INVESTIGATIONS ON THE INTERACTIONS OF NITROGEN AND POTASSIUM ON THE POTASSIUM DYNAMICS OF THE SOILS OF THANJAVUR

Thesis submitted in part fulfilment of the requirements for the degree of Doctor of Philosophy (Agriculture) in Soil Science and Agricultural Chemistry to the Tamil Nadu Agricultural University Coimbatore

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1990

CERTIFICATE

This is to certify that the thesis entitled "INVESTIGATIONS ON THE INTERACTIONS OF NITROGEN AND POTASSIUM ON THE POTASSIUM DYNAMICS OF THE SOILS OF THANJAVUR" submitted in part fulfilment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY (Agriculture) in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY to the Tamil Nadu Agricultural University, Coimbatore is a record of bona fide research work carried out by Mr.A.BASKER under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazines.

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ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

I have immense pleasure to express my deep sense of gratitude and heartfelt thanks to Dr.K.M.RAMANATHAN, Dean, Anbil Dharmalingam Agricultural College, Kumulur, Trichy, Chairman of the Advisory Committee, for suggesting this problem, valuable guidance, suggestions, encouragement and tireless efforts during the course of the investigation and critical evaluation of the manuscript. The facilities provided and the interest shown by the Chairman is gratefully acknowledged.

I have immense pleasure in expressing my deep sense of gratitude and indebtedness to Dr.M.R.IRUTHAYARAJ, Professor of Agronomy, Water Technology Centre, TNAU, Dr.D.AUGUSTINE SELVA SEELAN, Associate Professor of Soil Science, Water Technology Centre, TNAU, and Dr.M.GOPALAN, Professor and Head, Department of Entomology, TNAU for their valuable suggestions and envouragement as the Members of the Advisory Committee.

I have great pleasure in placing on record my gratitude and thanks to Dr.P.KANDASWAMY, Dr.RANI PERUMAL, Dr.S.SANKARAN, Dr.C.SYAMBULINGAM, Dr.SP.PALANIAPPAN, Dr.G.ARUNACHALAM, Dr.N.R.CHANDRASEKHARAN, Dr.R.VAITHYALINGAM and Dr.V.D.GURUSAMY RAJA who were associated during the earlier phases of this study.

I express my deep sense of gratitude and heartfelt thanks to Dr.P.KANDASWAMY, Director, Water Technology Centre, for his constant encouragement and support given.

I wish to thank all the Staff of Tamil Nadu Rice Research Institute for providing necessary facilities for the conduct of the field and pot experiments.

I gratefully acknowledge with thanks the help, encouragement and moral support given by my friend Mr.M.BALAKRISHNAN.

A word of appreciation is also due to Mr.G.VARADHARAJAN, Miss.T.VANATHI and Mr.A.VIJAYARATNAM for the pains taken in careful typing and Mr.V.SRINIVASAN for the perfect execution of the diagrams.

I profusely thank my parents, brothers, sister, wife and my daughter for their moral support and encouragement.

I gratefully acknowledge the Indian Council of Agricultural Research, New Delhi for providing me with Senior Research Fellowship for carrying out this study.

Place: Coimbatore

Date : 3.1.90

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ABSTRACT

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INVESTIGATIONS ON THE INTERACTIONS OF N AND K ON THE K DYNAMICS OF THE SOILS OF THANJAVUR

By

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Among the major nutrients of plants, potassium is abundant in Earth's Crust. It exists in different forms viz., water soluble, exchangeable, non-exchangeable and mineral K which are in a dynamic equilibrium. On account of the existence of dynamic equilibrium among these fractions of K, many challenges are faced by the scientists in choosing a reliable and precise method of K determination for predicting K availability. The moisture content of the upland soils plays a major role in determining the K availability by way of influencing mass flow and diffusion of K^+ to the root system in a soil of similar K status, clay content and composition. Submergence of paddy soils brings about drastic changes in the soil physico-chemical properties.

The reduced conditions prevailing in rice soils cause formation and accumulation of NH_4^+ ions. Both NH_4^+ and K^+ ions being lattice fixable cations of similar ionic radii compete for the same exchange sites. Hence these ions are inter dependant in the fixation or release based on the concentration of ions and sequence of application of fertilizers producing these ions. Investigations on the N x K interaction are many under upland conditions and meagre in low land conditions. Hence, investigations were carried out in the alluvial soils of Thanjavur with the objectives of studying the interaction of N and K on the availability indices of K including the Q/I parameters. Attempts were also made to choose a better method of K determination which could predict the grain yield and K uptake in rice.

