	42.56	5618
2.	Alathur	65.69	28.42	3751
3.	Kalathur	-	-	-
4.	Kivalur	-	-	-
5.	Nedumbalam	-	-	-
6.	Padugai	-	-	-
7.	Pattukkottai	-	-	-
8.	Sikar	-	-	-
9.	Madukkur	57.00	52.00	6864
10.	Melakadu	-	-	-

RESPONSE CURVES FOR DIFFERENT SOILS (POTCULTURE)



5. RESPONSE CURVES FOR DIFFERENT SOIl (POTCULTURE)



For soils S_1, S_2 and S_9 the cubic response functions were proved to be the best fit based on the highest R^2 value. For soils S_3, S_4, S_7, S_8 and S_{10}, linear functions were found to be the best fit. There was no response for added K in soils S_5 and S_6.

For soils S_1, S_2, and S_9 the physical optimum levels of K were 54, 66 and 57 kg K_2O/ha respectively. But for soils S_9 alone in field trial, both physical and economic optima of K were computed and reported under section 4:6:4:4:1. The corresponding maximum grain yield of ADT 31 rice for optimum levels of K, 54 (S_1), 66 (S_2) and 57 kg/ha (S_9) were 5618, 3751 and 6864 kg/ha respectively.

For soils S_3, S_4, S_7, S_8 and S_{10} linear function was observed to be the best fit and hence no physical optimum was worked out.

4.5.1.2. <u>Straw yield</u> (Table 16)

Among the K levels tried, K_2 and K_4 recorded higher straw yields than K_3, K_0 and K_1 levels which were on par with each other. Soils S_7, S_8, S_9, S_1, S_6 and S_{10} were on par, but the soils S_7 and S_8 in the above group were found to perform better than the rest since all other soils except S_4 and S_2 were also on par.

TABLE 16

STRAW YIELD OF ADT 31 RICE IN g/pot - POT CULTURE

(Mean of two replications)

Soil No.	Name of soil series \ K levels	K_0	K_1	K_2	K_3	K_4	Mean
1.	Adanur	46.1	56.4	49.1	35.3	44.2	46.2
2.	Alathur	26.9	28.4	50.0	27.5	39.4	34.4
3.	Kalathur	40.3	39.1	47.1	34.2	46.1	41.3
4.	Kivalur	33.4	28.3	39.7	34.0	41.7	35.4
5.	Nedumbalam	48.9	36.0	43.5	38.7	37.2	40.8
6.	Padugai	48.4	38.1	44.1	41.6	56.8	45.8
7.	Pattukkottai	40.1	41.8	65.5	61.9	53.5	52.5
8.	Sikar	45.2	45.6	53.1	58.0	49.7	50.3
9.	Madukkur	41.3	56.3	54.2	49.5	42.0	48.8
10.	Melakadu	44.2	39.7	46.9	45.9	48.2	45.0
	Mean	41.5	41.0	49.3	42.6	46.0	

	Particulars	S.E.	C.D. (0.05)
i)	K levels	2.2	6.1
ii)	Soils	3.1	8.7

4.5.2. Uptake of nutrients

4.5.2.1. Uptake of K in grain (Table 17)

The K_4 and K_2 levels being on par induced higher uptake than K_3 and K_1 between which there was no difference. The lowest uptake was recorded in K_0 level. The soils S_9, S_7 and S_8 performing similarly recorded higher uptake of K than S_1 and S_3 which in turn were superior to S_{10}, S_4, S_6 and S_5. The results of interaction between soils and K levels revealed that the added K levels did not influence the uptake in soils S_5, S_6 and S_{10}. In soil S_9, the K_4 level followed by K_2 increased the uptake. In the case of soils S_4, S_7 and S_8 higher levels of K promoted the uptake while lower levels reduced the same. The rest of the soils did not follow a regular pattern in K uptake.

4.5.2.2. Uptake of K in straw (Table 18)

The levels K_4 and K_2 being on par registered higher uptake of K in straw than K_3, K_1 and K_0 among which K_1 and K_0 remained on par. The soils S_1, S_7, S_8 and S_9 behaving similarly recorded higher uptake of K than soils S_2, S_6 and S_{10} which in turn recorded higher uptake than soils S_3, S_5 and S_4.

4.5.2.3. Total uptake of K (Table 19)

The effect of K levels on total uptake of K was conspicueus. Among the K levels, K_4 and K_2 reflecting same influence

TABLE 17

POTASSIUM UPTAKE IN GRAIN IN mg/pot - POT CULTURE

(Mean of two replications)

Soil No.	K levels / Name of soil series	K_0	K_1	K_2	K_3	K_4	Mean
1.	Adanur	248	355	441	189	373	321
2.	Alathur	75	150	281	136	322	192
3.	Kalathur	216	270	386	241	398	302
4.	Kivalur	141	124	252	332	305	231
5.	Nedumbalam	277	282	264	221	269	262
6.	Padugai	276	249	288	207	286	261
7.	Pattukkottai	181	281	379	392	481	343
8.	Sikar	196	242	389	457	366	330
9.	Madukkur	191	246	499	253	606	379
10.	Melakadu	236	203	280	313	309	268
	Mean	203	250	346	274	371	

	Particulars	S.E.	C.D.(0.05)
i)	K levels	13	36
ii)	Soils	18	51
iii)	Interaction Soils x K levels	40	113

TABLE 18

POTASSIUM UPTAKE IN STRAW IN mg/pot - POT CULTURE

(Mean of two replications)

Soil No.	K levels / Name of soil series	K_0	K_1	K_2	K_3	K_4	Mean
1.	Adalur	551	704	763	612	704	662
2.	Alathur	397	469	811	457	622	551
3.	Kalathur	377	403	489	435	618	464
4.	Kivalur	274	280	474	437	676	428
5.	Nedumbalam	450	455	450	460	482	459
6.	Padugai	460	432	561	542	702	539
7.	Pattukkottai	391	485	829	692	735	626
8.	Sikar	386	476	693	584	808	589
9.	Madukkur	356	556	718	732	583	589
10.	Melakadu	362	398	536	569	741	521
	Mean	400	466	632	552	670	

	Particulars	S.E.	C.D.(0.05)
i)	K levels	26	73
ii)	Soils	36	103

TABLE 19

TOTAL UPTAKE OF POTASSIUM IN mg/pot - POT CULTURE

(Mean of two replications)

Soil No.	Name of soil series \ K levels	K_0	K_1	K_2	K_3	K_4	Mean
1.	Adamur	799	1055	1204	806	1077	988
2.	Alathur	472	618	891	592	944	703
3.	Kalathur	593	672	874	675	1015	766
4.	Kivalur	415	404	725	769	981	659
5.	Nedumbalam	727	787	714	681	751	734
6.	Padugai	741	681	849	749	964	796
7.	Pattukkottai	576	766	1208	1084	1216	970
8.	Sikar	581	718	1083	1039	1174	919
9.	Madukkur	547	902	1217	985	1188	967
10.	Melakadu	598	601	816	881	1050	789
	Mean	605	720	958	826	1036	

	Particulars	S.E.	C.D.(0.05)
i)	K levels	35	100
ii)	Soils	50	141

recorded highest uptake followed by K_3, K_1 and K_0 in decreasing order.

Among the soils, the total uptake ranged from 659 to 988 mg of K/pot. The soils S_1, S_7, S_9 and S_8 being on par resulted in higher uptake. However, the 1st three soils were found to register higher uptake than S_8 which in turn was on par with the rest of soils.

4.5.3. <u>Correlation studies for identifying suitable extractant for availability</u>

The K extracted by different extractants in the initial soil samples of the 10 major soil series was correlated with grain and straw yields of ADT 31 rice on one hand and with the uptake in grain and straw and total uptake of K on the other hand. The simple correlations along with regression equations are furnished in Tables 20, 20a, 20b, 20c and 20d.

The results of correlations made between grain yield and different K availability indices suggested that the neutral N NH_4OAc was significantly correlated with grain yield ($r = 0.636^*$) whereas the ΔG values were negatively correlated ($r = -0.655^*$). When the K availability indices were correlated with K uptake in grain, the boiling 1N HNO_3-K ($r = 0.852^{**}$) and neutral N NH_4OAc-K ($r = 0.640^*$) were significant.

Among the K availability indices correlated with straw yields and K uptake in straw, it was revealed that the neutral

TABLE 20

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN GRAIN YIELD (Y) AND K AVAILABILITY INDICES (X) - POT CULTURE
(n = 10)

Sl. No.	K availability indices	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	H_2O-K	0.309	NS
2.	0.1N HNO_3-K	0.382	NS
3.	0.5N HNO_3-K	0.433	NS
4.	1N HNO_3-K	0.201	NS
5.	0.1N HCl-K	0.380	NS
6.	0.5N HCl-K	0.325	NS
7.	1 per cent citric acid-K	0.386	NS
8.	0.5N EDTA-K	0.272	NS
9.	Morgan-K	0.331	NS
10.	0.01M $CaCl_2$-K	0.131	NS
11.	0.5N NaCl-K	0.219	NS
12.	Neutral N NH_4OAc-K	0.636*	Y = 26.5 + 0.06x
13.	AR_e^k	0.546	NS
14.	$-\Delta K^o$	0.363	NS
15.	PBC^k	0.356	NS
16.	ΔG	-0.655*	Y = 77.9 - 0.01x
17.	K potential	0.239	NS

* - Significant at 5 per cent level

NS - Not significant

TABLE 20a

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN STRAW YIELD (Y) AND K AVAILABILITY INDICES (x) - POT CULTURE
(n = 10)

Sl. No.	K availability indices	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	H_2O-K	0.008	NS
2.	Neutral N NH_4OAc-K	0.645*	Y = 36.3 + 0.05x
3.	0.1N HNO_3-K	0.319	NS
4.	0.5N HNO_3-K	0.340	NS
5.	1N HNO_3-K	0.131	NS
6.	0.1N HCl-K	0.301	NS
7.	0.5N HCl-K	0.194	NS
8.	1 per cent citric acid-K	0.272	NS
9.	0.5N EDTA-K	0.143	NS
10.	Morgan-K	0.197	NS
11.	0.01M $CaCl_2$-K	0.078	NS
12.	0.5N NaCl-K	0.153	NS
13.	AR_e^k	0.358	NS
14.	$-\Delta K^o$	0.272	NS
15.	ΔG	-0.582	NS
16.	PBC^k	0.291	NS
17.	K potential	0.190	NS

* - Significant at 5 per cent level

NS - Not significant

TABLE 20b

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN K UPTAKE IN GRAIN (Y) AND K AVAILABILITY INDICES (x) - POT CULTURE
(n = 10)

Sl. No.	K availability indices	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	H_2O-K	0.393	NS
2.	Neutral N NH_4OAc-K	0.640*	Y = 226.7 + 0.44x
3.	0.1N HNO_3-K	0.214	NS
4.	0.5N HNO_3-K	0.249	NS
5.	1N HNO_3-K	0.852**	Y = 277.4 + 0.01x
6.	0.1N HCl-K	0.222	NS
7.	0.5N HCl-K	0.150	NS
8.	1 per cent citric acid-K	0.184	NS
9.	0.5N EDTA-K	0.077	NS
10.	Morgan-K	0.127	NS
11.	0.01M $CaCl_2$- K	0.142	NS
12.	0.5N NaCl -K	0.087	NS
13.	AR_e^k	0.553	NS
14.	$-\Delta K^o$	0.508	NS
15.	ΔG	-0.537	NS
16.	PBC^k	0.484	NS
17.	K potential	0.398	NS

* - Significant at 5 per cent level

** - Significant at 1 per cent level

NS - Not significant

TABLE 20e

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN K UPTAKE IN STRAW (Y) AND K AVAILABILITY INDICES (x) - POT CULTURE

Sl. No.	K availability indices	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	H_2O-K	0.196	NS
2.	Neutral N NH_4OAc-K	0.634*	Y = 454.2 + 0.65x
3.	0.1N HNO_3-K	0.285	NS
4.	0.5N HNO_3-K	0.254	NS
5.	1N HNO_3-K	0.207	NS
6.	0.1N HCl-K	0.327	NS
7.	0.5N HCl-K	0.164	NS
8.	1 per cent citric acid-K	0.199	NS
9.	0.5N EDTA-K	0.014	NS
10.	Morgan-K	0.118	NS
11.	0.01M $CaCl_2$-K	0.019	NS
12.	0.5N NaCl-K	0.182	NS
13.	AR_e^k	0.459	NS
14.	$-\Delta K^o$	0.586	NS
15.	ΔG	-0.008	NS
16.	PBC^k	0.554	NS
17.	K potential	0.534	NS

* - Significant at 5 per cent level

NS - Not significant

TABLE 20d

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN TOTAL K UPTAKE (Y) AND K AVAILABILITY INDICES (x) - POT CULTURE
(n = 10)

Sl. No.	K availability indices	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	H_2O-K	0.139	NS
2.	Neutral N NH_4OAc-K	0.652*	Y = 675.9 + 1.09x
3.	0.1N HNO_3-K	0.251	NS
4.	0.5N HNO_3-K	0.258	NS
5.	1N HNO_3-K	0.132	NS
6.	0.1N HCl-K	0.269	NS
7.	0.5N HCl-K	0.143	NS
8.	1 per cent citric acid-K	0.193	NS
9.	0.5N EDTA-K	0.017	NS
10.	Morgan-K	0.087	NS
11.	0.01M $CaCl_2$-K	0.139	NS
12.	0.5N NaCl-K	0.108	NS
13.	AR_e^k	0.455	NS
14.	$-\Delta K^o$	0.555	NS
15.	ΔG	-0.489	NS
16.	PBC^k	0.545	NS
17.	K potential	0.464	NS

* - Significant at 5 per cent level

NS - Not significant

N NH_4OAc-K was significantly correlated with straw yield (r = 0.645*) and K uptake in straw (r = 0.634*).

Similarly, when K availability indices were correlated with total uptake of K, the neutral N NH_4OAc-K only was correlated (r = 0.652*).

4.5.3.1. Path analysis of different extractants towards grain, straw yield of rice and K uptake

Correlation matrix and path analysis of different extractants with grain, straw yields and K uptake are presented in Tables 20e, 20f and 20g. The results of path analysis in respect neutral N NH_4OAc alone was highlighted since other reagents were not significantly correlated with grain, straw yields and uptake of K. The results of simple correlations revealed that N NH_4OAc had a positive correlation with grain yield (r = 0.636*), straw yield (r = 0.645*) and K uptake (r = 0.652*). In the path analysis also it had positive direct effect.

4.6. Field experiment

A field trial was conducted in Madukkur soil series (S_9) based on the factual data obtained from the pot culture studies to elucidate the cubic response of the soil S_9 to added K in ADT 31 rice. This led to the investigation of status of other nutrients, nutrient ratios both in soil and plant, trend and magnitude of nutrient absorption in different physiological stages of rice as tools to explain the above behaviour.

TABLE 20e

DIRECT AND INDIRECT EFFECTS OF DIFFERENT EXTRACTANTS WITH GRAIN YIELD (Path analysis)

	N NH_4OAc	0.1N HNO_3	0.5N HNO_3	1N HNO_3	0.1N HCl	0.5N HCl	1% citric acid	0.5N EDTA	Morgan	0.01M $CaCl_2$	0.5N NaCl	Grain yield
N NH_4OAc	0.1272	-0.9601	2.1608	-0.3599	0.3030	-0.8036	0.1042	-0.0229	0.2655	-0.0610	-0.1173	0.636
0.1N HNO_3	0.0940	-1.2992	2.9403	-0.4218	0.4027	-1.0929	0.1243	-0.0728	0.3746	-0.1464	-0.5208	0.382
0.5N HNO_3	0.0927	-1.2888	2.9640	-0.4173	0.3999	-1.0929	0.1255	-0.0730	0.3738	-0.1436	-0.5072	0.433
1N HNO_3	0.0908	-1.0874	2.4542	-0.5040	0.3363	-0.9364	0.1109	-0.0508	0.3218	-0.1260	-0.4084	0.201
0.1N HCl	0.0951	-1.2914	2.9255	-0.4183	0.4051	-1.0974	0.1248	-0.0716	0.3734	-0.1444	-0.5208	0.380
0.5N HCl	0.0908	-1.2615	2.8780	-0.4193	0.3950	-1.1255	0.1294	-0.0719	0.3765	-0.1539	-0.5127	0.325
1% citric acid	0.1002	-1.2199	2.8099	-0.4223	0.3820	-1.1007	0.1323	-0.0270	0.3699	-0.1621	-0.4763	0.386
0.5N EDTA	0.0363	-1.1784	2.6972	-0.3190	0.3618	-1.0084	0.0445	-0.0802	0.3456	-0.1353	-0.4920	0.272
Morgan	0.0864	-1.2446	2.8336	-0.4147	0.3869	-1.0839	0.1252	-0.0709	0.3910	-0.1670	-0.5029	0.331
0.01M $CaCl_2$	0.0399	-0.9783	2.1904	-0.3266	0.3010	-0.8914	0.1104	-0.0558	0.3358	-0.1944	-0.3921	0.131
0.5N NaCl	0.0275	-1.2459	2.7684	-0.3790	0.3885	-1.0625	0.1161	-0.0727	0.3620	-0.1403	-0.5431	0.219

(Underlined values are direct effects)

R^2 .. 0.5707

Residual .. 0.6542

TABLE 20f

DIRECT AND INDIRECT EFFECTS OF DIFFERENT EXTRACTANTS WITH STRAW YIELD (Path analysis)

	N NH_4OAc	0.1N HNO_3	0.5N HNO_3	1N HNO_3	0.1N HCl	0.5N HCl	1% citric acid	0.5N EDTA	Morgan	0.01M $CaCl_2$	0.5N NaCl	Straw yield
N NH_4OAc	0.0867	1.3304	1.3215	-0.3571	0.2963	-1.3970	0.2243	-0.0277	-0.7530	0.0879	-0.1683	0.645
0.1N HNO_3	0.0648	1.8003	1.7982	-0.4186	0.3938	-1.8998	0.2673	-0.0881	-1.0624	0.2108	-0.7478	0.319
0.5N HNO_3	0.0639	1.7859	1.8127	-0.4141	0.3910	-1.8998	0.2698	-0.0883	-1.0602	0.2069	-0.7278	0.340
1N HNO_3	0.0626	1.5069	1.5009	-0.5002	0.3288	-1.6278	0.2385	-0.0615	-0.9127	0.1814	-0.5860	0.131
0.1N HCl	0.0656	1.7895	1.7891	-0.4151	0.3961	-1.9076	0.2684	-0.0867	-1.0591	0.2080	-0.7473	0.301
0.5N HCl	0.0626	1.7481	1.7601	-0.4161	0.3862	-1.9565	0.2784	-0.0869	-1.0680	0.2218	-0.7356	0.194
1% citric acid	0.0691	1.6905	1.7184	-0.4191	0.3736	-1.9135	0.2846	-0.0326	-1.0491	0.2335	-0.6834	0.272
0.5N EDTA	0.0250	1.6329	1.6496	-0.3166	0.3538	-1.7530	0.0956	-0.0971	-0.9360	0.1949	-0.7060	0.143
Morgan	0.0595	1.7247	1.7329	-0.4116	0.3783	-1.8841	0.2693	-0.0819	-1.1090	0.2405	-0.7216	0.197
0.01N $CaCl_2$	0.0275	1.3557	1.3396	-0.3241	0.2943	-1.5496	0.2374	-0.0676	-0.9526	0.2800	-0.5626	0.078
0.5N NaCl	0.0189	1.7265	1.6930	-0.3761	0.3799	-1.8470	0.2496	-0.0880	-1.0269	0.2022	-0.7793	0.153