To achieve the objectives of the study, field and pot experiments were conducted in the Tamil Nadu Rice Research Institute, Aduthurai. Field experiments were conducted with four levels of N (0, 50, 100 and 150 kg $N \cdot ha^{-1}$) and four levels of K (0, 50, 100 and 150 kg $K_2O\ ha^{-1}$) in three different seasons (Samba, Kuruvai and Thaladi) of the Thanjavur delta. Two pot experiments were also conducted using ten dominant soil series of Thanjavur district. The levels of N and K tried were same as in the field experiment. Fifteen extractants comprising of solutions of netural salts, weak and strong acids of varying concentrations were tried to extract K. The K potential parameters like

AR_e^K, $-\Delta K^o$, PBC^K and ΔG were determined. The data thus obtained were statistically scrutinised and the conclusions drawn.

The results of field experiments indicated that the K extracted by different extractants increased with the application of K in all the seasons and with the application of N during Kuruvai and Thaladi seasons. The blocking effect of NH_4^+ at the edge positions of clay minerals reduced the concentration of K in soil solution at higher levels of N during Samba season. Application of N increased AR_e^K values at lower levels, but decreased this value at higher levels of N. The labile K values decreased with N application. The PBC^K values were unaltered due to the application of N. The ΔG values increased with the increase in the levels of N. Application of K increased the AR_e^K and labile K values, decreased ΔG values while the PBC^K value was unaltered. Depletion of K due to crop uptake reduced the values of AR_e^K and labile K and increased the ΔG values. PBC^K values were not changed due to cropping. The drymatter yield and yield of rice increased steadily with N application. Application of K did not result in the response of the rice in all the seasons. The response functions of grain yield of rice with the levels of N were quadratic during Kuruvai and Thaladi seasons and linear during Samba season. The response of rice to N application increased with the application of K. The content and uptake of N, P and K increased with the application of N and K. To predict the rice yield 1N HNO_3-K was found to be a better index of K availability. The 0.01N HNO_3-K was found to be a better index for predicting K uptake in rice.

The results of the pot culture experiments indicated that K application increased the K extracted by all the extractants. Application of N increased the K extraction by majority of the extractants. The blocking effect of NH_4^+ causing reduced availability of K was evident in the pot study also. Among the soils, highest and lowest AR_e^K values were obtained in Pattukkottai and Adanur soil series respectively. Kalathur soil series registered the highest labile K and PBC^K values. Kivalur soil series contained the highest water soluble and exchangeable K whereas Kalathur soil series contained the highest non-exchangeable K. All these forms were the lowest in Valuthalakudi soil series. Application of N increased rice yield in all the ten soils investigated. Response of rice to K application was observed in five out of ten soils viz., Kondal, Padugai, Valuthalakudi, Pattukkottai and Madukkur. In these five soils, response of rice to K application was quadratic in the first season and linear in four out of these five soils. Kondal soil series exhibited quadratic response in both the crops. The results of the simple correlation studies made between the values of K extracted by different extractants and the yield of rice and uptake of K indicated that 1N HNO_3-K to be a better index of K availability.

CONTENTS

LIST OF TABLES

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF TABLES (CONTD.,)

LIST OF FIGURES

LIST OF FIGURE (CONTD.,)

ABBREVIATIONS USED

ppm	: parts per million
m.e.	: milli equivalent
C. eq.	: Centi equivalent
ds	: desi Siemens
CEC	: Cation exchange capacity
ml	: milli litre
mm	: millimeter
cm	: Centimeter
g	: gram
kg	: Kilogram
rpm	: revolution per minute
ha	: hectare
N	: Normal solution
M	: Molar solution
°C	: Degree celcius
Cal	: Calories
AR^K	: Activity ratio of potassium
AR^K_e	: Equilibrium Activity Ratio of Potassium
$-\Delta K^O$	: Labile K
PBC^K	: Potential Buffering Capacity of Potassium
ΔG	: Free energy change
'r'	: Co-efficeint of simple correlation
S.E.	: Standard Error
CD	: Critical difference
*	: Significant at 5 per cent level
**	: Significant at 1 per cent level
N.S.	: Not significant
Contd.,	: Continued
Fig.	: Figure

INTRODUCTION

CHAPTER 1

INTRODUCTION

Potassium among the major plant nutrients is the most abundant in the soil. The lithosphere contains on an average 2.8 per cent of K and the soil contains 1.7 per cent of K (Reitemeier, 1951). Of the three major essential plant nutrients, there is always universal response for N, where as the response for P and K has often been reported to be of doubtful nature and quite frequently controversial opinion about their behaviour is expressed. It has become an imperative need of the day to study the nutrient of least response viz., potassium among the other two for an intrinsive and intrinsic study to elicit its behaviour and performance in its natural habit in the soil and as a fertilizer when it is added to the soil. The dynamic equilibrium that exists among the different forms of K in soil, unlike N and P adds more complexity.