(Underlined values are direct effects)

R^2 .. 0.6670

Residual .. 0.5753

vth

TABLE 20g

DIRECT AND INDIRECT EFFECTS OF DIFFERENT EXTRACTANTS WITH TOTAL UPTAKE OF K (Path analysis)

	N NH_4OAc	0.1N HNO_3	0.5N HNO_3	1N HNO_3	0.1N HCl	0.5N HCl	1% citric acid	0.5N EDTA	Morgan	0.01M $CaCl_2$	0.5N NaCl	Total K uptake
N NH_4OAc	0.0339	-0.5394	1.0049	-0.1083	3.8317	-1.7569	0.3644	0.0141	-2.3128	0.3835	-0.2632	0.652
0.1N HNO_3	0.0250	-0.7299	1.3637	-0.1270	5.0919	-2.3892	0.4342	0.0486	-3.2174	0.9196	-1.1685	0.251
0.5N HNO_3	0.0247	-0.7241	1.3785	-0.1256	5.0560	-2.3892	0.4384	0.0451	-3.2102	0.9025	-1.1381	0.258
1N HNO_3	0.0242	-0.6109	1.1414	-0.1517	4.2318	-2.0472	0.3875	0.0314	-2.7695	0.7914	-0.9163	0.132
0.1N HCl	0.0253	-0.7255	1.3605	-0.1259	5.1227	-2.3991	0.4360	0.0443	-3.2081	0.9074	-1.1685	0.269
0.5N HCl	0.0242	-0.7087	1.3385	-0.1262	4.9946	-2.4606	0.4522	0.0444	-3.2323	0.9672	-1.1502	0.143
1% citric acid	0.0267	-0.6854	1.3068	-0.1271	4.8307	-2.4064	0.4624	0.0167	-3.1811	1.0185	-1.0686	0.193
0.5N EDTA	0.0097	-0.6620	1.2544	-0.0960	4.5745	-2.2047	0.1534	0.0496	-2.8099	0.8500	-1.1039	0.017
Morgan	0.0230	-0.6993	1.3178	-0.1248	4.8921	-2.3695	0.4374	0.0418	-3.3522	1.0490	-1.1283	0.087
0.01M $CaCl_2$	0.0106	-0.5496	1.0187	-0.0983	3.8061	-1.9488	0.3856	0.0345	-2.8619	1.2212	-0.	0.139
0.5N NaCl	0.0073	-0.6999	1.2875	-0.1141	4.9126	-2.3228	0.4055	0.0449	-3.0762	0.8817	-	

(Underlined values are direct effects)

R^2 .. 0.9970

Residual .. 0.0544

4.6.1. Available nutrients at different stages of crop growth

4.6.1.1. Available nitrogen (Table 21; Fig.9)

Among the stages, tillering and flowering stages being on par registered more available N than the post-harvest stage. A general progressive increase of available N was noticed with increasing levels of K. The highest value was recorded under the K_4 level followed by K_2, K_1, K_3 and K_0 in decreasing order. The results of interaction between stages and K levels also followed similar trend as main effects.

4.6.1.2. Nitrate nitrogen (Table 21)

Nitrate nitrogen content of soil got reduced from tillering stage to post-harvest stage. The percentage reduction of NO_3-N was 10.0 and 21.0 respectively at flowering and post-harvest stages compared to tillering stage.

The applied K levels manifested conspicuous variation in NO_3-N in that as the K levels increased from K_0 to K_4, there were progressive increases of the above parameter. The results of interaction between stages and K levels also followed the same trend as main effects.

4.6.1.3. Ammoniacal nitrogen (Table 21)

Among the stages, tillering stage recorded the highest NH_4-N (20.6 ppm) which declined gradually and reached the lowest value (11.3 ppm) at post-harvest stage.

TABLE 21

AVAILABLE N, NO_3-N AND NH_4-N CONTENT OF SOIL (ppm)

(Mean of four replications)

K levels	Tillering			Flowering			Post-harvest			Mean		
	Av.N	NO_3-N	NH_4-N	Av.N	NO_3-N	NH_4-N	Av.N	NO_3-N	NH_4-N	Av.N	NO_3-N	NH_4-N
K_0	60.5	3.3	19.8	60.5	3.5	15.5	46.8	2.3	9.3	55.9	3.17	14.8
K_1	68.8	5.0	21.5	71.5	4.5	17.8	55.0	3.8	11.5	65.1	4.42	16.9
K_2	78.4	5.8	23.0	79.8	5.3	21.3	64.3	4.5	14.0	74.3	5.17	19.4
K_3	68.8	7.3	16.3	61.9	6.0	14.0	48.1	5.8	8.3	59.6	6.33	12.8
K_4	92.1	8.3	22.5	85.3	7.3	19.5	71.5	6.3	13.5	82.9	7.25	18.5
Mean	73.7	5.9	20.6	71.8	5.3	17.6	57.2	4.6	11.3			

	Particulars	S.E.			C.D.(0.05)		
		Av.N.	NO_3-N	NH_4-N	Av.N	NO_3-N	NH_4-N
i)	Stages	0.91	0.16	0.4	2.6	0.45	1.0
ii)	K levels	1.2	0.20	0.5	3.4	0.58	1.3
iii)	Interaction						
	Stages x K levels	2.0	0.35	0.8	5.9	1.01	2.3

FIG. 9 INFLUENCE OF K ON AVAILABLE N, P AND K

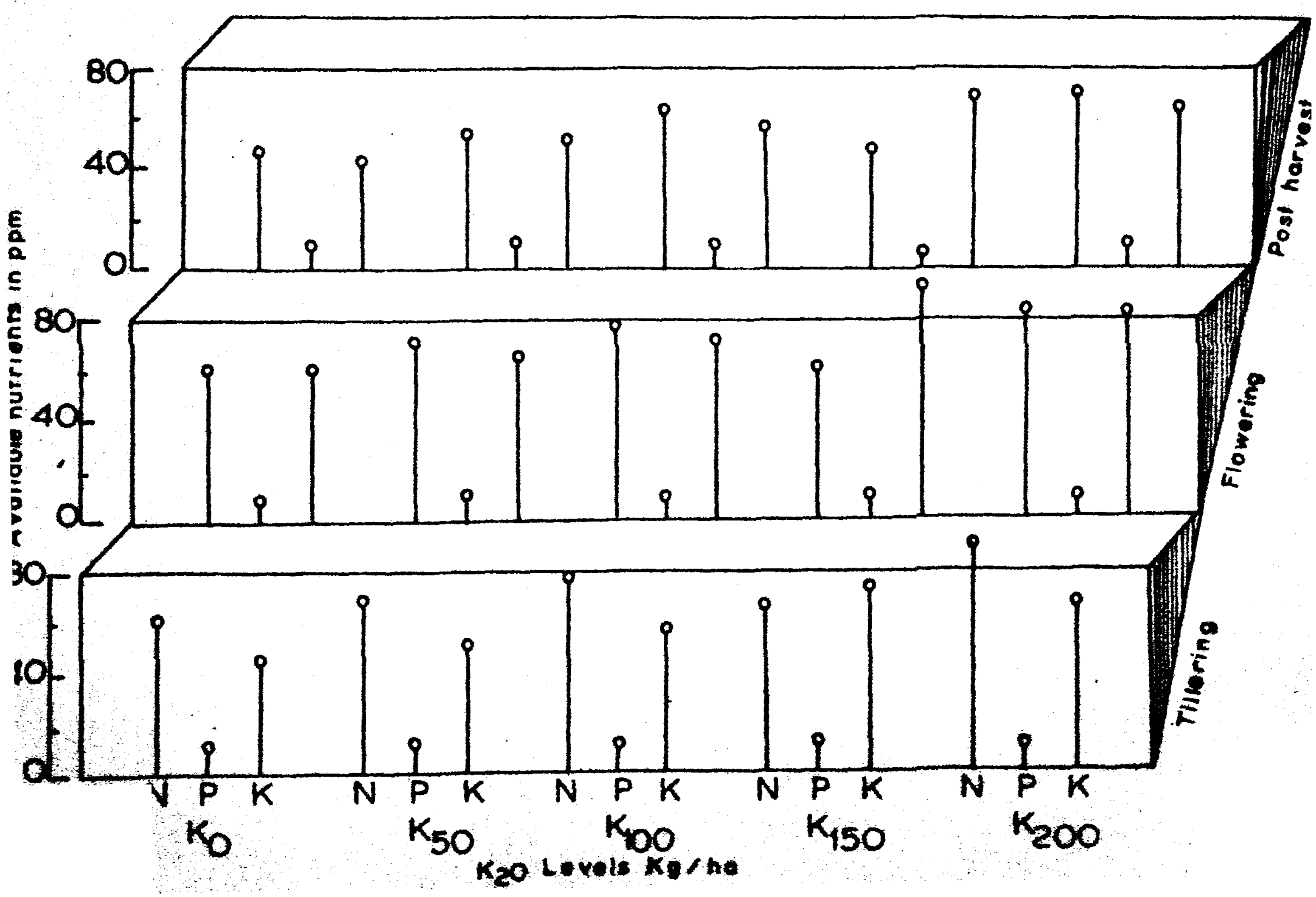
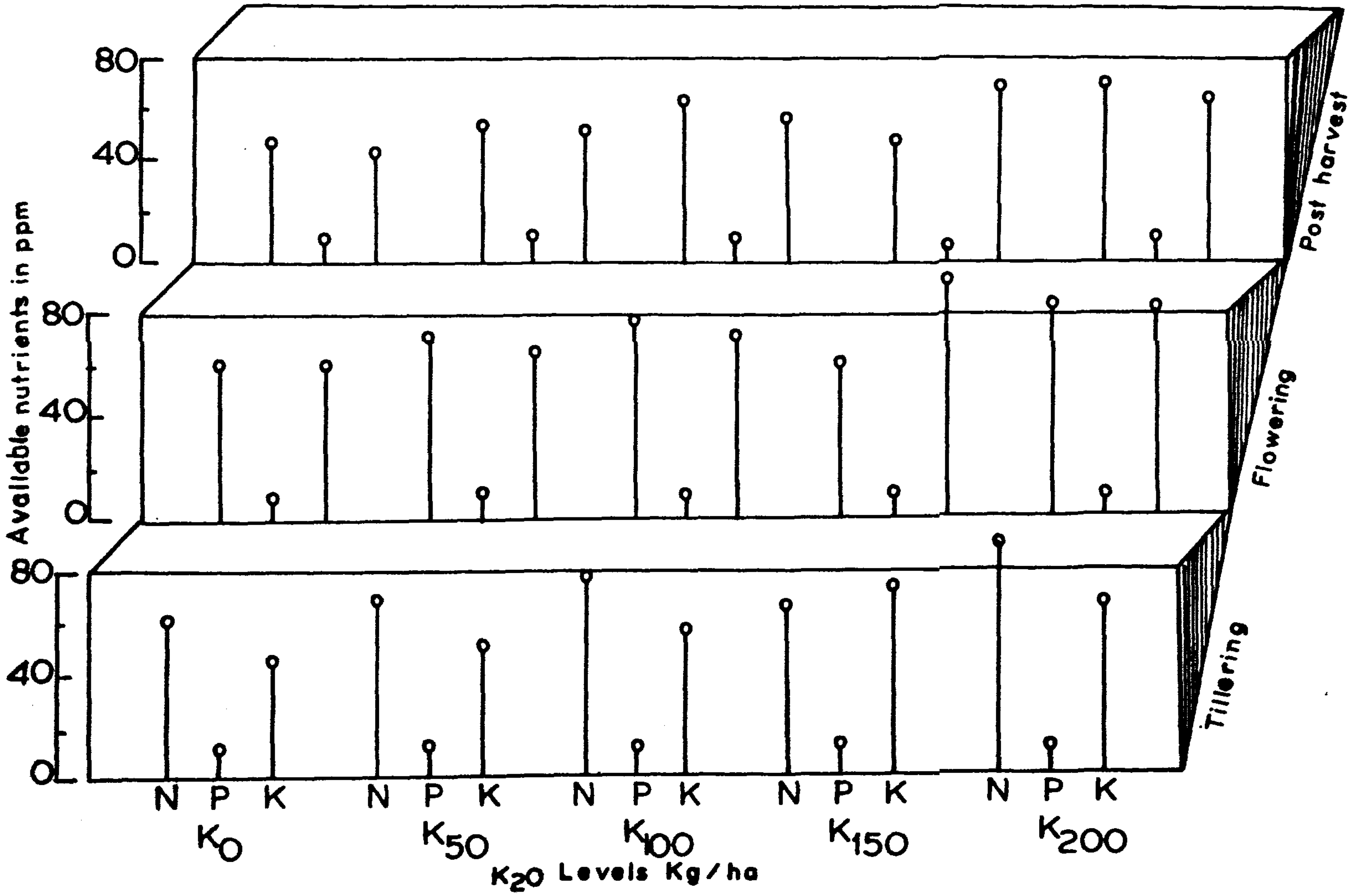


FIG. 9 INFLUENCE OF K ON AVAILABLE N, P AND K



Potassium levels exercised their influence on NH_4-N in soil. The levels K_2 and K_4 being on par accounted for higher values of NH_4-N than the rest. However, the level K_3 recorded the lowest value. The results of interaction between stages and K levels revealed that irrespective of K levels, tillering and post-harvest stages recorded the highest and lowest values of NH_4-N respectively.

4.6.1.4. Available phosphorus (Table 22; Fig.9)

The available P content ranged from 9.3 ppm (flowering stage) to 10.5 ppm (tillering stage). Though applied K levels promoted the P availability compared to control, all the levels were on par. Almost a similar trend was observed in the interaction of stages and K levels.

4.6.1.5. Exchangeable-K (Kex) (Table 22; Fig.9)

Flowering stage recorded the highest value which was 27 and 29 per cent more than the tillering and post-harvest stages respectively. However, there was no marked difference between tillering and post-harvest stages. Increased addition of K resulted in progressive increase in Kex at all stages but there was a spectacular increase in the above parameter at K_3 level than the rest.

TABLE 22

AVAILABLE-P, Kex AND Knex CONTENT OF SOIL (ppm)

(Mean of four replications)

K levels	Stages of rice growth											
	Tillering			Flowering			Post-harvest			Mean		
	Av.P	Kex	Knex	Av.P	Kex	Knex	Av.P	Kex	Knex	Av.P	Kex	Knex
K_0	10.1	45.1	623	8.9	60.0	604	8.9	43.8	583	9.3	49.6	603
K_1	10.5	50.0	634	9.7	65.0	616	9.1	52.5	601	9.8	55.8	617
K_2	10.6	58.8	645	9.5	72.0	633	9.9	58.8	614	10.0	63.3	630
K_3	10.8	73.8	663	9.7	93.8	649	8.9	70.0	630	9.8	79.2	647
K_4	10.8	67.5	679	10.0	83.8	665	9.7	65.0	646	10.1	72.1	663
Mean	10.5	59.0	649	9.6	75.0	633	9.3	58.0	615			

	Particulars	S.E.			C.D.(0.05)		
		Av.P	Kex	Knex	Av.P	Kex	Knex
i)	Stages	0.17	0.5	1.0	0.50	1.5	4.0
ii)	K levels	0.14	0.7	2.0	0.41	1.9	5.0
iii)	Interaction						
	K levels x Stages	0.25	1.2	3.0	0.77	3.5	8.0

4.6.1.6. Non-exchangeable-K (Knex) (Table 22)

The value of Knex declined from tillering stage (649 ppm) to post-harvest stage (615 ppm). As the K levels were increased from K_0 to K_4, the value of Knex also increased markedly at all the stages.

4.6.1.7. Boiling N HNO_3-K (Table 23)

Tillering and flowering stages being on par recorded higher values than post-harvest stage. As the K levels were increased, the above parameter also increased appreciably irrespective of stages.

4.6.1.8. Total potassium (Table 23)

Total potassium declined from tillering stage (1.08 per cent) to post-harvest stage (0.99 per cent).

Though applied K levels increased the total K in soils significantly over control, they were on par.

4.6.1.9. Available calcium (Table 24)

Available Ca was the highest (818 ppm) at tillering stage and the same declined towards post-harvest stage and reached the lowest value (636 ppm).

Added K levels promoted the Ca availability in that the level K_4 registered a 54.0 per cent increase in Ca availability over control. The results of interaction displayed between

TABLE 23

BOILING N HNO_3-K (ppm) AND TOTAL-K CONTENT OF SOIL (PERCENTAGE)

(Mean of four replications)

K levels	Stages of rice growth							
	Tillering		Flowering		Post-harvest		Mean	
	Boiling N HNO_3-K	Total-K	Boiling N HNO_3-K	Total-K	Boiling N HNO_3-K	Total-K	Boiling N HNO_3-K	Total-K
K_0	665	1.00	664	0.99	626	0.95	652	0.98
K_1	684	1.09	681	1.03	654	0.99	673	1.04
K_2	704	1.10	705	1.04	673	1.00	694	1.05
K_3	730	1.11	733	1.06	695	1.00	719	1.06
K_4	753	1.11	760	1.06	716	1.00	743	1.06
Mean	707	1.08	709	1.04	673	0.99		

	Particulars	S.E. Boiling N HNO_3-K	S.E. Total-K	C.D. (0.05) Boiling N HNO_3-K	C.D. (0.05) Total-K
i)	Stages	1.0	0.01	4.0	0.04
ii)	K levels	2.0	0.01	5.0	0.04
iii)	Interaction K levels x Stages	3.0	0.024	8.0	0.06

TABLE 24

AVAILABLE Ca, Mg AND Fe CONTENT OF SOIL (ppm)

(Mean of four replications)

K levels	Stages of rice growth											
	Tillering			Flowering			Post-harvest			Mean		
	Av.Ca	Av.Mg	Av.Fe	Av.Ca	Av.Mg	Av.Fe	Av.Ca	Av.Mg	Av.Fe	Av.Ca	Av.Mg	Av.Fe
K_0	650	252	130	580	217	129	470	205	117	567	225	125
K_1	730	301	149	650	266	146	570	223	134	650	263	143
K_2	820	329	167	720	320	179	640	266	150	727	305	165
K_3	900	371	128	820	333	125	740	274	117	820	326	123
K_4	990	413	117	880	353	125	760	302	112	877	356	118
Mean	818	333	138	730	298	141	636	254	126			

	Particulars	S.E.			C.D.(0.05)		
		Av.Ca	Av.Mg	Av.Fe	Av.Ca	Av.Mg	Av.Fe
i)	Stages	5.0	3.0	1.4	14.0	9.0	4.0
ii)	K levels	6.0	4.0	1.8	18.0	12.0	5.2
iii)	Interaction						
	K levels x Stages	11.0	7.0	3.0	31.0	21.0	9.0

stages and K levels also followed the same trend as that of main effects.