The importance of K in soil and plant is well recognised. It influences or participates directly or indirectly in most of the phases of plant metabolism. It acts as a catalyst in the assimilation of carbohydrates, synthesis of sugars and starch and translocation of carbohydrates within the plant. Similarly the synthesis of amino acids and proteins and of simple organic acids to vegetable oils also are mediated by K. It maintains optimum turgor in plants through its tendency for hydration. It induces resistence to pest and diseases, protects the plant against low temperature injury and ensures maturity of the crop at the proper time. It is also associated with several quality factors in marketable crops. Thus, the sweetness of grapes, the sourness of lime, the attractive colouring of apples, tomato, the strength of cotton fibre, the sucrose content of sugarcane, starch production in banana and tuber crops, oil production in oil seeds, firmness of the head in lettuce and cabbage, the keeping quality of fruits and vegetables and fire holding capacity of tobacco are all associated with the optimum levels of potassium and hence it is rightly recognised as the 'quality factor' element.

The study of soil K is complex, as several interacting factors are involved in its availability and release. The dynamic equilibrium of K that exists in the soil is influenced by many factors like the nature and amount of primary and secondary minerals, texture of the soil, the magnitude of transformation of the primary minerals have undergone, soil moisture regime, soil reaction, soil organic matter content, concentrations of K and other complementary cations in the soil solution and exchange complex and the fertilizer K added. The high amount of non-exchangeable K which is made available to the plants, due to the influence of the above factors results in the lack of response to K fertilisation.

A shift of the K equilibrium from mineral lattice K to water soluble K in the soil would make the comparitively less or non-available forms of K into available forms and vice versa. Hence determination of K availability in soil is a difficult task, since a clear demarcation among the various forms of K is not possible. Several methods of K determination have been studied to estimate soil K for different situations including extraction with different extractants such as water through straight salt solutions or mixed salt solutions, solutions of organic and inorganic acids of varying strength and temperature and K potential parameters and biological methods. Depending upon the strength of the extractants used and method of extraction the amount of K extracted would vary. Thus strong acids extracting greater proportion of soil K and weak solutions extracting lesser proportion of K in relation to the K removal by crops are well known. Therefore, any single method of K extraction which approaches more closely to the nutrient uptake by crop can be considered as the most suitable method (Ramanathan, 1977). Further, it is imperative that the ionic concentration in the soil solution should be measured along with the potentially available nutrient which can match the plant's ability to extract. This concept has been reported by Beckett (1964a) as the activity ratio in a soil solution which provides a satisfactory measure of the availability or the potential of K. In order to describe K status of a soil, not only the current potential of K in the labile pool but also the quantity and intensity parameters should be specified.

Predicting the availability of K in soil becomes little more difficult, when the soils are submerged, the process causing drastic changes in the physical, chemical, physico-chemical and biological properties of soil. Due to the reduced conditions prevailing due to submergence, considerable redox reactions take place in soil resulting in the release or fixation of nutrient elements. The study of nutrient transformations in a paddy soil, the release and fixation of nutrients become more important than in an aerable soil. Among the different complementary ions in the soil solution and on the exchange complex the role of NH_4^+ is of primary importance. Owing to their similar ionic radii, the NH_4^+ and K^+ compete for the same exchange sites and cause mutual fixation and release. Thus the application of ammoniacal or ammonium producing fertilizers may cause the increase or decrease in the K availability and vice versa depending upon the concentration of the respective ions in the soil solution, time and mode of application and moisture conditions of the soil.

The study of Soil Science is endowed with complexity on account of the formation of a number of soil groups through the conjoint action and interplay of pedogenic factors. Of the major soil groups of Tamil Nadu viz., black, red, alluvial and laterite, the alluvial soils occurring in the deltaic areas are relatively more fertile than the rest. The alluvial soils of Thanjavur occupying considerable area of Cauvery delta are the predominant soil groups grown with rice. These soils are reported to contain considerable amounts of K, in the primary and secondary minerals and hence record less or no response to added K fertilizers. Although sporadic attempts have been made on the study of K status of these soils, detailed investigations of the K status of these soils in relation to rice growth under submergence are few. Secondly the investigations on the interactions of NH_4^+ and K^+ on the K availability in general and quantity/intensity relationship in particular are totally absent. More over the suitability of different extractants to different soil groups is yet to be evaluated. Keeping in view all these factors, a study was proposed to research upon the dynamics of K in the submerged soils of Thanjavur as influenced by N and K applications with rice as test crop. The investigation was proposed with the following objectives:

1) To study the quantity - intensity relationship of K in submerged soils as influenced by N and K application,

2) To investigate the influence of seasons on the changes in the parameters of the Quantity/Intensity relationships,

3) To evaluate the suitability of different methods of K determination for the different soil series of Thanjavur delta,

4) To understand the transformations of N and K in the major soil series of Thanjavur delta with the application of N and K,

5) To study the effect of N and K application on the yield and drymatter production of rice in different seasons and in the major soil series of Thanjavur delta and

6) To estimate the effect of application of N and K on the content and uptake of nutrients by the plants in the different seasons and in the major soil series of Thanjavur delta.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Potassium, one of the major nutrients of the plant world has specific roles in the plant metabolism. Soil K has been extensively studied by various workers and remarkable advances have been made. The progress of development in the following aspects of soil K has been reviewed in this Chapter.