4.6.1.10. Available magnesium (Table 24)

Available Mg varied from 254 (post-harvest stage) to 330 ppm (tillering stage). The above parameter increased markedly with successive addition of K levels at all stages of crop growth.

4.6.1.11. Available iron (Table 24)

Tillering and flowering stages being on par registered higher available iron than post-harvest stage. Application of K up to K_2 level promoted the iron availability significantly. Evidently the level K_4 depressed the availability of iron. The results of interaction between stages and K levels also followed similar trend of main effects.

4.6.2. Nutrient ratios in soils (Table 25)

4.6.2.1. K/N ratio

Flowering stage numerically recorded the highest K/N ratio followed by post-harvest and tillering stages. The level K_3, being on par with K_4 recorded the highest value than the rest.

TABLE 25

AVAILABLE NUTRIENT RATIOS IN SOIL AT DIFFERENT STAGES OF CROP GROWTH

(Mean of four replications)

Stages	Nutrient ratios / K levels	K/N	K/NH_4-N	K/P	K/Knex	K/Ca	K/mg	K/Fe
Tillering stage (St_I)	K_0	0.26	1.05	8.09	0.07	0.04	0.05	0.51
	K_1	0.26	1.02	8.61	0.08	0.04	0.05	0.58
	K_2	0.27	1.19	10.14	0.09	0.04	0.06	0.51
	K_3	0.35	1.94	11.29	0.10	0.04	0.06	0.75
	K_4	0.39	1.51	12.26	0.11	0.04	0.06	0.91
Flowering stage (St_{II})	K_0	0.36	1.79	12.25	0.09	0.05	0.09	0.96
	K_1	0.33	1.69	11.97	0.09	0.05	0.08	0.64
	K_2	0.33	1.60	13.73	0.10	0.05	0.07	0.58
	K_3	0.49	2.80	15.49	0.12	0.05	0.08	0.94
	K_4	0.41	2.23	16.89	0.13	0.06	0.08	1.08
Post-harvest stage (St_{III})	K_0	0.33	2.18	3.93	0.08	0.05	0.07	0.53
	K_1	0.34	2.11	4.60	0.09	0.05	0.07	0.56
	K_2	0.33	1.94	4.73	0.10	0.05	0.07	0.56
	K_3	0.49	3.65	5.80	0.10	0.05	0.07	0.79
	K_4	0.35	2.38	5.75	0.11	0.05	0.07	0.88

(Contd...)

TABLE 25 (CONTINUED)

	Particulars		Mean values					S.E.	C.D.(0.05)
I.	K/N ratio:	Stages	St_I	St_{II}	St_{III}				
			0.288	0.389	0.368			0.037	0.085
		K levels	K_0	K_1	K_2	K_3	K_4		
			0.319	0.322	0.309	0.442	0.350	0.048	0.110
II.	K/NH_4-N ratio:	Stages	St_I	St_{II}	St_{III}				
			1.34	2.03	2.45			0.125	0.288
		K levels	K_0	K_1	K_2	K_3	K_4		
			1.68	1.61	1.57	2.79	2.04	0.160	0.369
III.	K/P ratio:	Stages	St_I	St_{II}	St_{III}				
			10.1	14.1	5.0			0.469	1.082
		K levels	K_0	K_1	K_2	K_3	K_4		
			8.09	8.52	9.53	10.8	11.3	0.606	1.398
IV.	K/Knex ratio:	Stages	St_I	St_{II}	St_{III}				
			0.091	0.104	0.094			0.0058	0.013
		K levels	K_0	K_1	K_2	K_3	K_4		
			0.078	0.086	0.097	0.107	0.115	0.0074	0.017

(Contd...)

TABLE 25 (CONTINUED)

	Particulars		Mean values					S.E.	C.D.(0.05)
V.	K/Ca ratio:	Stages	St_I		St_{II}		St_{III}		
			0.038		0.053		0.047	0.0005	0.001
		K levels	K_0	K_1	K_2	K_3	K_4		
			0.046	0.045	0.046	0.046	0.047	0.0006	0.001
VI.	K/Mg ratio:	Stages	St_I		St_{II}		St_{III}		
			0.054		0.078		0.070	0.004	0.0097
		K levels	K_0	K_1	K_2	K_3	K_4		
			0.068	0.067	0.064	0.069	0.070	0.0054	0.013
VII.	K/Fe ratio	Stages	St_I		St_{II}		St_{III}		
			0.631		0.841		0.662	0.055	0.128
		K levels	K_0	K_1	K_2	K_3	K_4		
			0.667	0.558	0.549	0.826	0.958	0.072	0.165

4.6.2.2. K/NH_4-N ratio

This ratio increased from tillering stage to post-harvest stage markedly. Application of K manifested both synergetic and antagonistic effect on the above parameter. The plot receiving no K recorded a value of 1.68. Subsequently, when the K level was increased to K_2, the above ratio value decreased to 1.57. Again when the K level was increased to K_3, the above parameter significantly increased to 2.79 and when the K level was further increased, the value declined to 2.04.

4.6.2.3. K/P ratio

The highest and lowest values of the above ratio were recorded at flowering and post-harvest stages respectively. Generally the ratio value increased as the K levels were increased. The levels of K_4 and K_3 behaving similarly recorded higher values of the ratio than the rest.

4.6.2.4. K/Knex ratio

The above ratio value did not differ significantly among stages. However, flowering and tillering stages numerically recorded the highest and lowest values respectively. With increase in K levels, there was an increase in the above value.

4.6.2.5. K/Ca ratio

This value ranged from 0.038 (tillering stage) to 0.053 (flowering stage). The levels K_4 and K_3 behaving similarly recorded higher ratio value than K_2, K_0 and K_1 among which there were no differences.

4.6.2.6. K/Mg ratio

Flowering and post-harvest stages being on par recorded higher values of K/Mg ratio than tillering stage. Added K levels did not cause conspicuous variation in the above value. However, the levels of K_4 and K_2 recorded numerically the highest and lowest values respectively.

4.6.2.7. K/Fe ratio

Flowering stage recorded the highest value (0.841) while post-harvest and tillering stages being on par registered the lowest. The lowest K/Fe ratio occurred at K_2 level and the same escalated as the K levels were lowered. Again when the K levels were increased to K_3 and K_4 the above ratio value also increased.

4.6.3. Q/I parameters

4.6.3.1. $-\Delta K^o$ (Table 26)

Tillering stage recorded the highest value of $-\Delta K^o$ (0.13 me/100 g soil) and the lowest value was associated in post-harvest stage (0.10 me/100 g soil). Among the K levels tried, K_4 and K_0 recorded respectively the highest and lowest values of the above parameter. The interaction effect was absent.

TABLE 26

$-\Delta K^{\circ}$ (me/100 g soil) AND AR_e^k (10^{-3} moles/litre)$^{1/2}$

(Mean of four replications)

K levels	Stages of rice growth							
	Tillering		Flowering		Post-harvest		Mean	
	$-K^{\circ}$	AR_e^k	$-K^{\circ}$	AR_e^k	$-K^{\circ}$	AR_e^k	$-K^{\circ}$	AR_e^k
K_0	0.11	8.1	0.09	7.7	0.08	6.8	0.09	7.5
K_1	0.12	9.5	0.11	8.4	0.08	7.2	0.10	8.3
K_2	0.13	10.6	0.12	9.2	0.10	8.5	0.11	12.9
K_3	0.12	11.2	0.13	10.4	0.11	8.7	0.12	10.1
K_4	0.14	12.1	0.13	11.2	0.12	9.3	0.13	10.8
Mean	0.13	10.3	0.11	9.4	0.10	8.1		

Particulars	S.E.		C.D.(0.05)	
	$-K^{\circ}$	AR_e^k	$-K^{\circ}$	AR_e^k
i) Stages	0.003	0.2	0.01	0.6
ii) K levels	0.002	0.3	0.005	0.8
iii) Interaction				
K levels x Stages	NS	0.5	NS	1.5

4.6.3.2. AR_e^k (Table 26)

The highest value of AR_e^k $(10.3 \times 10^{-3}$ m/1$)^{1/2}$ was observed at tillering stage and the same declined towards post-harvest stage significantly. The level K_2 recorded the higher value of AR_e^k than K_4 and K_3 which were on par recording higher values than K_1 and K_0 (on par).

4.6.3.3. PBC^k (Table 27)

Flowering and tillering stages being on par resulted in higher values of PBC^k than post-harvest stage. The added K levels did not influence the above parameter markedly. The interaction result did not follow a regular pattern.

4.6.3.4. ΔG (Table 27)

The above parameter significantly increased from tillering (-2761 calories) to post-harvest stage (-2903 calories). With increasing addition of K, ΔG values decreased markedly at all stages.

4.6.3.5. Potash potential (Table 27)

Tillering stage recorded the highest value (1.52) which declined towards post-harvest stage. The levels K_4 and K_0 respectively recorded the highest and lowest values of K - potential. Though the levels K_1, K_3 and K_2 increased the above parameter over K_0, they did not differ among themselves appreciably.

TABLE 27

ΔG (CALORIES) AND K POTENTIAL

(Mean of four replications)

K levels	Stages of rice growth											
	Tillering			Flowering			Post-harvest			Mean		
	PBC^k	ΔG	K pot	PBC^k	ΔG	K pot	PBC^k	ΔG	K pot	PBC^k	ΔG	K pot
K_0	12.9	-2898	1.37	12.0	-2928	1.12	11.0	-3001	0.83	12.0	-2942	1.10
K_1	12.9	-2804	1.59	12.6	-2882	1.33	11.2	-2975	0.91	12.2	-2897	1.28
K_2	12.3	-2737	1.60	12.9	-2827	1.51	11.2	-2873	1.07	12.1	-2812	1.40
K_3	10.9	-2706	1.35	12.0	-2750	1.51	11.7	-2850	1.26	11.6	-2768	1.37
K_4	11.8	-2659	1.69	11.7	-2705	1.52	13.2	-2817	1.60	12.2	-2727	1.60
Mean	12.2	-2761	1.52	12.2	-2818	1.40	11.7	-2903	1.13			

	Particulars	S.E.			C.D.(0.05)		
		PBC^k	ΔG	K pot	PBC^k	ΔG	K pot
i)	Stages	0.18	-2.2	0.04	0.50	-6.4	0.10
ii)	K levels	0.23	-2.8	0.05	0.65	-8.4	0.13
iii)	Interaction K levels x Stages	0.4	-5.0	0.08	1.1	-14.0	0.23

4.6.3.6. K_x values (Table 28)

Stages of crop growth did not differ among themselves in influencing K_x values markedly but added K levels brought out variation in the above parameter. The levels K_4 and K_0 recorded the highest and lowest values respectively at all stages.

4.6.3.7. K_L values (Table 28)

Tillering and flowering stages being on par recorded higher values of K_L than post-harvest stage. The levels K_4 and K_0 at all stages recorded the highest and lowest values respectively.

4.6.4. Dry matter yield of ADT 31 rice at different growth stages (Table 29)

4.6.4.1. Dry matter yield at tillering stage

The dry matter yield at tillering stage ranged from 5265 to 6413 kg/ha. Added K levels did not influence the above parameter significantly.

4.6.4.2. Dry matter yield at flowering stage

At flowering stage the level K_4 recorded the highest yield followed by K_2 level. The levels K_3 and K_1 being on par recorded more yield than K_0.

TABLE 28

K_x AND K_L (me/100 g soil)

(Mean of four replications)

K levels	Stages of rice growth							
	Tillering		Flowering		Post-harvest		Mean	
	K_x	K_L	K_x	K_L	K_x	K_L	K_x	K_L
K_0	0.20	0.30	0.19	0.28	0.18	0.25	0.19	0.28
K_1	0.21	0.33	0.20	0.31	0.20	0.28	0.20	0.30
K_2	0.21	0.34	0.22	0.34	0.23	0.33	0.22	0.33
K_3	0.23	0.35	0.23	0.36	0.23	0.34	0.23	0.35
K_4	0.23	0.38	0.24	0.37	0.24	0.36	0.24	0.37
Mean	0.22	0.34	0.22	0.33	0.22	0.31		

Particulars	S.E.		C.D.(0.05)	
	K_x	K_L	K_x	K_L
i) Stages	0.003	0.003	0.01	0.01
ii) K levels	0.002	0.003	0.005	0.008
iii) Interaction K levels x Stages	0.003	0.005	0.008	0.01

TABLE 29

DRY MATTER, STRAW AND GRAIN YIELDS OF ADT 31 RICE (kg/ha)

(Mean of four replications)

K levels	Stages of rice growth			
	Tillering	Flowering	Harvest-Straw	Harvest-Grain
K_0	5873	7763	7763	3983
K_1	6345	9315	7425	4860
K_2	6413	11813	8573	6008
K_3	5265	9855	7965	4253
K_4	5940	13163	8438	6750
Mean	5967	10382	8033	5171

	Particulars	S.E.	C.D.(0.05)
i)	Dry matter yield at tillering stage		
	K levels	489	1508
ii)	Dry matter yield at flowering stage		
	K levels	286	880
iii)	Straw yield		
	K levels	380	1170
iv)	Grain yield		
	K levels	384	1182

4.6.4.3. Straw yield (Fig.10)

Added K levels did not cause notable differences in straw yield but the level K_2 numerically increased the straw yield followed by K_4, K_3, K_0 and K_1 levels.

4.6.4.4. Grain yield (Fig.10)

Application of K at K_4 and K_2 levels being on par resulted in higher grain yields than K_1 level which in turn produced more grain yield than K_3 and K_0 between which there was no conspicuous variation.

4.6.4.4.1. Response function (Table 29a; Fig.11)

The response curve drawn between grain yield and K levels was of similar nature as it was reported for soil S_9 under pot culture experiment. Once again under field trial also soil S_9 manifested cubic response as best fit. The optimum level of K was found to be 59 kg K_2O/ha for getting the maximum grain yield of 5477 kg/ha. The economic dose of K for achieving maximum profit with different combinations of unit cost of K and grain ranged from 54 to 57 kg K_2O/ha as evidenced from Table 29a. Among the economic levels 54 kg K_2O/ha resulted in the highest profit of Rs.10823/ha.

FIG. 10 INFLUENCE OF K ON YIELD OF RICE (ADT31)

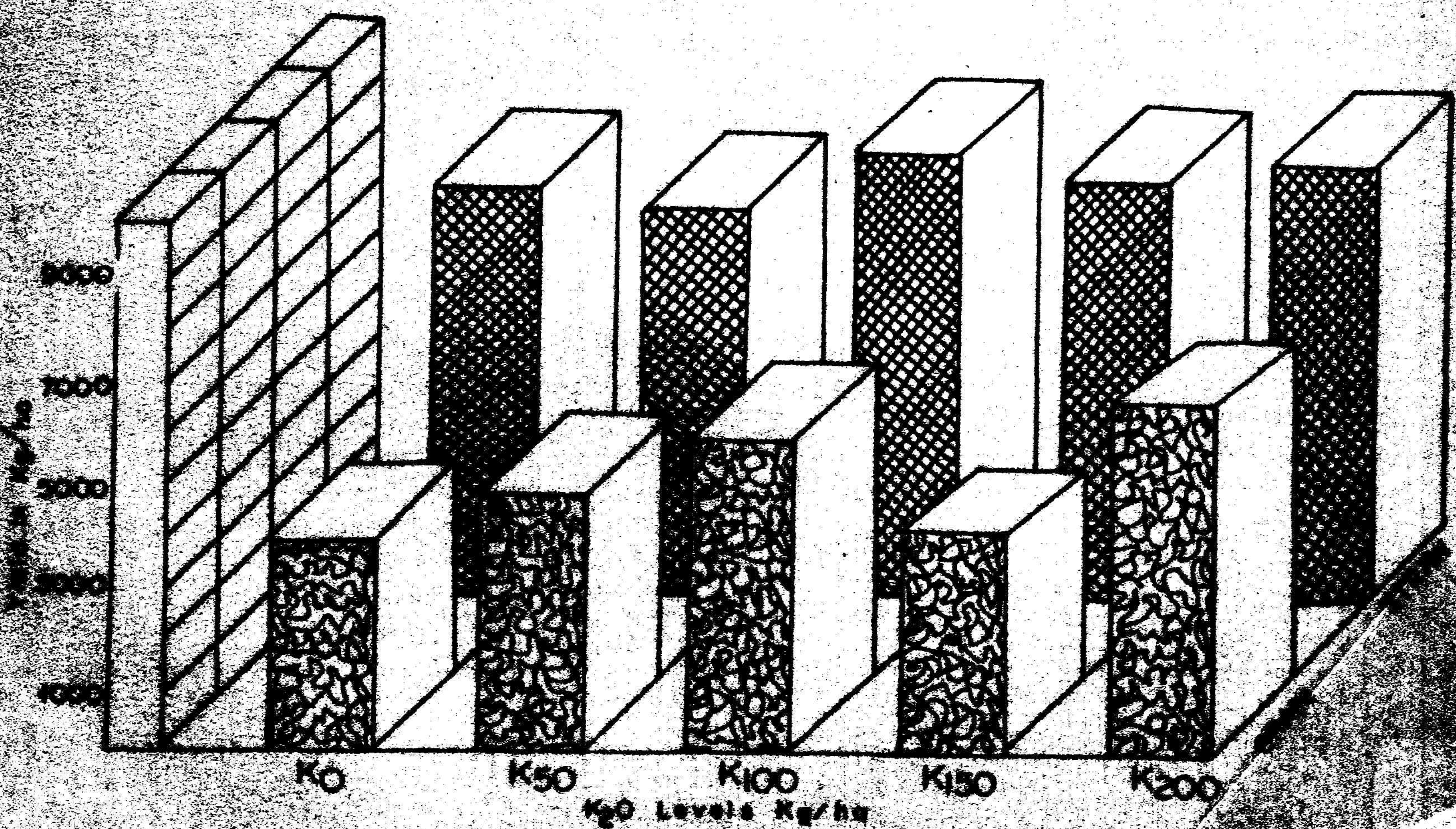


FIG. 10 INFLUENCE OF K ON YIELD OF RICE (ADT31)