2.1. Forms and Status of K in Soils
2.2. Fixation and Release of K
2.3. Availability of K
2.4. Methods of Available K Determination Using Different Extractants
2.5. K Potential Parameters
2.6. Influence of K on Rice Yield
2.7. Interaction of N and K

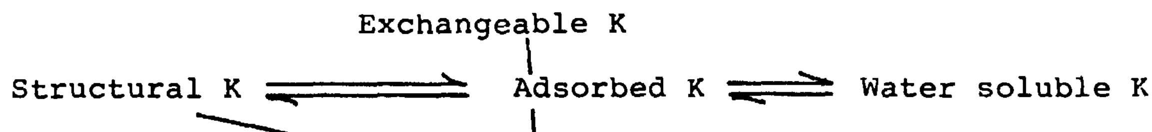
2.1. Forms and Status of K in Soils

2.1.1. Forms of K in Soils

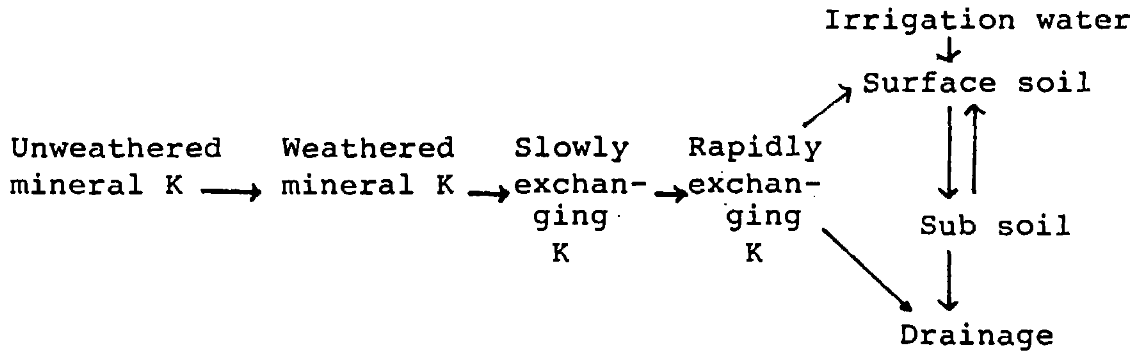
Eversince Hissink (1925) first proposed the basic concept of an equilibrium between different forms of soil K, many modifications have been suggested. Bartholomew and Jansen (1931), Chaminade (1934) and Schachtschabel (1937) expresseed the opinion that the non-exchangeable K, exchangeable K and the dissolved K are in a joint equilibrium. Perhaps the most widely used schematic arrangement has been the one described by Peech and Bradfield in 1943 which is as follows:

Non-exchangeable K $\rightleftharpoons$ Exchangeable K $\rightleftharpoons$ Water soluble K

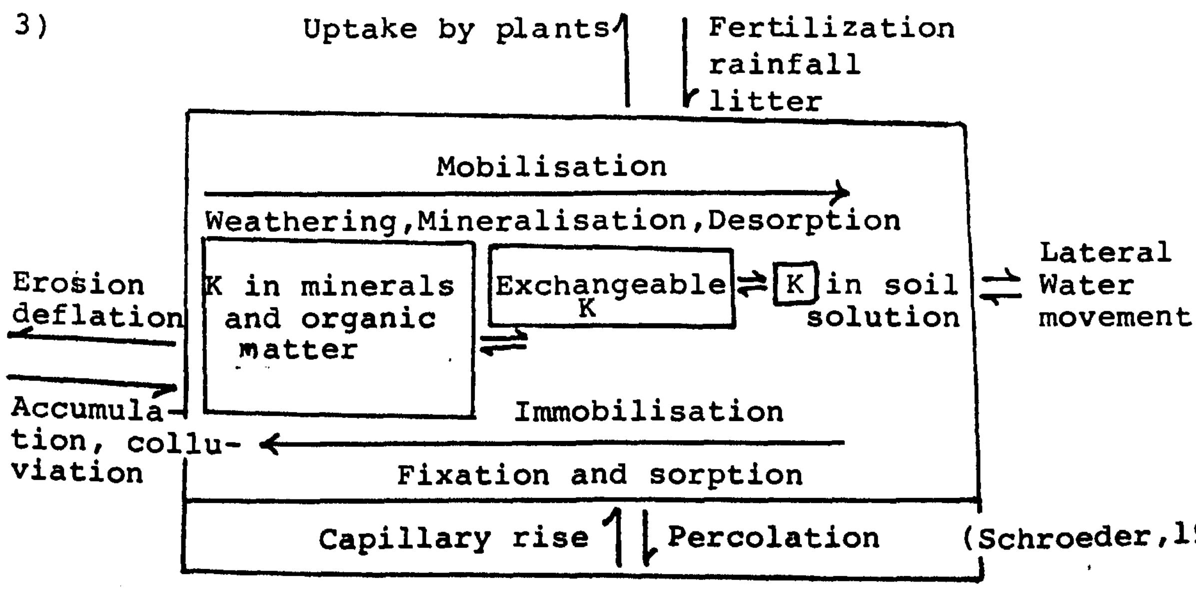
The other types of schematic representations are:

1) 

(Garman,1957)

2) 

(Talibudeen, 1972)

3) 

(Schroeder,1972)

The nature of the equilibrium is variable and depends upon the soil type and nature of the clay minerals present. Because of the reaction involving fixation and release of K, there does not exist a clear line of demarcation between exchangeable and non-exchangeable forms.

2.1.2. Status of K in Soils

The different forms of K viz., total, exchangeable, non-exchangeable and water soluble K fractions, vary in their status depending upon the soil type and condition.

2.1.2.1. Total Potassium

The total K content of the soil varies widely, in particular it depends on the K composition of the parent rock, primary minerals and the stage of development of the soils, between less than 0.1 per cent and more than 3.0 per cent, with a frequently found average around 1.0 per cent (Schroeder, 1974). Except for the soils of high organic matter, by far, the greatest part of the K is found by minerals of the crystal lattice of primary silicates (K feldspars, muscovites and biotites) and secondary clay minerals (illite and the transition of illite to montmorillonite or vermiculite). Though plants can take up only soil solution and adsorbed K, the mineral K constitutes a very large reserve. The K feldspars dominate among the primary potassic minerals and have higher K contents than the micas and biotite (Schroeder, 1974). Though the secondary K containing minerals like illite and transitional clay minerals contain K, their contents vary greatly depending upon the parent rock and the conditions under which the soils have been formed.

2.1.2.2. Water Soluble Potassium

Water soluble K is defined as the quantity existing at any one time dissolved in water of a soil under normal field moisture conditions and relatively unbound by cation exchange forces. The distinction between this form and the others are arbitrary. For non-saline soils, the water soluble K is normally included in the exchangeable fraction. The replenishment of soluble K may occur sufficiently rapidly,directly from the exchangeable form and indirectly from non-exchangeable form,to satisfy plant needs.

The content of water soluble K in soil may vary widely according to the soil type and particle size (Ranganathan and Satyanarayana, 1980). The water soluble K fraction is roughly 0.1 per cent of the total K in the soils of Uttar Pradesh according to Mehrotra and Singh (1970), 0.08 per cent of the total K in the soils of Maharashtra (Kadrekar and Kibe, 1972), 0.23 per cent of the total K in the soils of Karnataka (Ranganathan and Satyanarayana, 1980) and 0.11 per cent of the total K in the soils of Tamil Nadu (Ramanathan and Krishnamoorthy, 1981). The water soluble fraction of K increases with the increase in the fineness of the soil particles (Ranganathan and Satyanarayana, 1980) and was highly correlated to the other forms of K viz., exchangeable and non-exchangeable K (Misra and Shankar, 1970; Bhatnagar et al., 1973; Kalbande and Swamynatha, 1976; Ranganathan and Satyanarayana, 1980; Singh et al., 1983 and Prezotti and Defelipo, 1987).

2.1.2.3. Exchangeable Potassium

The exchangeable K of soil, is the K either sorbed to the soil exchangers or present in the soil solution, is of decisive importance for the K supply to plants, although its quantity is rather low compared to total soil K. Usually the percentage of exchangeable K in total K is below 2 per cent or in absolute values between 10 and 400 ppm (Shroeder, 1974).

Though the exchangeable K and available K are used synonymously, they are not identical because of the following considerations (Reitemeier,1951).

i) The inability of a plant to remove completely the exchangeable K even after prolonged intensive cropping of a soil.

ii) The usual inclusion of the soluble K in the exchange extraction.

iii) The release of non-exchangeable K of the primary and secondary clay minerals.

iv) Fixation of difficultly exchangeable forms during cropping periods and

v) Specific differences among the abilities of the plants to utilize exchangeable or non-exchangeable K or both.