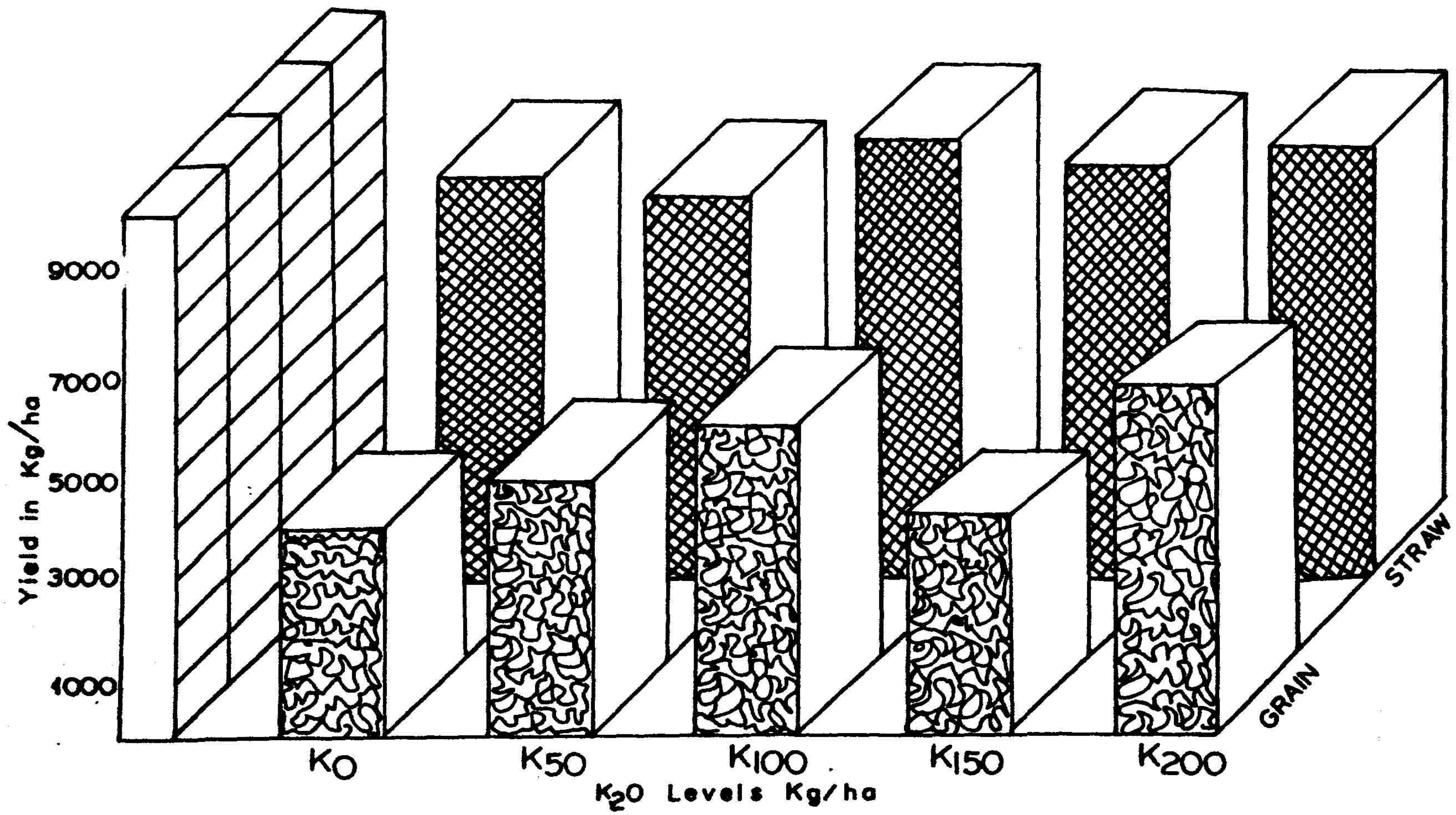


TABLE 29a

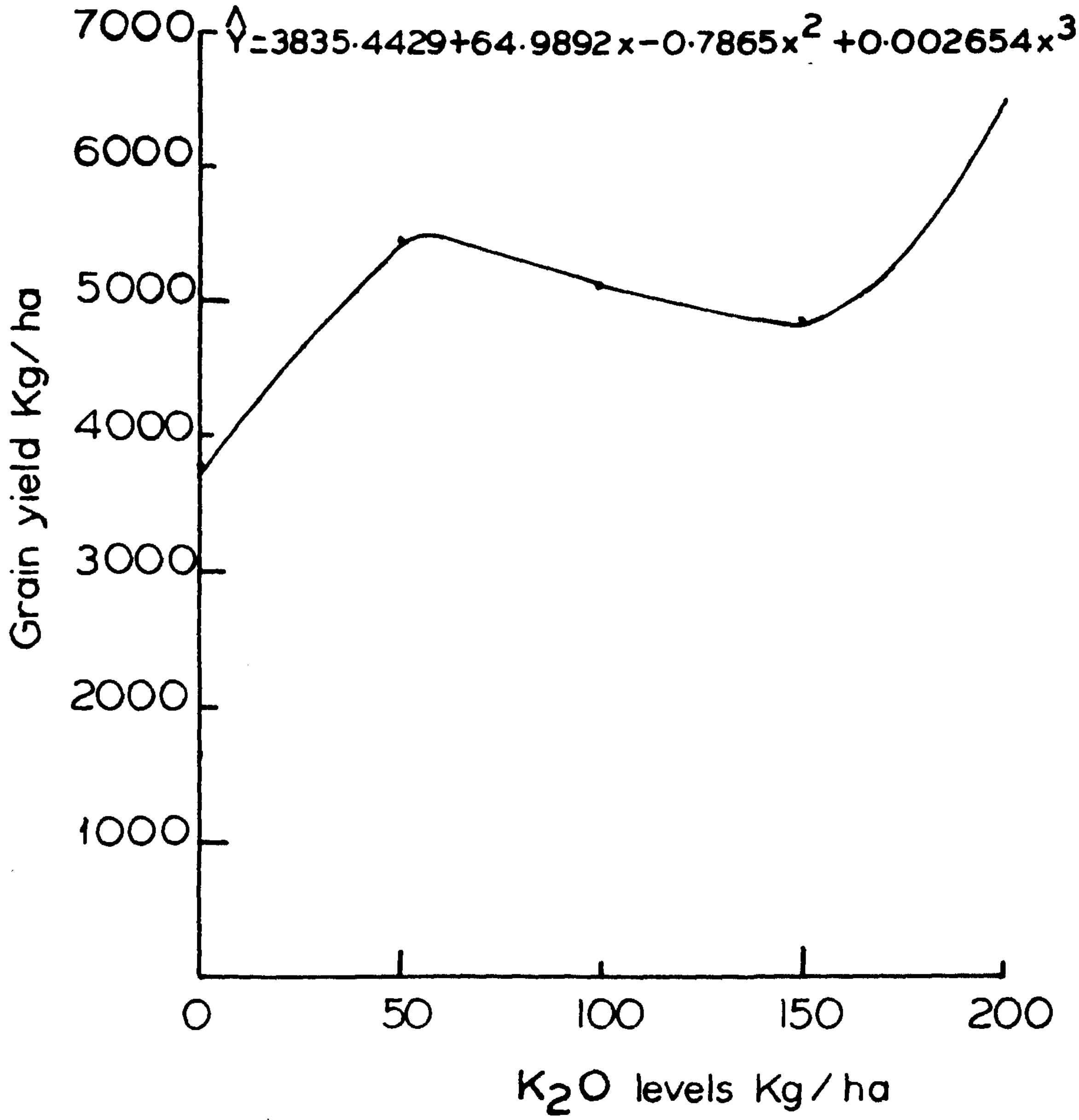
RESPONSE OF ADT 31 RICE TO K APPLICATION IN MADUKKUR SOIL SERIES - FIELD TRIAL

Soil No.	Response functions			Best fit	Response equation	R^2	Grain yield (kg/ha)	
	Linear	Quad-ratic	Cubic				Actual	Predicted
9	Sig*	Sig**	Sig**	Cubic	$Y = 3835.4429 + 64.9892x - 0.7865x^2 + 0.002654x^3$	0.723	K_0 = 3983	3835
							K_1 = 4860	5450
							K_2 = 6008	5123
							K_3 = 4253	4843
							K_4 = 6750	6602

PHYSICAL OPTIMUM AND ECONOMIC DOSE FOR ADT 31 RICE

Physical optimum level of K_2O (kg/ha)	Maximum grain yield (kg/ha)	Economic dose for different combination of P_x and P_y (kg/ha)								
		$P_x = 2.1$, $P_y = 1.6$			$P_x = 2.1$, $P_y = 1.8$			$P_x = 2.1$, $P_y = 2.0$		
		Economic dose	Yield	Maximum profit (Rs.)	Economic dose	Yield	Maximum profit (Rs.)	Economic dose	Yield	Maximum profit (Rs.)
59	5477	57	5475	8640	55	5462	9716	54	5468	10823

FIG. 11 RESPONSE CURVE FOR MADUKKUR SERIES (FIELD TRIAL)



4.6.5. Nutrient content at tillering, flowering and harvest stages

The contents of N, P, K, Ca,Mg and Fe at different physiological stages of ADT 31 are presented in Tables 30, 31 and 32.

In general, the above nutrient elements varied appreciably due to stages, K levels and their interaction effects.

Tillering stage recorded the highest content of all the nutrients followed by flowering stage and straw. In the case of nitrogen, the level K_4 recorded the highest value (1.57 per cent) followed by K_2, K_1, K_0 and K_3 levels. While increasing levels of added K increased the concentration of P and K, the concentration of Ca, Mg and Fe in ADT 31 rice decreased with increasing levels of added K. The results of interaction between stages and K levels also followed similar trend as that of the main effects.

4.6.5.1. Nutrient content in grain

The effect of K levels on the concentration of N, P, K, Ca and Fe except Mg was well pronounced. In the case of N, the levels of K_3, K_4 and K_1 being on par recorded more N content than K_2 level which was on par with K_0. With regard to P content in grain, increasing levels of K promoted the P content of grain markedly. In the case of K, the levels K_4 and K_3 being on par recorded more K content than K_2 level which in turn

TABLE 30

NITROGEN AND P CONTENT OF RICE (PERCENTAGE)

(Mean of four replications)

K levels	Stages of rice growth									
	Tillering		Flowering		Straw		Grain		Mean*	
	N	P	N	P	N	P	N	P	N	P
K_0	1.50	0.128	1.20	0.125	0.74	0.107	1.54	0.253	1.15	0.120
K_1	1.63	0.141	1.40	0.134	0.88	0.124	1.76	0.281	1.30	0.133
K_2	1.75	0.166	1.45	0.149	0.98	0.132	1.65	0.342	1.39	0.149
K_3	1.01	0.178	1.10	0.166	0.63	0.140	1.89	0.367	0.91	0.161
K_4	2.00	0.202	1.60	0.184	1.12	0.149	1.79	0.383	1.57	0.178
Mean	1.58	0.163	1.35	0.152	0.88	0.130	1.72	0.325		

*Represents mean for St_I, St_{II} and straw

	Particulars	S.E. N	S.E. P	C.D.(0.05) N	C.D.(0.05) P
i)	Stages	0.03	0.001	0.08	0.004
ii)	K levels	0.04	0.002	0.10	0.005
iii)	Interaction				
	Stages x K levels	0.06	0.003	0.18	0.008
iv)	Grain content				
	K levels	0.05	0.004	0.15	0.014

TABLE 31

POTASSIUM AND Ca CONTENT OF RICE (PERCENTAGE)

(Mean of four replications)

K levels	Stages of rice growth									
	Tillering		Flowering		Straw		Grain		Mean*	
	K	Ca	K	Ca	K	Ca	K	Ca	K	Ca
K_0	1.39	0.94	1.02	0.83	1.01	0.56	0.26	0.57	1.12	0.78
K_1	1.88	0.84	1.10	0.74	1.19	0.47	0.28	0.51	1.39	0.69
K_2	2.05	0.76	1.35	0.67	1.49	0.42	0.33	0.45	1.63	0.62
K_3	2.23	0.69	1.32	0.60	1.69	0.38	0.36	0.41	1.74	0.56
K_4	2.43	0.59	1.41	0.52	1.92	0.31	0.36	0.35	1.92	0.48
Mean	1.98	0.76	1.22	0.67	1.46	0.43	0.32	0.46		

*Represents mean of St_I, S_{II} and straw

Particulars	S.E. K	S.E. Ca	C.D.(0.05) K	C.D.(0.05) Ca
i) Stages	0.01	0.005	0.03	0.014
ii) K levels	0.01	0.006	0.04	0.018
iii) Interaction				
K levels x Stages	NS	0.011	NS	0.032
iv) Grain content				
K levels	0.01	0.008	0.03	0.026

TABLE 32

MAGNESIUM (PERCENTAGE) AND Fe (ppm) CONTENT OF RICE

(Mean of four replications)

K levels	Stages of rice growth									
	Tillering		Flowering		Straw		Grain		Mean*	
	Mg	Fe	Mg	Fe	Mg	Fe	Mg	Fe	Mg	Fe
K_0	0.54	830	0.50	710	0.48	600	0.17	125	0.51	710
K_1	0.47	780	0.44	650	0.37	530	0.17	113	0.43	650
K_2	0.43	700	0.36	590	0.30	450	0.17	106	0.36	580
K_3	0.41	650	0.30	490	0.26	410	0.15	94	0.32	520
K_4	0.32	560	0.27	430	0.23	310	0.17	85	0.27	430
Mean	0.44	700	0.38	570	0.33	460	0.17	105		

*Represents mean for St_I, St_{II} and straw

	Particulars	S.E.		C.D.(0.05)	
		Mg	Fe	Mg	Fe
i)	Stages	0.003	6.0	0.019	16.0
ii)	K levels	0.004	7.0	0.011	20.0
iii)	Interaction				
	K levels x Stages	0.007	10.0	0.019	40.0
iv)	Grain content				
	K levels	0.008	2.0	0.024	8.0

recorded more K than K_1 and K_0 between which there was no difference. While the added K levels depressed Ca content of grain appreciably, Mg status was not affected significantly. With respect to Fe content in grain, increasing levels of K, depressed the Fe content.

4.6.6. Uptake of nutrients at tillering, flowering and harvest stages

4.6.6.1. Nitrogen uptake (Table 33; Fig.12)

Nitrogen uptake was the highest at harvest stage followed by flowering and tillering stages. The level K_4 registered the highest value of N uptake while K_0 and K_3 levels being on par recorded the lowest value.

4.6.6.1.1. Nitrogen uptake in grain

The levels K_4 and K_2 performing similarly recorded higher values of N uptake than K_1 and K_3 which were in turn on par registering more N uptake than K_0 level.

4.6.6.1.2. Straw N uptake

The levels K_4 and K_2 being on par registered higher uptake than K_1 level which was on par with K_0 and K_3 levels.

4.6.6.1.3. Total N uptake

Application of K at K_4 level caused numerically more uptake of N than the rest of treatments.

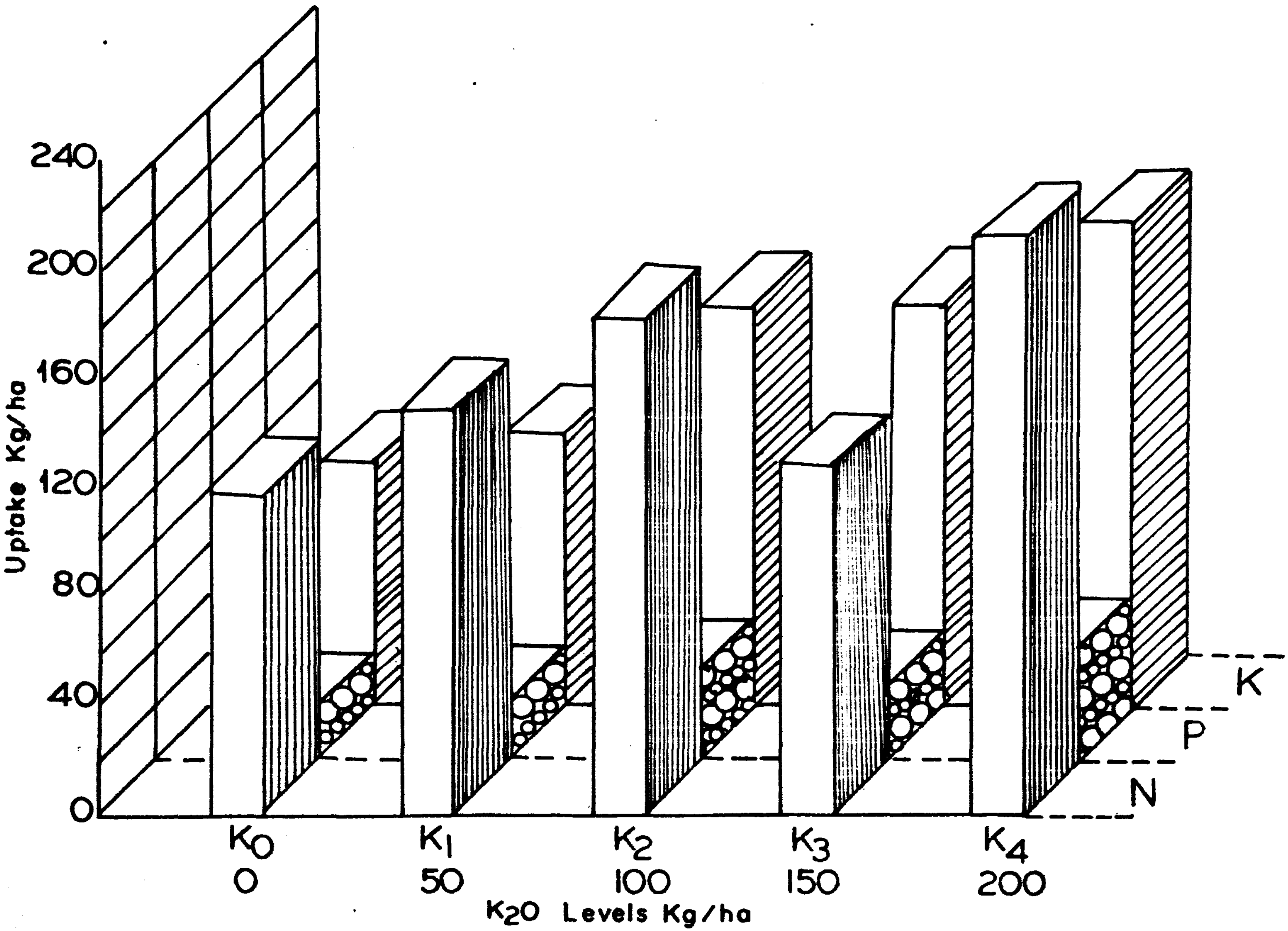
TABLE 33

UPTAKE OF N AND P IN RICE (kg/ha)

(Mean of four replications)

K levels	Stages of rice growth											
	Tillering		Flowering		Straw		Grain		Total		Mean	
	N	P	N	P	N	P	N	P	N	P	N	P
K_0	88.1	7.6	93.2	9.7	57.3	8.3	61.1	10.1	118.4	18.4	99.8	11.8
K_1	103.4	8.9	130.4	12.5	64.3	9.2	85.4	13.6	149.7	22.8	127.5	13.6
K_2	112.2	10.7	171.3	17.5	83.9	11.3	99.1	20.5	183.0	31.8	155.5	20.0
K_3	53.2	9.4	108.4	16.3	50.3	11.2	80.2	15.6	130.5	26.8	97.3	17.4
K_4	118.8	11.9	210.6	24.3	94.4	12.6	121.5	25.9	215.9	38.5	181.7	25.0
Mean	95.1	9.7	142.8	16.1	70.0	10.5	89.5	17.2	159.5	27.7		

Particulars	S.E.		C.D.(0.05)	
	N	P	N	P
i) Stages	5.9	0.6	16.1	1.6
ii) K levels	7.6	0.6	16.9	1.7
iii) Interaction K levels x Stages	NS	1.3	NS	3.6
iv) Grain uptake K levels	5.3	1.0	16.3	3.1
v) Straw uptake K levels	5.3	0.4	16.4	1.2
vi) Total uptake K levels	12.8	1.1	37.8	3.2


Uptake Kg/ha
240
200
160
120
80
40
0
K_0
0
K_1
50
K_2
100
K_3
150
K_4
200
K_2O Levels Kg/ha
K
P
N

4.6.6.2. Phosphorus uptake (Table 33; Fig.12)

The P uptake was the highest at harvest stage registering two and three folds increase in P uptake over flowering and tillering stages respectively. The P uptake ranged from 11.8 (K_0) to 25.0 kg/ha (K_4). The influence of K levels on P uptake was in the following decreasing order of K_4, K_2, K_3, K_1 and K_0.