The contents and proportion of exchangeable K to the total K vary markedly based on the clay minerology of the soils. It is about 0.77 per cent of the total K (Misra and Shankar, 1970) and 21.0 mg. 100 g^{-1} of soil (Mishra et al., 1970) in the soils of Uttar Pradesh and 2.0 per cent of the total K ranging from 20-442 ppm in the soils of Maharashtra (Kadrekar and Kibe, 1972) 2 per cent in the soils of Karnataka (Ranganathan and Satyanarayana, 1980) and 1.11 per cent of the total K in the soils of Tamil Nadu (Ramanathan, 1977).

The exchangeable K was found to be closely correlated with the clay content, pH, organic carbon, calcium carbonate content, and cation exchange capacity (Kalbande and Swamynatha, 1976; Joshi et al., 1978 and Singh et al., 1983) and the exchangeable sodium of the soils (Raghbir Singh and Kuhad, 1981). Though the exchangeable K is highly correlated with clay, it may be less when the pH of the soil is low, since the cation exchange capacity gets reduced when there is a reduction in the pH of the soil (Ranganathan and Satyanarayana, 1980). In slightly alkaline and neutral soils, the Ca^{2+} ion is the dominating ion which promotes the opening of the clay mineral pockets and consequent release of lattice K. As excepted, there existed a close correlation between the exchangeable K and other forms of K (Misra and Shankar, 1970 and Prezotti and Defelipo, 1987) and particularly with fixed K (Bhatnagar et al., 1973; Ramanathan, 1977 and Ranganathan and Satyanarayana, 1980).

2.1.2.4. Non-exchangeable Potassium

Non-exchangeable K includes all of the soil K except the solution and immediately exchangeable forms of K. The term difficultly exchangeable K is applied to that which is more slowly released by the usual exchange extractants, or dependant for replacement on a particular cation or group of cations or more or less quickly released by more vigorous extractants (Narayanan Nambiar, 1972).

The content of non-exchangeable K or fixed K to total K was 6 per cent in the soils of Uttar Pradesh (Mehrotra and Singh, 1970 and Misra and Shankar, 1970), 11 per cent in the soils of Maharashtra (Kadrekar and Kibe, 1972), 6.6 per cent in the soils of Karnataka (Ranganathan and Satyanarayana, 1980) and 3.58 per cent of the total K in the soils of Tamil Nadu (Ramanathan and Krishnamoorthy, 1981).

The amount of fixed K in the soil varied according to the particle size distribution and nature and amount of clay minerals. The sources of fixed K or slowly available K in the coarse textured soils include mica from the very fine and fine sands and the clay alone accounts for only half the slowly available K (McCallister, 1987). It was positively correlated with silt fraction of the soil (Mehrotra et al., 1973), with the clay fraction of the soil (Ram and Singh, 1975 and Raghbir Singh and Kuhad, 1981), with the type of a bearing minerals (Choudhari and Jain, 1979) and with the content of mica in the clay fraction (r = 0.957). There was significant correlation between the fixed K and other forms of K (Misra and Shankar, 1970; Ramanathan, 1977 and Prezotti and Defelipo, 1987).

2.1.2.5. Lattice Potassium

It is that fraction of K that has been fixed in the inter lattice space of the 2:1 clay minerals. They are relatively unavailable since they are tightly held in the clay lattices. This form of K is distinct from mineral K in that, is not bonded co-valently within the crystal structure of soil mineral particles but held between the adjacent tetrahedral layers of dioctahedral and trioctahedral micas, vermiculites and intergrade clay minerals as well as in the wedge zones of weathered micas and Vermiculites (Sparks, 1987).

The lattice K occupies the major proportion of the total K. Approximately 62 per cent of the total K is the lattice K in the Uttar Pradesh soils (Mehrotra and Singh, 1970) where as it was 91 per cent of the total K in the soils of Karnataka (Ranganathan and Satyanarayana, 1980). The release or fixation of the lattice K is mainly governed by the type of clay minerals, whether expanding or non-expanding, soil reaction, type of cation etc. Its content was also related to the presence of feldspars and illite (Ranganathan and Satyanarayana, 1980). It was also found to be related with other forms of K (Prezotti and Defelipo, 1987).

2.2. Fixation and Release of Potassium

The fixation and release of K are two important phenomena which govern the availability of K to plants. The occurrence of any of these reactions mainly depends on the shift in the dynamic equilibrium which is again governed by the addition or uptake of the K in the readily available pool of K.

2.2.1. Fixation of Potassium

Fixation is a phenomenon wherein the ions are held by the electrostatic forces in between the clay lattices that are not easily removed by other cations since they are held at specific points in the clay minerals. It is the conversion of added or unused K into a form which is temporarily unavailable or difficultly available. The fixation of soil solution and exchangeable K occurs between the platelets of illite or hydrated mica and vermiculite and in between the frayed edges of mica platelets particularly in environments with high concentrations of these two readily available K forms. The mechanism of K fixation in soils through clays is believed to be the result of the precipitation of K ions in the interior of the lattice clays (Mehrotra et al., 1972) or due to the contraction of the sheet of the clays in consequence of the entry of the K ions, which get locked up in the crystal lattice thereby causing K fixation (Beckett and Nafady, 1967; Davis et al., 1971; Mehrotra et al., 1972 and Palaniappan, 1972) or by ion exchange reaction (Davis, 1972) or due to the synthesis of new minerals resulting from the reverse reactions in the sequences of transformations of K bearing minerals (Davis, 1972 and Perkins and Tan, 1973).

2.2.1.1. Factors Affecting K Fixation

The fixation of K varied with soil type because K fixation depends on many factors like organic carbon, calcium carbonate content, clay content, cation exchange capacity (Bisnoi and Khatri, 1974; Ram and Singh, 1975; Choudhari and Pareek, 1976; Joshi et al., 1978; Barber, 1979; Ranganathan and Satyanarayana, 1980; Pal and Durge, 1987 and Sahu and Gupta, 1987) pH (Ram and Singh, 1975; Singh and Singh, 1979; Sahu and Gupta, 1987 and Goulding, 1988), presence of counteracting ions like NH_4^+, Ca^{2+} and Mg^{2+} (Kar et al., 1975; Singh and Ram, 1975; Ranganathan and Satyanarayana, 1980), type of clay (Mehrotra et al., 1972; Bisnoi and Khatri, 1974; Barber, 1979; Bajwa, 1980; Bajwa, 1981a; Bajwa, 1981b and Bajwa, 1987), silt content (Mehrotra et al., 1972), exchangeable K, fixed K contents of soils (Choudhari and Jain, 1979) and soil structure, liming wetting and drying and the action of plant roots (Goulding, 1988).

2.2.1.2. Fixation of K in Different Soils and by Different Minerals

The fixation of K varied between the soils depending upon the factors described above. In soils where the process of eleviation is high, the B-horizon which is rich in clay minerals due to the illuviation of the clay minerals is responsible for maximum amount of K fixation. This also depends on the clay migration into the profile and the increase in the acidity of the layers, which results in the non-reversible migration of aluminium in the inter layers of the remaining expanded 2:1 layer minerals which also means the reduction of the K fixing capacity of the A-horizon.

The alluvial soils being rich in 2:1 type of clay minerals, fix relatively higher amount of applied K. The K fixation in the alluvial soils ranged from 33.9 to 40.4 per cent (Mehrotra et al., 1972), 31 to 65 per cent in the alluvial soils of North India (Sahu and Gupta, 1987) and 7.46 m.e.100 g^{-1} soil in the black soils (Bhatnagar et al., 1973), 9.6 to 115.3 mg K . 100 g^{-1} soil for Mewar Soils (Bisnoi and Khatri, 1974), 0.3 - 1.9 m.e.100 g^{-1} arid soils of Jodhpur region (Joshi et al., 1978), 0.092 to 0.449 m.e K.100 g^{-1} soil and with a mean of 0.31 m.e.100 g^{-1} soils of Tamil Nadu (Ramanathan, 1977).

The wide variation in these values is mainly due to the change in the nature and amount of clay minerals. The fixation capacity of the clay minerals varied with the clay type, the maximum fixation being recorded by beidellite clay (76 per cent) followed by clays either dominant or major amounts of vermiculite (51 to 61 per cent) and vermiculite clay containing hydrous mica (35 per cent). The other clay minerals, montmorillonite, chlorite, hydrous mica, halloysite, kaolinite and X-ray amorphous materials fixed lesser amount (less than 18 per cent) of the applied K (Bajwa, 1980 and 1981a). The soils with clay fractions containing dominant beidellite or vermiculite showed K deficiency and lack of response to K fertilizer application. The soils containing dominant montmorillonite or other clays contained adequate K and showed good response to K application (Bajwa, 1981b).

The fixation of K in higher levels in some soils was also due to their base exchange status and the difference in their silt content in soils of similar clay content. The K fixation by silt particles accounted for 3.6 to 18.6 per cent of the K fixation (Mehrotra et al., 1972). The K fixing power of the soil was found to increase with the increase in the pH of the soils (Singh and Ram, 1975), low pH corresponds to less exchangeable Ca and cation exchange capacity and is responsible for the low fixation of K. When pH increases, the H_3O^+ ions having similar ionic radius are displaced from the fixed or non-exchangeable position and in that place the K ions are entrapped (Ramanathan and Krishnamoorthy, 1976). Increase in the cation exchange capacity allows a greater quantity of K to enter the exchange complex and hence induce higher fixation (Ranganathan and Satyanarayana, 1980).