4.6.6.2.1. Straw P uptake

The level K_4 registered the highest uptake followed by K_2 and K_3. Again the levels K_2 and K_3 being on par induced more uptake than K_1 and K_0 levels between which there was no marked variation.

4.6.6.2.2. Phosphorus uptake in grain

The highest and lowest uptake of P in grain were associated in K_4 and K_0 treatments respectively. However, the level K_3 depressed the P uptake in grain.

4.6.6.2.3. Total P uptake

The total P uptake was the lowest at K_0 level, then the same increased up to K_2 level. When the level was further increased to K_3 there was a decline in P uptake followed by a conspicuous increase at K_4 level.

4.6.6.3. Potassium uptake (Table 34; Fig.12)

Harvest stage recorded the highest uptake of K (134.3 kg/ha) accounting for 4.09 and 13.7 per cent increase in K uptake than flowering and tillering stages respectively. As regards K application, increasing levels of K promoted the uptake and the highest and lowest uptake of K occurred at K_4 and K_0 levels respectively.

4.6.6.3.1. Potassium uptake in grain

Potassium uptake in grain was the highest at K_4 level followed by K_2 level. Further, the level K_3 being on par with K_1 registered higher uptake than K_0.

4.6.6.3.2. Straw K uptake

The highest uptake was recorded at K_4 level followed by K_3 and K_2 which were on par, registering higher uptake than K_1 and K_0 (on par).

4.6.6.3.3. Total K uptake

The influence of added K levels on total K uptake was almost the same as reported under straw uptake.

4.6.6.4. Calcium uptake (Table 34)

Significant differences in Ca uptake among stages were noticed. Harvest stage being on par with flowering stage recorded higher uptake than tillering stage. The added K levels antagonised Ca uptake by rice.

TABLE 34

UPTAKE OF K AND Ca IN RICE (kg/ha)

(Mean of four replications)

K levels	Stages of rice growth											
	Tillering		Flowering		Straw		Grain		Total		Mean	
	K	Ca	K	Ca	K	Ca	K	Ca	K	Ca	K	Ca
K_0	78.8	55.3	79.2	66.3	78.2	47.7	10.5	22.6	88.7	70.3	82.2	64.0
K_1	118.7	53.1	102.5	60.3	88.2	39.2	13.6	24.8	101.8	64.0	108.0	59.1
K_2	131.4	49.0	147.7	63.4	128.0	40.2	19.4	27.2	147.5	67.4	142.2	59.1
K_3	117.4	36.5	130.1	47.2	133.1	34.0	15.2	17.3	148.3	51.2	131.9	45.0
K_4	144.0	35.5	185.6	49.6	161.8	29.8	23.4	23.7	185.2	53.6	171.6	46.2
Mean	118.1	45.9	129.0	57.3	117.8	38.2	16.4	23.1	134.3	61.3		

	Particulars	S.E.		C.D. (0.05)	
		K	Ca	K	Ca
i)	Stages	3.4	1.5	9.7	4.3
ii)	K levels	4.4	1.9	12.6	4.3
iii)	Interaction K levels x Stages	NS	NS	NS	NS
iv)	Grain uptake K levels	1.2	1.6	3.8	4.9
v)	Straw uptake K levels	5.3	1.9	16.4	4.3
vi)	Total uptake K levels	6.1	3.3	18.8	10.2

4.6.6.4.1. Calcium uptake in grain

The lowest uptake was associated in K_3 level while other levels of K, though favoured the Ca uptake in grain did not differ notably among themselves.

4.6.6.4.2. Straw Ca uptake

The highest uptake occurred at K_0 level and the same decreased as the K levels were increased.

4.6.6.4.3. Total Ca uptake

The influence of K levels on total uptake was almost similar to the straw uptake.

4.6.6.5. Magnesium uptake (Table 35)

The Mg uptake was the highest at harvest stage followed by flowering and tillering stages. Added K levels, in general reduced the Mg uptake.

4.6.6.5.1. Magnesium uptake in grain

The uptake of Mg in grain as influenced by K levels did not follow a regular pattern. However, the levels of K_4 and K_0 registered numerically the highest and lowest uptake respectively.

TABLE 35

UPTAKE OF Mg AND Fe IN RICE (kg/ha)

(Mean of four replications)

K levels	Stages of rice growth											
	Tillering		Flowering		Straw		Grain		Total		Mean	
	Mg	Fe	Mg	Fe	Mg	Fe	Mg	Fe	Mg	Fe	Mg	Fe
K_0	31.9	4.83	36.1	5.52	39.0	5.74	7.8	0.50	46.8	6.24	38.3	5.53
K_1	30.0	4.92	38.2	6.05	29.3	4.91	10.0	0.55	39.3	5.46	35.5	5.48
K_2	27.7	4.49	38.9	6.96	27.3	4.95	11.4	0.64	38.7	5.59	35.1	5.68
K_3	21.4	3.42	26.8	4.80	20.8	4.47	8.6	0.40	29.4	4.87	25.9	4.41
K_4	18.9	3.33	32.9	5.59	19.6	3.73	12.5	0.58	32.1	4.31	28.4	4.41
Mean	26.0	4.20	34.6	4.19	27.2	4.76	10.1	0.53	37.3	5.29		

	Particulars	S.E.		C.D. (0.05)	
		Mg	Fe	Mg	Fe
i)	Stages	0.8	0.12	2.2	0.35
ii)	K levels	1.0	0.16	2.8	0.46
iii)	Interaction K levels x Stages	NS	NS	NS	NS
iv)	Grain uptake K levels	0.7	0.04	2.1	0.13
v)	Straw uptake K levels	1.3	0.20	4.1	0.62
vi)	Total uptake K levels	1.6	0.22	4.9	0.68

4.6.6.5.2. Straw Mg uptake

Increasing levels of added K reversed the Mg uptake.

4.6.6.5.3. Total Mg uptake

The total Mg uptake as influenced by K addition followed similar trend as reported in straw uptake.

4.6.6.6. Iron uptake (Table 35)

The highest uptake of Fe occurred at harvest stage (5.29 kg/ha) followed by tillering (4.20 kg/ha) and flowering stages (4.19 kg/ha) which were on par. In respect of K levels, generally lower levels of K treatments promoted the Fe uptake while higher levels depressed it.

4.6.6.6.1. Iron uptake in grain

Although the added K levels did not follow a regular pattern in influencing the Fe uptake, the levels K_2 and K_3 numerically recorded the highest and lowest values of Fe uptake respectively.

4.6.6.6.2. Straw Fe uptake

As the levels of K were increased, the uptake of Fe declined significantly.

4.6.6.6.3. Total Fe uptake

As reported in the uptake of Fe in straw, the depressive and antagonistic effect of increasing levels of K on total uptake of Fe was well pronounced.

4.6.7. Equivalent nutrient ratios of ADT 31 rice at different stages of growth (Table 36)

4.6.7.1. K/N ratio

Straw recorded the highest value of K/N ratio whereas grain registered the lowest. The ratio value increased as the K levels were increased up to K_3 and further increase to K_4 level depressed the above ratio. Further, the ratio worked out based on actual uptake of N and K are presented in Table 37. It is also perused from the above Table that though there was increase in K/N ratio with increase in K levels, there was a spectacular increase at K_3 level than the rest at all the stages except in grain.

4.6.7.2. K/P ratio

The above ratio value ranged from 0.78 (grain) to 9.67 (tillering stage). Tillering and flowering stages and straw did not differ among themselves notably with respect to the above parameter. Though applied K levels increased the ratio, they did not vary appreciably among themselves. The level K_3 registered the highest value followed by K_4, K_2, K_1 and K_0 in the decreasing order.

TABLE 36

EQUIVALENT NUTRIENT RATIOS OF ADT 31 RICE AT DIFFERENT STAGES OF CROP GROWTH

(Mean of four replications)

Nutrient ratio / K levels	Tillering stage					Flowering stage				
	K/N	K/P	K/Ca	K/Mg	K/Fe	K/N	K/P	K/Ca	K/Mg	K/Fe
K_0	0.22	8.35	0.73	0.76	23.7	0.19	6.72	0.65	0.64	20.8
K_1	0.26	10.49	1.16	1.22	35.7	0.25	9.42	1.06	1.06	32.6
K_2	0.24	9.88	1.30	1.46	41.6	0.25	10.07	1.41	1.61	47.1
K_3	0.43	10.00	1.53	1.69	47.6	0.45	9.63	1.71	2.01	59.9
K_4	0.24	9.61	2.09	2.31	66.0	0.25	9.14	2.02	2.35	71.6
	Grain					Straw				
K_0	0.06	0.83	0.24	0.47	24.7	0.49	7.48	0.73	0.65	23.7
K_1	0.06	0.80	0.26	0.53	35.3	0.49	7.63	1.30	0.99	31.6
K_2	0.07	0.76	0.37	0.58	43.2	0.55	8.99	1.82	1.53	46.8
K_3	0.07	0.77	0.45	0.71	53.4	0.96	9.58	2.28	2.00	58.0
K_4	0.07	0.74	0.66	0.66	58.8	0.62	10.23	3.17	2.56	87.2

Particulars		Mean values					S.E.	C.D.(0.05)
I. K/N ratio:	Stages	St_I	St_{II}	S	G			
		0.28	0.28	0.62	0.07		0.060	0.132
	K levels	K_0	K_1	K_2	K_3	K_4		
		0.24	0.26	0.28	0.48	0.29	0.050	0.118

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TABLE 36 (CONTINUED)

	Particulars		Mean values					S.E.	C.D.(0.05)
II.	K/P ratio:	Stages	St_I	St_{II}	S	G			
			9.67	9.00	8.78	0.78		0.565	1.231
		K levels	K_0	K_1	K_2	K_3	K_4		
			5.85	7.08	7.43	7.50	7.43	0.505	1.101
III.	K/Ca ratio:	Stages	St_I	St_{II}	S	G			
			1.35	1.37	1.86	0.40		0.226	0.494
		K levels	K_0	K_1	K_2	K_3	K_4		
			0.58	0.93	1.23	1.49	1.99	0.202	0.442
IV.	K/Mg ratio:	Stages	St_I	St_{II}	S	G			
			1.49	1.43	1.53	0.59		0.221	0.483
		K levels	K_0	K_1	K_2	K_3	K_4		
			0.63	0.95	1.30	1.46	1.97	0.198	0.432
V.	K/Fe ratio:	Stages	St_I	St_{II}	S	G			
			41.7	46.4	49.4	43.1		4.19	9.15
		K levels	K_0	K_1	K_2	K_3	K_4		
			23.2	32.3	44.7	54.7	70.9	3.75	8.18

TABLE 37

POTASSIUM AND NITROGEN ABSORBED AT DIFFERENT STAGES OF RICE GROWTH

Stages / K levels	Dry matter yield (q/ha)				K absorbed (kg/ha)				N absorbed (kg/ha)				K/N ratio			
	T	F	S	G	T	F	S	G	T	F	S	G	T	F	S	G
K_0	58.7	77.6	77.6	39.8	78.8	79.2	78.2	10.5	88.1	93.2	57.3	61.1	0.9	0.9	1.4	0.2
K_1	63.5	93.2	74.3	48.6	118.7	102.5	88.2	13.6	103.4	130.4	64.3	85.4	1.0	0.8	1.4	0.2
K_2	64.1	118.1	85.7	60.1	131.4	147.7	128.0	19.4	112.2	171.3	83.9	99.1	1.3	0.9	1.5	0.2
K_3	52.7	98.6	79.7	42.5	117.4	130.1	133.1	15.2	53.2	108.4	50.3	80.2	2.5	1.2	2.7	0.2
K_4	59.7	131.6	84.4	67.5	144.0	185.6	161.8	23.4	118.8	210.6	94.4	121.5	1.6	0.9	1.7	0.2

T = Tillering; F = Flowering; S = Straw; G = Grain.

4.6.7.3. K/Ca ratio

The highest and lowest ratio values were observed in straw and grain respectively. There was a phenomenal increase of the above ratio value from 0.58 to 1.99 as the K levels were increased from K_0 to K_4.

4.6.7.4. K/Mg ratio

Straw, tillering and flowering stages being on par recorded higher K/Mg ratio than grain. Among the K levels, K_4 recorded the highest ratio value (1.97) followed by K_3 and K_2 and the lowest value was associated in K_0 (0.63).

4.6.7.5. K/Fe ratio

The above ratio value ranged from 41.7 (tillering stage) to 49.4 (straw). However, there was no conspicuous variation among stages. Increasing dose of K upgraded the K/Fe ratio from 23.2 (K_0) to 70.9 (K_4).

4.6.8. Relationship studies

4.6.8.1. Relationship between K availability indices at tillering stage and yield parameters (Tables 38, 38a and 41)

Available N was significantly correlated with grain yield ($r = 0.835^{**}$) as well as straw yield ($r = 0.446^{*}$), whereas Kex ($r = 0.492^{*}$), Knex ($r = 0.564^{**}$), available Ca ($r = 0.551^{*}$), available Mg ($r = 0.568^{**}$) and NH_4-N ($r = 0.541^{*}$), were significantly correlated with grain yield only.

TABLE 38

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN GRAIN YIELD VERSUS OTHER PARAMETERS AT TILLERING STAGE - FIELD TRIAL (n = 20)

Sl. No.	x variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	Available N	0.835**	Y = -1137.6 + 85.6x
2.	NH_4-N	0.541*	Y = 365.0 + 233.3x
3.	Kex	0.492*	Y = 1971.4 + 54.2x
4.	Knex	0.564**	Y = -15571 + 31.9x
5.	Available Ca	0.551*	Y = 672.9 + 5.5x
6.	Available Mg	0.568**	Y = 1113.0 + 12.2x
7.	Available Fe	0.089	NS
8.	N %	0.152	NS
9.	K %	0.581**	Y = 1464.4 + 1867.1x
10.	K % in index leaf	0.447*	Y = 2259.5 + 1743.1x
11.	Ca %	0.401	NS
12.	Mg %	-0.649**	Y = 9809.5 - 10664.4x
13.	Fe %	-0.572**	Y = 10078.7 - 69868.3x
14.	N uptake	0.664**	Y = 2624.4 + 15.7x
15.	K uptake	0.573**	Y = 2178.6 + 25.3x
16.	Ca uptake	0.332	NS
17.	Mg uptake	-0.407	NS
18.	Fe uptake	-0.292	NS

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TABLE 38 (CONTINUED)

Sl. No.	x variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
19.	AR_e^k	0.589**	Y = -135.1 + 514853.8x
20.	$-\Delta K^o$	0.704**	Y = -2874.9 + 64622.3x
21.	PBC^k	-0.106	NS
22.	K_L	0.625**	Y = -5045.1 + 30178.9x
23.	K_x	0.467*	Y = -3550.2 + 40655.9x
24.	ΔG	-0.608**	Y = 29672.6 - 8.9x
25.	K potential	0.522*	Y = 404.0 + 3152.4x
26.	Neutral N NH_4OAc	0.492*	Y = 1971.4 + 54.2x
27.	K/N ratio in soil	0.217	NS
28.	K/NH_4-N ratio in soil	0.037	NS
29.	K/P ratio in soil	0.189	NS
30.	K/Knex ratio in soil	0.474*	Y = 1560.2 + 32.6x
31.	K/Mg ratio in soil	-0.014	NS
32.	K/Ca ratio in soil	0.142	NS
33.	K/Fe ratio in soil	0.366	NS
34.	K/N ratio in plant	0.358	NS
35.	K/Ca ratio in plant	0.632**	Y = 2917.3 + 1666.9x
36.	K/Mg ratio in plant	0.497*	Y = 3626.0 + 1073.6x
37.	K/Fe ratio in plant	0.669**	Y = 2739.7 + 56.3x

* - Significant at 5 per cent level; ** - Significant at 1 per cent level

TABLE 38a

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN STRAW YIELD VERSUS OTHER PARAMETERS AT TILLERING STAGE-FIELD TRIAL
(n = 20)

Sl. No.	x variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	Available N	0.466*	Y = 5810.2 + 30.2x
2.	NH_4-N	0.149	NS
3.	Kex	0.329	NS
4.	Knex	0.459*	Y = -3108.2 + 17.2x
5.	Available Ca	0.323	NS
6.	Available Mg	0.304	NS
7.	Available Fe	0.042	NS
8.	N %	0.099	NS
9.	K %	0.302	NS
10.	K % in index leaf	0.204	NS
11.	Ca %	0.349	NS
12.	Mg %	-0.325	NS
13.	Fe %	0.414	NS
14.	N uptake	0.194	NS
15.	K uptake	0.199	NS
16.	Ca uptake	0.283	NS
17.	Mg uptake	-0.282	NS
18.	Fe uptake	-0.311	NS

* - Significant at 5 per cent level

NS - Not significant

In the case of nutrient content, Mg and Fe contents were negatively correlated with grain yield whereas K content was positively correlated (r = 0.581**). Besides the K content in third leaf of rice was also well correlated with grain yield (r = 0.447*).

In respect of uptake, nitrogen uptake at tillering stage was significantly correlated with grain yield (r = 0.664**) followed by K uptake (r = 0.573**), $-\Delta K^{\circ}$ (r = 0.704**), K_L (r = 0.625**), G (r = -0.608**), AR_e^k (r = 0.589**), K_x (r = 0.467*) and K_{pot} (r = 0.522*) were significantly correlated with grain yield. All the above potassium potential parameters except K_{pot} were correlated with total K uptake. Grain yield was closely correlated with K extracted by neutral N NH_4OAc (r = 0.492*).

Among the nutrient ratios in soil, only K/Knex was significantly correlated with grain yield (r = 0.574*). Among the nutrient ratios in plant, K/Ca, K/Mg and K/Fe were correlated significantly with grain yield.

4.6.8.2. Relationship between K availability indices at flowering stage and yield parameters (Tables 39, 39a and 41)

As reported at tillering stage once again available-N was significantly correlated with grain yield (r = 0.793**). Other parameters which had significant correlations with grain yield were available Mg (r = 0.613**), Knex (r = 0.596**),

TABLE 39

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN GRAIN YIELD VERSUS OTHER PARAMETERS AT FLOWERING STAGE - FIELD TRIAL (n = 20)

Sl. No.	x variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	Available N	0.793**	Y = -1233.2 + 89.2x
2.	NH_4-N	0.563**	Y = 1170.2 + 227.3x
3.	Kex	0.536*	Y = 1338.6 + 51.9x
4.	Knex	0.596**	Y = -1485 + 31.6x
5.	Available Ca	0.555*	Y = 765.0 + 6.0x
6.	Available Mg	0.613**	Y = 935.9 + 14.2x
7.	Available Fe	0.227	NS
8.	N %	0.801**	Y = 696.6 + 1954.5x
9.	K %	0.575**	Y = 2038.6 + 1842.3x
10.	K % in index leaf	0.483*	Y = 2105.4 + 2362.3x
11.	Ca %	0.371	NS
12.	Mg %	-0.559*	Y = 8110.9 - 7841.3x
13.	Fe %	-0.471*	Y = 8147.2-51994.8x
14.	N uptake	0.852**	Y = 2526.3 + 10.8x
15.	K uptake	0.743**	Y = 2725.1 + 13.4x
16.	Ca uptake	0.466*	Y = 351.7 + 70.9x
17.	Mg uptake	0.122	NS
18.	Fe uptake	0.366	NS
19.	AR_e^k	0.549*	Y = 331.8 + 516955.6x
20.	$-\Delta K^o$	0.536*	Y = -19.9 + 45529.4x
21.	PBC^k	-0.113	NS
22.	K_L	0.539*	Y =-1615.9+20658.9x
23.	K_x	0.531*	Y =-2617.4 + 36307.4x
24.	ΔG	-0.548*	Y = 27797.9-8.0x
25.	K potential	0.442	NS
26.	Neutral N NH_4OAc	0.547*	Y = 1236.2 + 52.3x
27.	K/N ratio in soil	0.166	NS
28.	K/NH_4-N ratio in soil	0.028	NS

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TABLE 39 (CONTINUED)

Sl. No.	x variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
29.	K/P ratio in soil	0.235	NS
30.	K/Knex ratio in soil	0.502*	Y = 1710.1 + 45.7x
31.	K/Ca ratio in soil	0.030	NS
32.	K/Mg ratio in soil	-0.259	NS
33.	K/Fe ratio in soil	0.319	NS
34.	K/N ratio in plant	0.187	NS
35.	K/Ca ratio in plant	0.579**	Y = 3189.3 + 1448.4x
36.	K/Mg ratio in plant	0.477*	Y = 3600.7 + 990.6x
37.	K/Fe ratio in plant	0.543*	Y = 3526.2 + 35.5x

* - Significant at 5 per cent level

** - Significant at 1 per cent level

NS - Not significant

TABLE 39a

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN STRAW YIELD VERSUS OTHER PARAMETERS AT FLOWERING STAGE-FIELD TRIAL (n = 20)

Sl. No.	x variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	Available N	0.234	NS
2.	NH_4-N	0.112	NS
3.	Kex	0.291	NS
4.	Knex	0.436	NS
5.	Available Ca	0.322	NS
6.	Available Mg	0.361	NS
7.	Available Fe	0.060	NS
8.	N %	0.326	NS
9.	K %	0.371	NS
10.	K % in index leaf	0.169	NS
11.	Ca %	0.307	NS
12.	Mg %	-0.346	NS
13.	Fe %	-0.243	NS
14.	N uptake	0.374	NS
15.	K uptake	0.474*	Y = 7004.8 + 5.6x
16.	Ca uptak	0.388	NS
17.	Mg uptake	0.101	NS
18.	Fe uptake	0.318	NS

* - Significant at 5 per cent level

NS - Not significant

NH_4-N (r = 0.563**), available Ca (r = 0.555**) and Kex (0.536**) whereas none of the above parameters were correlated with straw yield.

In the case of nutrient contents as in tillering stage, Mg and Fe contents were negatively correlated. Nitrogen and K contents including K in third leaf were positively related to grain yield significantly.

At flowering stage, N uptake (r = 0.852**), K uptake (r = 0.743**) and Ca uptake (r = 0.466*) were significantly correlated with grain yield. With straw yield, only K uptake was significantly correlated (r = 0.474*).

Among K potential parameters, AR_e^k, $-\Delta K^o$, K_L, K_x values were positively correlated while ΔG was negatively correlated both with grain yield and total uptake of K. Grain yield (r = 0.547*) and total K uptake (r=0.890**) were well correlated with K extracted by neutral N NH_4OAc.

As regards nutrient ratios in soil, only K/Knex ratio was well correlated with grain yield (r = 0.502*). In the case of nutrient ratios in plants as observed at tillering stage, K/Ca, K/Mg and K/Fe ratios at flowering stage were also significantly correlated with grain yield.

4.6.8.3. Relationship between K availability indices and yield parameters at post-harvest stage (Tables 40, 40a and 41)

Grain yield was significantly correlated with available N (r = 0.819**), available Mg (r = 0.577**), Knex (r=0.638**), NH_4-N (r = 0.764**), available Ca (r = 0.498*) and Kex (r = 0.513*) whereas none of these parameters were correlated with straw yield.

In the case of nutrient content, Fe content in grain was negatively correlated with grain yield.

The uptake of N, K and Ca in grain were significantly correlated with grain yield, whereas uptake of N and K in grain was significantly correlated with straw yield.

The K potential parameters viz., AR_e^k, $-\Delta K^o$, K_L and K_x were significantly correlated with grain yield whereas ΔG was negatively correlated. AR_e^k, $-\Delta K^o$, K_L, K_x and PBC^k were significantly correlated with total uptake of K. Grain yield and total K uptake were closely correlated with neutral N NH_4OAc-K.

TABLE 40

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN GRAIN YIELD VERSUS OTHER PARAMETERS AT POST-HARVEST STAGE - FIELD TRIAL (n = 20)

Sl. No.	x variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	Available N	0.819**	Y = -412.8 + 97.6x
2.	NH_4-N	0.764**	Y = 1318.7 + 340.9x
3.	Kex	0.513*	Y = 1435.6 + 64.4x
4.	Knex	0.638**	Y = -15201.7 + 33.1x
5.	Available Ca	0.498*	Y = 1683.5 + 5.5x
6.	Available Mg	0.577**	Y = 421.1 + 18.7x
7.	Available Fe	0.192	NS
8.	N % in grain	0.191	NS
9.	K % in grain	0.415	NS
10.	Ca % in grain	0.413	NS
11.	Mg % in grain	0.073	NS
12.	Fe % in grain	-0.448*	Y = 8839.3 - 351084.5x
13.	N uptake in grain	0.949**	Y = 991.9 + 46.7x
14.	K uptake in grain	0.925**	Y = 1579.5 + 221.3x
15.	Ca uptake in grain	0.674**	Y = 566.1 + 199.3x
16.	Mg uptake in grain	0.449	NS
17.	Fe uptake in grain	0.392	NS
18.	AR_e^k	0.578**	Y = -801.7 + 736404.2x
19.	$-\Delta K^o$	0.446*	Y = 2345.5 + 29581.0x
20.	PBC^k	0.287	NS
21.	K_L	0.562*	Y = 143.2 + 16190.8x
22.	K_x	0.611**	Y = -1106.9 + 29197.7x
23.	ΔG	-0.567**	Y = 32805.7 - 9.51x
24.	K potential	0.419	NS
25.	Neutral N NH_4OAc	0.513*	Y = 1435.6 + 64.4x

* - Significant at 5 per cent level
** - Significant at 1 per cent level
NS - Not significant

TABLE 40a

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN STRAW YIELD VERSUS OTHER PARAMETERS AT POST-HARVEST STAGE-FIELD TRIAL (n = 20)

Sl. No.	x variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
1.	Available N	0.509*	Y = 5746.9 + 39.9x
2.	NH_4-N	0.263	NS
3.	Kex	0.288	NS
4.	Knex	0.418	NS
5.	Available Ca	0.309	NS
6.	Available Mg	0.275	NS
7.	Available Fe	0.230	NS
8.	N %	0.156	NS
9.	K %	0.376	NS
10.	Ca %	0.392	NS
11.	Mg %	-0.239	NS
12.	Fe %	-0.117	NS
13.	N uptake	0.509*	Y = 6555.6 + 16.5x
14.	K uptake	0.549*	Y = 6626.7 + 86.6x
15.	Ca uptake	0.258	NS
16.	Mg uptake	0.394	NS
17.	Fe uptake	0.487	NS

* - Significant at 5 per cent level

NS - Not significant

TABLE 41

RESULTS OF STATISTICAL ANALYSIS FOR CORRELATION BETWEEN TOTAL UPTAKE OF K AND K AVAILABILITY INDICES (n = 20)

Sl. No.	x variables	Correlation coefficient (r)	Regression equation (Y = a + bx)
	<u>Tillering stage</u>		
1.	AR_e^k	0.912**	Y = -114.1 + 24125.6x
2.	$-\Delta K^o$	0.799**	Y = -142.1 + 2221.9x
3.	PBC^k	0.511*	Y = 372.6 + 19.6x
4.	K_L	0.878**	Y = 299.4 + 1281.9x
5.	K_x	0.838**	Y = -338.7 + 2206.1x
6.	ΔG	-0.876**	Y = 1203.7 - 3.8x
7.	K potential	0.377	NS
8.	Neutral N NH_4OAc	0.889**	Y = -59.02 + 2.6x
	<u>Flowering stage</u>		
9.	AR_e^k	0.917**	Y = -110.1 + 26130.3x
10.	$-\Delta K^o$	0.879**	Y = -123.6 + 2264.1x
11.	PBC^k	0.234	NS
12.	K_L	0.913**	Y = -213.6 + 1059.8x
13.	K_x	0.922**	Y = -274.9 + 1909.0x
14.	ΔG	-0.918**	Y = 1281.4 - 4.1x
15.	K potential	0.705**	Y = -60.3 + 139.5x
16.	Neutral N NH_4OAc	0.890**	Y = -47.7 + 3.1x
	<u>Post-harvest stage</u>		
17.	AR_e^k	0.941**	Y = -160.1 + 36322.3x
18.	$-\Delta K^o$	0.808**	Y = -20.6 + 1624.7x
19.	PBC^k	0.447*	Y = -26.3 + 13.8x
20.	K_L	0.894**	Y = -107.5 + 779.5x
21.	K_x	0.899**	Y = -145.3 + 1301.6x
22.	ΔG	-0.933**	Y = 1517.3 - 4.8x
23.	K potential	0.717**	Y = 41.5 + 82.1x
24.	Neutral N NH_4OAc	0.864**	Y = -56.0 + 3.3x

* - Significant at 5 per cent level
** - Significant at 1 per cent level
NS - Not significant

DISCUSSION

CHAPTER 5

DISCUSSION

The soils occurring in Thanjavur district, a major part of Cauvery delta in Tamil Nadu State vary widely in their physico-chemical properties and invite the attention of soil scientists to venture in depth soil research on several aspects. Since it is the rice granary of Tamil Nadu, much interest was evinced on a rice based soil research. Although systematic research on soil has been planned and carefully executed with reference to soil fertility in general, still several aspects of soil and plant relationships are yet to be tackled. To cite an example a large number of experiments in the country have shown rather inconsistent trend in the response of field crops to fertiliser K. It has often been difficult to predict the responses of rice based on soil available K status or to applied K. Responses of rice to added K were reported by Varma et al. (1979); Mahapatra et al. (1981); Shyam Sundar Mondal et al. (1982) and Bhargava et al. (1985). Absence of response to added K was claimed by Krishnasamy et al. (1974); Ramasamy and Palaniappan (1974) and Deol et al. (1985). Cubic response to added K was observed by Raman Kutty (1971); Dhanapalan Mosi et al. (1973) and Goswami et al. (1976).

In view of the widely differing as well as contradictory findings in this respect, an attempt was made in the present investigation to study the dynamics of soil K with particular reference to status, forms, fixation, release characteristics and the pattern of response to K with rice as test crop. Different K availability parameters have also been related to uptake and response of ADT 31 rice in the 10 major soil series of Thanjavur district. The results so obtained from laboratory, pot culture and field experiments detailed in the preceding chapter are discussed in the light of crop performance.

5.1. Forms, status and K availability indices of soils

The 10 soil series of the study area chosen for investigation are heterogeneous as revealed from their physico-chemical characteristics. Pattukkottai, Madukkur and Melakadu soil series occurring in the new delta area are relatively open textured with loamy sand texture while the other soil series are fine textured comparatively and they occur in the old delta area. Such variations in the textural components of soils could be ascribed to the genesis of these soil series in the respective area. The old delta soils are of recent origin and they originated from deposits of Cauvery whereas the new delta soils are derived from lateritic parent materials.

These soils are neutral in reaction except Madukkur and Pattukkottai series whose pH is slightly acidic. They are non-saline and are relatively low in organic carbon content. The soils from new delta are non-calcareous whereas soils of old delta contain about 1 per cent free $CaCO_3$ and the highest value was recorded in Nedumbalam series with 1.3 per cent. As regards the fertility status, these soils fell under low in available N status and in respect of available P they varied from medium to high and available K content was between low and high.

Ever since Bray (1954) proposed the concept of nutrient availability in soils, several extractants and methods have been developed from time to time to monitor the nutrient availability in soils. The estimation of available K being simple compared to the availability of N and P estimations, more number of extractants and methods have been evolved by different workers. These extractants include mineral acids of different concentrations, solutions of neutral salts and buffer solutions. Besides this, a number of K potential parameters are also being employed to determine the K availability in soils. These methods are based on Schofield ratio law (1947) and Woodruff free energy proposed as potash potential by Beckett (1964).

The results obtained through the use of a number of extractants to extract different forms of K and K potential parameters employed are discussed hereunder.

A perusal of the mean values of K extracted by water, neutral N NH OAc, 0.1N HNO_3, 0.5N HNO_3, 1N HNO_3, 0.1N HCl, 0.5N HCl, 1 per cent citric acid, 0.5N EDTA, Morgan's reagent and 0.01M $CaCl_2$ revealed that these values corresponded to about 0.06, 1.06, 0.53, 0.67, 7.47, 0.47, 0.45, 0.43, 0.41, 0.65 and 0.38 per cent of the total K. These values indicate that most of these extractants extract similar amount of K representing mostly Kex except boiling 1N HNO_3 which extracts a considerable portion of the Knex fraction of K as well. Neutral N NH_4OAc extracts relatively higher proportion of K than the rest of the extractants.

The percentage distribution of various forms of K to the total-K reported under the present study is of similar trend and magnitude as reported by Grewal and Kanwar (1966); Ram and Singh (1975); Biddappa and Sarkunan (1981) and Brar and Sekhon (1985) for different soils of India.

The inter-relationship studies revealed that K extracted by neutral N NH_4OAc had significant correlations with K extracted by 0.1N HNO_3, 0.5N HNO_3, 1N HNO_3, 0.1N HCl, 0.5N HCl, 1 per cent citric acid and Morgan's reagent. As most of these extractants extracted the readily exchangeable and water soluble-K, significant correlations could be obtained among them.

Considering the relationships between K extracted by 0.1N HCl, 0.5N HCl, 0.1N HNO_3, 0.5N HNO_3 and 1N HNO_3 and other K potential parameters ($-\Delta K^o$, AR_e^k, K_L, PBC^k, ΔG, K_x etc.) it was observed that they exhibited close correlations with all K potential parameters except PBC^k and ΔG. This mutual relation indicates the possibility of substituting one extractant of K for the other to predict the K availability in soil.

5.1.1. Derived parameters of Q/I relationships

The availability of any nutrient in soil is governed by the quantity, intensity and rate factors. The quantity term (q) is a measure of amount of K in the reserve pool in soil. The intensity term describes the strength of K ion in solution. The relationship between quantity and intensity as a measure to predict the K availability is again governed by rate factor or replenishment factor which denotes the rate at which the depleted K is replenished from the reserve K. Based on this concept several Q/I parameters have been proposed to predict K availability in soils (Narain and Singh, 1979).

Among the 10 soils studied, soils S_1 to S_6, S_8 and S_{10} (category I) recorded higher values of $-\Delta K^o$ than the soils S_7 and S_9 (category II) which registered low values of $-\Delta K^o$. The differences in $-\Delta K^o$ values between the two categories of soils might be due to the variations in the specific adsorption sites (K_x). The former category of soils having relatively higher proportion of finer fractions and predominantly with 2:1 expanding type of clay minerals (Ramanathan, 1974; Ramanathan, 1977; and Manickam, 1977) are accompanied by larger surface area, obviously larger specific adsorption sites for K accounted for higher values of $-\Delta K^o$. The latter category of soils being low in finer fraction and predominant with 1:1 non-expanding clay minerals (Ramanathan, 1977) with lower adsorption sites showed low labile K values. This has an important practical significance relating to the predictability of K status of soils, the former being rich in K status compared to latter category of soils. Biddappa and Sarkunan (1981) established that black soils registered higher values of labile-K compared to red soils, is in accordance with the present findings.

The AR_e^k values which are measures of instantaneous available K or status of immediately exchangeable K, are low in first category of soils and high in second category. Thus, the above values are influenced by nature and amount of clay coupled with soil pH. It is observed from the results that the clay content and pH of second category of soils are low which might have led to low amount of fixed K and higher concentration of solution K reflecting higher AR_e^k. Similar results of higher activity ratio of K being associated in soils having pH in acid range and soils with low clay content were observed by Ramakrishnayya and Chatterjee (1976) and Maji and Sen Gupta (1982). Soils, predominant with non-expanding kaolinitic type of clay minerals releasing K at a faster rate because of its weak bondage to adsorbed K is well known.

The Pattukkottai and Madukkur soil series being lateritic in origin and predominant with kaolinitic type minerals might have contributed for higher AR_e^k on account of the fact that the K is held with low tenacity.

Low values of AR_e^k observed in the first category of soils could be ascribed to higher fraction of 2:1 expanding type of clay minerals having relatively higher CEC. It appears that soils with cation retention power have small amount of K in soil solution, so that the immediate available K in these soils was lower compared to second category of soils. Zandstra and Mackenzie (1968) and Subba Rao et al. (1984) were also of the same opinion.

Further, it is seen from the Q/I curves that the solution concentrations of K at which these soils adsorb K are different. The first category of soils started adsorbing K even from low concentration compared to second category which adsorbed K at a high concentration. These findings indicate that the first category of soils might have got greater affinity for K adsorption than the second category of soils. These results also suggest the possibility that K might be present in selected wedge zones in the first category of soils making it difficult for release and the same might be absent in the second category of soils resulting in lower retentivity for K. In the Q/I graphs, the lower curved portion was associated with adsorption of K at specific sites whereas the linear part indicated the non-specific adsorption of K (Beckett and Nafady, 1968).

The values of PBC^k (a measure of the ability of soil to resist reduction in the relative activity of K (AR_e^k), were higher in the first category of soils compared to the second category which is a true reflection of its buffering capacity. The first category of soils contained more proportion of clay, organic carbon and CEC than the second category. The above results might be expected because with increasing clay content and CEC, the PBC^k values might have increased due to increased buffering capacity (Ram and Prasad, 1981). Again, the possibility of the presence of 2:1 type of clay minerals particularly montmorillonite or illite as major clay minerals could be responsible for such increased values of PBC^k signifying the fact that these soils are well buffered against depletion of K by crop removal, warrants less K fertilization as against second category of soils with low PBC^k, needing frequent K fertilization. These results are in line with the findings of Zandstra and Mackenzie (1968); Ram and Prasad (1981) and Bandyopadhyay *et al*. (1985).

Further, the first category of soils registered higher values of K potential than the second category. This is useful in placing the soils on a comparative basis and it fully describes the K status of soils over short depletion period. In the present study, although the observed activity ratios were high, the lower values of K potential in the second category of soils, suggest that these soils are least buffered against depletion of K which is also evidenced by the low values of PBC^k. Earlier, Maji and Sen Gupta (1982) and Chatterjee et al. (1983) made similar observations.

The Woodruff free energy values (ΔG) were also generally higher in the first category of soils than the second category. The higher values of free energy change observed in these soils could be attributed to their greater magnitude of exchange capacity and retention of K on exchange complex. The first category of soils possessed higher clay content coupled with high CEC compared to second category as evidenced from initial analysis of soils. Thus, it could be possible in the first category of soils that K ions are held more tenaciously and firmly that higher energy has to be expended to release K and make it available to plants. Similar view points were also expressed on different soils by Balasundaram (1973), Ramanathan (1977), Mahendra Singh et al. (1982) and Valliappan (1984).

5.2. Potassium fixing capacity of soils

Potassium fixation has a detrimental effect on the immediate availability of added-K in the soil. But it is not the total loss, as the fixation of K adds to the reserve pool of K in soil. Information generated from such study may help to determine the relative effectiveness of K application and in turn to evolve sound strategy of K fertiliser use programme based on the magnitude of the fixation.

The results of K fixation study revealed that soils differing in their physico-chemical properties with special reference to nature and amount of clay, CEC, organic carbon, pH and $CaCO_3$ content varied very much in their fixing capacities.

In the present investigation, K fixation was significantly correlated with clay (Singh and Ram, 1976 and Bajwa, 1980), CEC and $CaCO_3$ (Thomas and Hipp, 1968 and Valliappan, 1984). The possible reasons for the above relation might be that soils with higher amount of clay and CEC fix more of added K. Again the fixation was negatively correlated with AR_e^k. When K ions from soil solution get adsorbed on K fixation sites causing a reduction in solution concentration of K might be the possible reasons for such a negative relation. Zandstra and Mackenzie (1968) were also of the same view.

It was revealed from the study that the amount of K fixed continued to increase with increase in the levels of added K which might be due to larger proportion of K being forced into inter-lattice position from labile pool as influenced by the concentration gradient as reported by Graham and Lopez (1969). Further, Ramanathan et al. (1975); Howeler and Spain (1980), Dutta and Joshi (1983) established evidences that increasing levels of K increased the K fixation.

When the magnitude of K fixation was considered from the percentage of K fixation at different levels of added K, it was seen that the per cent K fixation declined with increasing levels of added K in all the soils. This could be attributed to the saturation of specific adsorption sites for K fixation with progressive increase in the levels of added K (Narayana Nambiar, 1972; Joshi et al., 1978 and Valliappan, 1984).

Considering the different incubation periods, it was observed that the lowest fixation occurred during the first day and the same increased as the incubation period was extended to 72 hours beyond which there was no marked increase in K fixation. These results indicate that the rate of sorption was greater initially which declined gradually until an equilibrium was reached. Increasing fixation of K with varying time of contact in different soils was also revealed by Grewal and Kanwar (1967) and Valliappan (1984).

It was also observed that the soils differed in their fixing capacities on account of their variations in their properties. Soils S_6 and S_7 registered the highest and lowest fixation respectively. The highest fixation in S_6 could be ascribed to the presence of greater proportion of 2:1 type of clay minerals which offered greater surface area for fixation as established earlier by Bolt et al. (1963), Black (1968) and Perkins and Tan (1973). The lowest fixation in S_7 could be attributed to the relatively low amount of clay in the soil predominant with 1:1 type minerals. Duthion (1968), Badiger and Rao (1969) and Narayana Nambiar (1972) observed reduced fixation of K in soils predominant with 1:1 type of clay minerals.

On the basis of the magnitude of K fixation, the 10 soils under study could be classed into three groups following $\bar{X} \pm$ S.E. statistics (Fig.5b).

i) Soils with K fixation values exceeding 1.0650 me/100 g soil (S_5 and S_6).

ii) Soils with K fixation values less than 1.0650 but more than 0.9008 me/100 g soil (S_1, S_2, S_3, S_4, S_8 and S_{10}).

iii) Soils with K fixation values less than 0.9008 me/100 g (S_7 and S_9).

The soils of group (i) might have mixtures of clay minerals with dominant types especially illites, montmorillonites and vermiculites as observed by Ramanathan (1977). These soils provided a larger surface area which increased the K fixation (Davis <u>et al</u>., 1971). Further, the force of binding could again be enhanced by the existence of different adsorption sites viz., Planar, edge and inter-lattice positions as revealed by Barber <u>et al</u>. (1963), Mengel (1971) and Ramanathan (1977).

The second group of soils (S_1, S_2, S_3, S_4, S_8 and S_{10}) fixed moderate amounts of K. These soils, having dominance of 2:1 type minerals especially montmorillonite might have fixed moderate K as reported by Bajwa (1980).

The third group of soils (S_7 and S_9) fixed low amounts of K. These soils belonged to Alfisol with dominance of 1:1 type clay minerals (Ramanathan, 1977). The clay minerals of these soils being non-expanding, having less surface area would have fixed less quantity of added K.

5.3. Potassium supplying power of soils

The K desorption and K supplying power of soils are used as synonyms (Arnold and Close, 1961; Doll *et al.*, 1965; and Nash, 1971). Apropos to this Ramanathan (1977) defined K releasing power of soil as the sum of Knex converted to Kex, thus becoming available to crops apart from Kex and water soluble-K already present in soil. On the other hand K supplying power of soil is defined as the amount of K supplied to growing plants from soil solution, Kex and Knex forms. The K releasing power denotes the total availability and not the total uptake since the entire amount of K that is released or available is not used by the plant. Thus, any chemical method denoting the available K in a soil would mean the K releasing power of soils, while the K supplying power could be equated to the actual uptake of K by the plants by any biological method.

5.3.1. Chemical method-K releasing power of soils (Step-K)

The K releasing power of soils by successive extraction with 0.1N HCl gradually decreased from first extraction to fifteenth extraction by the time most of the soils released very little K or no K.

Considering the individual soil samples it was observed that S_5 and S_7 released the highest and lowest amount of K by first extraction. The sample S_5, a Vertisol with high Kex and K saturation at edge position possibly held the K with less tenacity and bondage released K rapidly (Ramanathan, 1975). The sample S_7, an Alfisol with K depleted state could release K as its cumulative K release was also the least. Soils S_9 and S_{10} released K up to tenth extraction. Soils S_1, S_7 and S_8 released K up to eleventh extraction and S_2 and S_3 released K up to twelfth extraction but the soils S_4, S_5 and S_6 continued to release K upto fifteenth extraction.

Such variation in the K rlease pattern among different soils could be attributed to the relative clay content, nature of clay and differences in bonding energy with which K is held over clay lattices. Soil S_6 recorded the highest K release, while the other soils released very little K or no K, in the fifteenth extraction. The soil S_6, an Entisol possibly with illitic dominance released K steadily and gradually even up to fifteenth extraction signifying its highly buffered nature as the values of PBC^k, clay content were also high in this soil.

5.3.1.1. Cumulative K release

The cumulative K release pattern of the soils under study followed the order $S_6 > S_5 > S_2 > S_1 > S_8 > S_3 > S_4 > S_{10} > S_9 > S_7$. The soil S_6 being one rich in 2:1 type clay with high buffering capacity contributed for the highest K release. The low release in the case of S_7 might be due to its K depleted state as it was a coarse textured Alfisol.

Further, the cumulative K release curves of the ten soils revealed that the soil S_5 exhibited a curve with a high degree of steepness initially indicating the rapid release of K by the soil. Such rapid and high release of K might lead to non-responsiveness of crops to added K. The labile-K ($-\Delta K^{o}$) value was also high in this soil. On the other hand the soils S_7 and S_9 exhibited a curve with little slope initially might respond to K application. The labile-K values in these soils were low. These inferences are also evident from the highest and lowest 'a' coefficient values obtained from Cobb-Douglas exponential equations for cumulative release-K for S_6 and S_7. The absence of response of rice to K application in soils S_5 and S_6, a linear response in the case of S_7 and a cubic response in S_9 obtained through a pot culture experiment discussed in section 5.4.1. is in support of the above conclusions drawn from the cumulative K release studies. Soils with relatively high and low cumulative release of K leading to non-responsiveness and responsiveness of crops respectively to added K were revealed earlier by Rathnaprasad (1985) in soils of Madurai.

5.3.2. Biological-K supplying power of soils by exhaustive cropping

Exhaustive cropping through a continuous system of raising crops are considered to be effective and reproducible methods employed in assessing the nutrient supplying power of soils. This study was undertaken to make effective comparison of the K releasing power of soils vis-a-vis K supplying power of soils.

The dry matter yield, K concentration and K uptake values gradually decreased for every successive short term cropping of rice which could be due to the intensive relay cropping in the same soil although the macro nutrients alone were added in adequate quantities. The trend of decline was nearly the same for both control and K treated pots. But the rate of decline of K uptake was lower in K treated soils than that of control with every successive crops which is in agreement with the findings of Biswas (1974), Ramanathan (1977) and Simonis and Nemeth (1985).

5.3.2.1. Cumulative dry matter yield of rice

The level K_3 caused the highest dry matter yield, while the pot receiving no K recorded the lowest dry matter yield in almost all the soils studied pronouncing the beneficial effect of K on biomass production. Increasing levels of K might have mediated in a beneficial way in the process of absorption and assimilation of growth elements needed by rice which is reflected in the final dry matter accumulation.

The ten soils studied, differed markedly in the production of dry matter indicating the diversity of soils in their production potential. Among the soils, S_7 which belonged to Alfisol produced the highest dry matter yield, while S_{10} belonging to Entisol recorded the lowest yield. The soil S_7, producing higher dry matter yield could be expected because it responded linearly to added K as evidenced by the response function fitted for the above soil and discussed in section 5.4.1. Further the labile-K value ($-\Delta K^o$) for the soil (S_7) was also low leading to positive response to added K thus, resulting in higher yield. The influence of K in promoting the dry matter yield in Alfisol was also established by Bansal *et al*. (1985). The poor dry matter yield in soil S_{10} could be ascribed to the fact that it was a psamment which could not integrate the nutrients so added on account of its poor physical condition, low fertility and productivity which reflected in the poor biomass production.

5.3.2.2. Potassium uptake by rice - Exhaustive cropping

Application of K increased the K uptake in all the soils, although the magnitude of K uptake differed on account of its heterogeneity. Such increased uptake of K due to increased levels of K is obvious because when the dry matter is increased by addition of K, one could expect the uptake to increase since uptake value is only the product of dry matter yield and content of K. It is also noteworthy to mention here that the added K levels did not appreciably increase the K content in rice plant. Among the soils, S_7 and S_{10} accounted for the highest and lowest uptake of K. This indicated that the uptake values followed the same trend as dry matter yield as revealed earlier that the soils S_7 and S_{10} registering the highest and lowest dry matter yield respectively.

As regards the number of crops and uptake of K, the value of K uptake decreased from first crop to sixth crop as the dry matter yield decreased in the same way.

The cumulative K uptake curves of different soils revealed that the uptake values differed largely among soils for the added K levels. When the K levels were increased from K_0 to K_3 the corresponding increase in cumulative K uptake was well manifested in the soils in the order $S_8 > S_7 > S_3 > S_2 > S_4 > S_1 > S_6 > S_5 > S_9 > S_{10}$.

5.3.2.3. Extent of Kex and Knex used by Exhaustive cropping

It is often referred that K is an elusive element on account of its dynamic equilibrium in soil and the difficulty encountered in demarcating one form from the other. Secondly, its elusive character is further qualified due to the lack of proper elucidation in decoding various biochemical functions the K has in the plant body. But on the contrary the existence of dynamic equilibrium among different forms in soil has a remarkable practical significance in the soil fertility studies in relation to response of crops and uptake of K. This is evident from the fact that the crop during its growing period not only removes water soluble-K and Kex but also utilizes a considerable amount of Knex which of course depends upon the soil characteristics especially of Kex content and the quantity of K fertilisers added.

It was observed that the Kex used increased with increasing levels of added K, while the Knex used decreased with increased levels of added K in all the soils studied. When soils are adequately added with fertiliser K, plants derive their K requirement from added source. Thus, it might be possible that the Kex used increased with increasinglevels of K. On the other hand, the Knex source is not exploited by plants as long as their need for K is met from Kex or the K derived from Knex is progressively smaller with such increase in added K. Further, when crops are raised successively without K application, the demand for the nutrient K increases and the soil available pool remains continuously under K stress. Due to this the flow of K in the dynamic equilibrium was from Knex to Kex form and thus, the former declined considerably. The above findings are in line with the reports of Salmon (1965), Elsokkary (1973), Ghosh and Ghosh (1976), Ramanathan (1977) and Ganeshamurthy and Biswas (1985).

5.4. Pot experiment to study the response of rice to K application

For precise interpretation the results of the pot experiment are discussed under the following two headings.

5.4.1. Effect of K on grain yield and uptake of K in ADT 31 rice

Application of K_2 and K_4 levels being on par registered higher grain yield than the rest of the treatments. Also the K_4 and K_2 levels being on par induced higher uptake of K than K_3 and K_1. Addition of K to soils increased the available K status. Plants growing in such condition absorbed higher proportion of K which was reflected in increased uptake of K. The effect of K on grain yield might be mediated possibly due to the increased N use efficiency and greater utilization of N in the presence of added K. Increased N use efficiency with increasing levels of K resulting higher biomass production was observed by Tahir Saleem *et al*. (1980).

Soils S_9, S_7 and S_8 behaving similarly registered higher grain yield than S_{10}, S_5, S_3, S_1 and S_6 which in turn yielded more than S_4 and S_2. Soils S_9 and S_7 being Alfisols having low K release values recorded higher grain yield. This is a clear evidence of existence of limitation of K in these soils and application of K had marked benefit in increasing the grain yield. Similar instances of higher grain yield of rice in red soils were observed by Mahapatra and Rajendraprasad (1970).

Further, the response functions worked out for K application in different soils with ADT 31 rice as test crop revealed that linear response functions were found to be the best fit based on R^2 values for soils S_3, S_4, S_7, S_8 and S_{10}. The linear trend observed in soil S_7 could be attributed to low initial K status, low cumulative K release, low $-\Delta K^o$ and PBC^k and open textured nature as revealed from the initial analysis, whereas the linear response in soils S_3, S_4 and S_8 could be ascribed to low cumulative K release. According to Barthakur et al. (1983) rice responded linearly to K application in Assam soils with low clay content, having no vermiculite minerals. The linear response obtained in the case of soil S_{10} in the present study could be due to the low clay content of soils and possibly with no vermiculites. The linear behaviour of the above soils signifies the fact that there is still further scope for increasing the dose of K to sustain higher yields.

The response functions in respect of soils S_5 and S_6 were not significant. These soils released relatively more K as evidenced from the K release studies which might have been sufficient to meet the crop requirement resulting in lack of response to applied K. Absence of response to added K could be expected in soils either with high K releasing power as observed in the present study or in soils having greater K fixing capacity. Mehta (1976) and Deol et al. (1985) observed absence of K response for added K in soils with greater fixing capacity.

In the case of soils S_1, S_2 and S_9 the best fit response function was found to be cubic indicating the elusive behaviour of K on grain yield showing a linear trend at lower levels of applied K followed by a decrease and again an increase in yield at higher level of K application.

Such cubic type of response could be related to the influence of K on N availability and uptake. The crop yield is primarily a reflection of N uptake. It is observed from field experiment discussed in section 5.5.6, that the yield decline corresponded to reduced N uptake consequent to reduced N availability. The possible reasons for reduction of N availability at K_3 level in soils (S_1, S_2 and S_9) could be theorised on the following mechanism. At lower levels of K (up to 100 kg K_2O/ha) the N availability was possibly influenced by K ions. At 150 kg K_2O/ha level the N availability was reduced. At 200 kg K_2O/ha the available N status was increased as evidenced from the soil analytical data. The possibility of mutual release or blocking effect between the K and NH_4 ions in the inter-lattice positions of clay mineral depending upon their concentration in soil solution could be a phenomenon operating in soils. This could be possible due to the similar ionic radii, K and NH_4 ions possess and both being lattice fixable cations. In the present study at 150 kg K_2O/ha level the K ions could have rendered less release of NH_4 ions into soil solution by blocking effect. Whereas at 200 kg K_2O/ha level the increased concentration of K in soil solution could have penetrated deeper into inter-lattice positions releasing NH_4 ions, resulting higher N availability.

5.4.2. Correlation studies for identifying suitable extractant for K availability

In the present investigation attempts were made to compare the suitability of empirical and biological methods for determining K availability. Although the biological methods could be more accurate and reproducible, yet they are time consuming and laborious and have limitations in adaptation for large number of soils. Hence an empirical method approaching closely to that of the biological method will be helpful for wider adaption.

To pitch upon a reliable reagent for predicting K availability in soils, eleven chemical extractants were tried. The results showed that out of the eleven extractants, neutral N NH_4OAc was closely correlated with grain and straw yields and uptake of K in grain and straw and total uptake suggesting the fact that it could be the best extractant. This could be ascribed to the following reasons. The K located in planar, edge, and inter-lattice positions are subjected to differential displacement by cations. The K located in planar positions are exchangeable and equally accessible to NH_4, H, Na, and Ca ions whereas K bonded on edge and inter-lattice positions are more easily accessible to the exchange by NH_4 ion than other cations. Stout (1982), Nagarajan *et al.* (1982), Bansal *et al.* (1985) claimed that neutral N NH_4OAc to be the best extractant to predict K availability on different soils.

Further, it is revealed from the quantity of K extracted by different extractants excepting boiling N HNO_3, neutral N NH_4OAc extracted higher values of K from soils than other reagents. This could be possible that it would have extracted a fraction of K from Knex apart from extracting K from Kex.

Any chemical extractant could be successfully used to measure the available nutrient status of soil provided the quantity of such extracted nutrient is closely related to the uptake of that nutrient in the plant as well as grain and straw yields. In the present study, it was noteworthy to observe that the K extracted, by widely and commonly used neutral N NH_4OAc had a significant correlations with yield of grain and straw and total uptake of K in rice. In addition, the total uptake of K is a true reflection of the K availability in the soil and therefore neutral N NH_4OAc extractant could be considered as a more reliable one to predict K availability. This was also evident from the path analysis carried out to predict the K availability in soil in that,that neutral N NH_4OAc extractant gave the highest R^2 value (0.977) with least residual error (0.0544).

5.5. Field trial

A field trial was conducted at Thamarankottai in Pattukkottai taluk on Madukkur soil series, an Alfisol which was representative of the soil S_9 used for the pot experiment. Under the pot culture study, the soil S_9 showed a cubic trend of response to the application of K with ADT 31 rice as test crop. Hence this field experiment was planned based on the factual data generated from pot culture study in order to elucidate more information relating to the response behaviour of the soil S_9 to the application of K. This led to the parallel investigation of the status of other nutrients in soil (N, P, Ca, Mg, Fe, etc.), nutrient ratios both in soil and plant, trend and magnitude of nutrient absorption in different physiological stages of rice growth to obtain experimental evidences to highlight the cubic response of this soil (S_9). The results of the field trial are discussed under the following eight aspects.

5.5.1. Effect of graded levels of K on nutrient availability at different stages of rice growth

The available nutrients tested (N, P, K, Ca, Mg and Fe) at various stages of rice growth were more at tillering stage and the same got reduced towards maturity stage. Besides, the Knex values also followed the same trend. This is quite obvious because plants derive nutrients from soil for their growth and development leading to depletion of soil nutrients.

The highest value of available N was observed at K_4 level followed by K_2, K_1, K_3 and K_0. In respect of NH_4-N, the levels K_4 and K_2 being on par recorded higher values while K_3 level recorded lower value. It leads to a situation where application of K at lower levels up to 100 kg K_2O/ha, the available N was relatively high. Whereas at 150 kg K_2O/ha level, the available N was reduced compared to 100 kg K_2O /ha. But at 200 kg K_2O/ha, the available N increased again compared to the rest. The possible reasons that are responsible for reduced availability of N at 150 kg K_2O/ha level and an increased availability of N at 200 kg K_2O/ha level could be as brought out and discussed in detail under the pot experiment in section 5.4.1.

The Kex, Knex, boiling N HNO_3-K, available Ca and Mg of soil increased with increasing levels of K. Addition of K causing an increase in Kex and Knex could be expected as the sink for added K might have taken the route of the above forms before K is absorbed by the crop.

Increase in the Kex and Knex due to the addition of K in different soils were reported by Esakkimuthu _et al_. (1974) and Negi _et al_. (1981).

In the case of available Fe, addition of K up to 100 kg/ha increased the Fe availability and further addition of K from 150 to 200 kg/ha depressed the availability. The positive effect was seen with 100 kg/ha which might have alleviated the

K-Fe antagonism and thereby increasing the availability of Fe. Such synergetic and antagonistic effects at lower and higher levels of added K on available Fe were brought out by Hernando and Sanfluents (1976).

5.5.2. Effect of graded levels of K on nutrient ratios in soil at different stages of rice growth

An attempt was made to study as to what happens to the nutrient ratios under low, medium and high levels of K application so that these values might serve as a tool to explain the curious situation where certain levels of K pull down the grain yield while other levels of K increase the yield.

The K/N and K/NH_4-N ratios also were helpful in predicting the reasons for the cubic trend of response as these ratios were reflections of the available N and K content of the soils. The K/NH_4-N ratio decreased up to 100 kg K_2O/ha and increased sharply (2.79) at 150 kg K_2O/ha and again decreased at 200 kg K_2O/ha. This was indicative of the fact that at 150 kg K_2O/ha (K_3 level) the available N was depressed which could be attributed to the reduced grain yield at this level.

5.5.3. Effect of graded levels of K on Q/I parameters in soils at different stages of rice growth

The values of different Q/I parameters viz., $-\Delta K^o$, AR_e^k, PBC^k, potash potential and K_L values were high at tillering stage and the same declined towards maturity stage. The decrease in the above Q/I parameters could be attributed to the following reasons. As the crop advances it absorbs K from available pool of K from the soil and since the above parameters are true reflections of the K availability, they decreased simultaneously.

The free energy values (ΔG) increased from tillering stage to maturity stage. The ΔG values denote the energy expended by the plants to extract K from soils. When K is readily available in soil, plants absorb K using lesser energy but plants expend higher energy if K is not readily available form. The above results are in line with the findings of Mahendra Singh *et al*. (1982).

The values of $-\Delta K^o$, K potential, K_x and K_L increased with increasing levels of added K while ΔG values decreased with increasing levels of K as observed by Ganeshamurthy and Biswas (1984).

5.5.4. Effect of graded levels of K on dry matter yield of ADT 31 rice at different stages

The dry matter yield was not influenced by K levels at tillering stage but application of K at K_4 level recorded the highest dry matter at flowering stage. At higher level of K (200 kg K_2O/ha) the N availability was relatively high as evident from the discussion brought out earlier (Section 5.5.1.). Increased availability of N and K could have resulted in enhanced N and K use efficiency, leading to increased biomass production.

Application of K increased the grain yield up to 100 kg K_2O/ha level. The yield decreased at 130 kg K_2O/ha and at 200 kg K_2O/ha it increased again indicating cubic response in the field trial also. Thus the results of pot-culture experiment were confirmed by the field trial in respect of the trend of response obtained.

In biological studies particularly, when the yield parameters are related to the inputs like fertilisers, the usual trend of responses obtained will be linear, quadratic etc. Cubic responses of crops to application of nutrients is a rare phenomenon. This is also a perplexing trend when such cubic responses are obtained. However, application of K at times resulting in the cubic pattern of response is also reported by Raman Kutty (1971) in soils of Kerala and Dhanapalan Mosi _et al_. (1973) in Thanjavur Delta.

In the present investigation cubic responses of rice to applied K were obtained in 3 out of 10 soil samples used for the pot culture experiment under section 4.5.1.1.1. In fact, this provoked more curiosity to investigate further the possible reasons for cubic trend of response. Possibly the varying trend of available N and NH_4-N resulting in the reduced values at K_3 level, compared to lower levels and again a sharp increase in their content at the next higher level as discussed under section 5.5.1. could be a tangible indirect reason for the cubic trend of response in rice to application of K. The magic element N contributing to the growth and yield parameters singly, is an unique phenomenon. The available N and NH_4-N contents of soil being low at K_3 level of K application have been possibly responsible for the reduced yield at this level causing a cubic trend of response.

The physical and economic optimum doses of K from the results of field trial were worked out employing Orthogonal polynomials (Bliss, 1970). The optimum level of K was found to be 59 kg K_2O/ha for getting the highest grain yield of 5477 kg/ha. The economic dose of K for obtaining the highest return of Rs.10,823/ha was 54 kg K_2O/ha.

5.3.3. <u>Effect of graded levels of K on nutrient content at different stages of rice growth</u>

It was observed from the results, that the content of N, P, K, Ca, Mg and Fe in rice plants were high at tillering stage. Such increased concentration of nutrients in the plants at young stage is a natural phenomenon since the biomass production is relatively low and the nutrients are distributed in relatively small volume of dry matter. With the advancement in the growth of plants accompanied by the corresponding increase in dry matter production, the concentration of nutrients get reduced due to dilution. Secondly such reduction in the concentration of nutrients at maturity stage was also due to the translocation of nutrient elements into economic parts of the plant and subsequent conversion into complex organic forms like protein.

As regards the concentration of various nutrients as influenced by different levels of K, it could be seen that at K_4 level the concentration of N was the highest followed by K_2, K_1, K_0 and K_3. As discussed earlier, lower concentration of N at K_3 level might be due to the relatively low NH_4-N in soil. The reasons for low Ca, Mg and Fe contents with increasing levels of K could be due to the antagonistic effect as reported by Johansson and Hahlin (1977). Increased concentration of P with increasing levels of K could be attributed to increased absorption accompanied by optimum growth of plants. Simonis and Nemeth (1985) revealed that the influence of K in increasing the P content in plants is a reflection of the interaction of K with P.

In the case of nutrient content in grain, added K levels in general, promoted the N, P and K contents while it depressed the Ca and Fe contents.

5.5.6. Effect of graded levels of K on the uptake of nutrients at different stages of rice growth

The uptake of N, P, K, Ca, Mg and Fe was the highest at maturity stage. This trend of result could be expected because at the maturity stage the dry matter production was the highest and since the uptake values are only the products of dry matter yield and content of the nutrients.

The effect of K levels on uptake of nutrients revealed that K_4 level followed by K_2 favoured the uptake of N while K_3

level reduced it. This might be ascribed to the reduced availability of N at K_3 level. Increased levels of K promoted the K uptake. Similar instances of higher uptake of K at higher levels of K fertilisation was reported by Sadanandam *et al.* (1969). The uptake of Ca and Mg were reduced with increasing levels of K could be attributed to ion antagonism as reported by Steward (1963). In the case of Fe generally, lower levels of K favoured the Fe absorption while higher levels of K depressed it. This again is a reflection of the effect of K on Fe availability as discussed in section 5.5.1. Similar results of reversal of Fe uptake due to higher levels of K addition were reported by Kim and Park (1973) and Ravindran (1985).

5.5.7. Effect of graded levels of K on nutrient ratios of rice at different stages of growth

The K/N and K/Ca ratios were the highest in straw and lowest in grain. The highest ratio of K/N and K/Ca in straw might be accomplished through higher accumulation of K in straw than in grain. Unlike all other macro metabolic mineral elements required by the plant, K is not definitely known to be built into any organic compound. It occurs in plant principally as soluble inorganic salts. As a rule the proportion of K is relatively high in straw and low in grain which is reflected in the ratio values. In respect of K/P, K/Mg and K/Fe there was not much variation among stages.

The effect of added K levels on different nutrient ratios in plants revealed that K/N ratio was the highest at K_3 level which is again a reflection of lower N content at K_3 level.

Park *et al*. (1971) opined that the amount of N absorbed decreased with increasing levels of K and K/N ratio increased with K application. Increased K levels causing a decrease in Ca content and thereby leading to higher ratio value of K/Ca was also reported by Randhawa and Pasricha (1976) highlighting the antagonistic effect of K on Ca. Regarding the effect of K on K/Mg ratio the antagonistic effect was also evident in that heavy application of K reversed the Mg absorption causing low content of Mg which led to a higher K/Mg ratio as reported by Nightingale (1937). Similarly, higher levels of added K caused Fe deficiency in plants resulting in higher K/Fe ratio (Bolle Jones, 1955).

5.5.8. Relationship studies

The relationship studies revealed that available N at all stages (Tillering, flowering and post-harvest) was positively correlated with grain yield. Considering the relationship among stages based on 'r' values, the relation was well pronounced at tillering stage. This indicates increased use of N at vegetative stage of the crop for ensuring higher grain yields.

The K extracted by neutral N NH_4OAc at all stages of rice growth was well correlated with grain and straw yields and total uptake of K implying that it could be a better chemical extractant to predict K availability in soil as discussed in section 5.4.2.

The K content of third leaf of rice at tillering and flowering stages were closely correlated with grain yield. Hence it could be concluded that third leaf of rice plant could be considered as an indicator leaf for fixing the critical values of K in rice plant and for scheduling fertiliser application.

The Q/I parameters viz., $-\Delta K^o$ and K_L values were positively correlated with grain yield whereas ΔG value was negatively correlated. This is obvious because the $-\Delta K^o$, the labile-K represents the readily available form of K. The possible reasons for negative correlation between ΔG and grain yield could be related to K availability flux in soils indicating low Kex at higher energy levels (ΔG) which reflected in low yields (Mahendra Singh *et al.*, 1982).

SUMMARY AND CONCLUSION

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1. Summery

Although much work has been carried out to elucidate K dynamics of soil in relation to plant nutrition, many aspects still remain to be clearly understood. Thus, it offers many challenges to researchers in the assessment of K availability and to predict the trend of response. The complexity and heterogeneity of natural soil system as influenced by differing physico-chemical characteristics of soils are the primary factors responsible for the peculiar behaviour of K in soil. In the present study, it was attempted to investigate the dynamics of K in 10 representative major soil series of Thanjavur district with the objectives contemplated in the introduction, particularly to compare different methods of K availability and to fix a more reliable method to measure K availability and to evaluate the response of rice to K fertilization in the major soil series of Thanjavur.

The studies were made in different phases involving laboratory investigations, green house experimentation followed by a field trial. The laboratory studies related to the characterisation of soils based on forms and status of K, K fixation and release characteristics and comparison of K availability indices including Q/I parameters based on thermodynamic functions.

The pot experiment under green house was ventured to study the influence of graded levels of K on rice to elicit the response behaviour of rice to K fertilisation in the ten major soil series. The field trial was undertaken to confirm the results obtained from the pot experiment.

6.2. Conclusions

The salient findings and conclusions emanating out of the present study are summarised and presented below.

6.2.1. Laboratory investigation

In the ten representative major soil series of Thanjavur chosen for the study, considerable variations in the physico-chemical properties were observed. These soils represented red, alluvial and black soils falling under the orders Alfisols, Entisols and Vertisols respectively, according to soil taxonomical classification.

There were close mutual relationships among K extracted by most of the reagents employed.

Adanur, Alathur, Kalathur, Kivalur, Nedumbalam, Padugai, Sikar and Melakadu soil series were associated with higher values of $-\Delta K^{o}$, PBC^{k}, K potential and low values of AR_{e}^{k} whereas Pattukkottai and Madukkur soil series registered lower values of $-\Delta K^{o}$, PBC^{k}, K potential and higher values of AR_{e}^{k}.

The extent of K fixation differed markedly in different soils mostly due to clay mineralogical make up and amount of clay.

The ten soils fell under three distinct groups based on Mean ± S.E. statistics. Soils S_6 and S_5 were placed under I group fixing higher proportion of added K. Soils S_1, S_2, S_3, S_4, S_8 and S_{10} fell under II group which fixed moderately whereas soils S_7 and S_9 (III group) fixed low amount of added K.

For assessing K fixation in soils the incubation period of 7 days appeared to be more appropriate.

With increasing levels of added K, the amount of fixed K increased while the per cent K fixation decreased in all soils.

Potassium fixation was significantly correlated with clay content, CEC and $CaCO_3$ and negatively correlated with AR_e^k.

The cumulative K release of soils followed the order of $S_6 > S_5 > S_2 > S_1 > S_8 > S_3 > S_4 > S_{10}$ $S_9 > S_7$

The cumulative K release curves of soils followed the Cobb-Douglas exponential functions and from the pattern of K release, it was possible to predict the response behaviour of soils to K application to a certain extent.

6.2.2. Pot studies

Application of K increased the grain yield of rice and uptake of K in 8 out of 10 soils investigated.

Linear response function was found to be the best fit for soils S_3, S_4, S_7, S_8 and S_{10} ; cubic function was the best fit for soils S_1, S_2 and S_9. The response function was not significant for soils S_5 and S_6.

Cubic response of rice to K application could be ascribed to the reduced availability of N at intermediary levels of K application.

Neutral N NH_4OAc was found to be the best extractant for predicting K availability in soils of Thanjavur district.

The Q/I parameters were found to be unsatisfactory measures of K availability.

The Kex used and Knex used by rice decreased and increased respectively with and without K application.

The ability of different soils to supply K from Knex form to the plant appeared to be dominant factor in the K nutrition of rice.

6.2.3. Field trial

The available nutrients in the soil (N, P, K, Ca, Mg and Fe) decreased with crop growth from tillering stage to post-harvest stage.

Application of K at 150 kg K_2O/ha alone reduced the N availability while the lower and higher levels of K increased its availability.

The K/NH_4-N ratio in soil decreased up to 100 kg K_2O/ha and increased sharply at 150 kg K_2O/ha and again decreased at 200 kg K_2O/ha.

With increasing levels of K, the values of Kex, Knex, total K and boiling N HNO_3-K increased.

Potassium application beyond 100 kg K_2O/ha depressed the iron availability.

The values of different Q/I parameters viz., $-\Delta K^{\circ}$, AR_e^k, PBC^k, potash potential and K_L were the highest at tillering stage and the same declined towards post-harvest stage of rice.

The free energy values (ΔG) increased from tillering stage to post-harvest stage. The above values decreased with increasing levels of added K.

Application of K increased the grain yield up to 100 kg K_2O/ha level. The yield declined at 150 kg K_2O/ha but at 200 kg K_2O/ha, again it increased reflecting cubic response.

The optimum and economic doses of K for ADT 31 rice were found to be 59 and 54 kg K_2O/ha for obtaining the highest grain yield and highest return, respectively.

The nutrient contents in rice plant (N, P, K, Ca, Mg and Fe) were high at tillering stage and the same declined towards maturity stage.

With increasing levels of K application, the Ca, Mg and Fe contents in rice were reduced while P content was increased.

The K/N and K/Ca ratios were the highest in straw and lowest in grain.

The K/N ratio in rice plant increased up to K_3 level (150 kg K_2O/ha) and then decreased at K_4 level (200 kg K_2O/ha). The K/Ca, K/Mg and K/Fe ratios increased with increasing levels of K.

Application of K at K_4 level (200 kg K_2O/ha) followed by K_2 level (100 kg K_2O/ha) favoured the N uptake while K_3 level (150 kg K_2O/ha) reduced it.

Increased dose of K promoted the K uptake in rice whereas uptake of Ca and Mg were reduced.

Lower level of K application up to 100 kg K_2O/ha favoured the absorption of Fe in rice while higher levels beyond 150 kg K_2O/ha depressed it.

The grain yield was closely correlated to available N in soil at tillering stage.

The K extracted by neutral N NH_4OAc at all stages of rice growth was highly correlated with yield of grain and straw and total uptake of K in rice.

The K content of the third leaf of rice at tillering and flowering stages could be considered as an indicator leaf for fixing the critical level of K in rice plant.

The Q/I parameters viz., $-\Delta K^{\circ}$ was positively correlated with grain yield while ΔG values were negatively correlated.

Summarising the conclusions it could be stated that the neutral N NH_4OAc has been found to be the best extractant for predicting the K availability in soils of Thanjavur district. Application of K was found to be beneficial to rice crop in eight out of ten soil series studied. Padugai and Nedumbalam series did not respond to the application of K. Possible reasons for the cubic pattern of response of rice to K application have been elucidated. The K content of the third leaf of rice at tillering and flowering stages could be considered as an indicator leaf for fixing the critical level of K in rice plant. The optimum and economic doses of K for ADT 31 rice were found to be 59 and 54 kg K_2O/ha for achieving the highest grain yield and highest return respectively.

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