The presence of counteracting ions influence the fixation and release characteristics of K, in particular, NH_4^+ because of its similar ionic radius with K^+. An increase in the level of NH_4^+ resulted in the greater fixation of K (Ramanathan et al., 1977 and Singh and Singh, 1979). On the contrary, Kar et al. (1975) reported lesser fixation of K in the presence of NH_4^+ ions. The relative fixation of NH_4^+ or K^+ when the fertilisers are applied alone or in combination was also reported by Raju and Mukhopadhyay (1973 and 1975b). Among the clay minerals, the montmorillonitic clay and amorphous clay are the greatest fixers of NH_4^+, but least of K^+, vermiculite and beidellite fix both NH_4^+ and K^+. Clays containing hydrous mica, chlorite, halloysite fix low proportions of applied NH_4^+ and K^+ but prefer K^+ or NH_4^+ (Bajwa, 1987). The preferential adsorption capacity for K was found to correlate strongly with the content of illite (Bar et al., 1988).

2.2.2. Release of Potassium

Ramanathan and Krishnamoorthy (1982) defined the K releasing power of soils as the sum of non-exchangeable K converted into exchangeable form and the exchangeable form into water soluble form. The weathering of the primary minerals resulting in the shift of the equilibrium towards water soluble fraction causes the release of K. When the exchangeable K is depleted by crop removal, it is replenished from the reserves of non-exchangeable K. The magnitude of this K reserve and its rate of displacement of exchangeable form decide the K supplying power of soils. Lack of response to added K in many soils was due to their greater ability to release non-exchangeable K (Herlihy and Moss, 1970; Medvedeva, 1971 and Mehta, 1976). The non-exchangeable K released by soil has been found to be sufficient to meet the entire needs of the crop as reported by Kiely and Ryan (1972) and Feigenbaum and Kafkafi (1972).

Kadrekar and Kibe (1973) studied the release of soil K with different degree of hydration and drying revealing the fact that under continuous moist conditions, the release of K took place only at the end of 50-60 days. Alternate wetting followed by drying released maximum K. Wetting followed by air drying brought about early release of soil K from the non-exchangeable K. The lower moisture level i.e., half of the moisture equivalent was conducive for greater release of soil K.

The fixation and release of K are reactions of similar type and so the factors that influence the fixation of K also influence the release of K in the soil solution. The trend of K release by the clay fractions of soil is by diffusion and the sand fraction released the K through the process of dissolution (Pal and Mandal, 1980). The presence of biotite not only influenced the fixation, but the release of K was increased by its presence (Pal and Durge, 1987). Goulding (1988) reported that the release of K from the soil was affected by type and particle size of the primary and secondary minerals, soil structure, soil pH and liming, manuring, temperature, wetting and drying and the action of plant roots. Though the presence or absence of NH_4^+ was found to influence the fixation of K its effect was not noted on the release rate of K (Beauchamp, 1982).

2.3. Availability of Potassium

Potassium availability to plants is regulated by:

i) its relatively weak adsorption on non-specific site charges (planar) of the cation exchange capacity

ii) its stronger adsorption to specific site charges (wedges) of the cation exchange capacity and

iii) its fixation in non-exchangeable form in the lattice of the clay crystals (McLean, 1978).

The soluble, exchangeable, non-exchangeable (fixed) and non-exchangeable (native minerals) forms of K are all inter related by an equilibrium which has progressively slower or more sluggish dynamics from left to right. The driving force (Intensity) of this equilibrium is largely a function of clay composition while the magnitude of the process is a function of the clay content of a given soil (McLean, 1978).

Among the different forms of K, water soluble, exchangeable and a portion of fixed or non-exchangeable K are considered as the satisfactory index of K availability and ranged about 1 to 10 per cent of the total K in vast majority of soils (Kadrekar and Kibe, 1972). Since K is one of the exchangeable cations, its level and availability are governed by the other cations on the exchange complex viz., exchangeable Ca (Ram and Singh, 1975), exchangeable Na (Raghbir Singh and Kuhad, 1981) and NH_4 (Venkatesh Bhadradwaj et al., 1982) and soil properties such as pH (Ram and Singh, 1975), texture (Dhanapalan Mosi et al., 1975), type of clay minerals (Raghbir Singh and Kuhad, 1981), contents of calcium carbonate and organic matter (Lodha and Seth, 1970; Ram and Singh, 1975) and moisture condition of the soil (Sparks, 1980).

The dynamic equilibrium existing among the various forms of K suggests that the soil minerals can function both as sources and of sinks for K. The capacity of a soil to supply K to crops over an extended period of time is fundamentally dependant upon the contents of the primary minerals, the rate of release of K by the primary minerals, the quantity of clay minerals present and the type of clay minerals (Van Diest, 1978).

Kadrekar and Kibe (1972) reported that the available K was about 0.82 per cent of the total K on an average. The available K was highly correlated not only with water soluble and fixed K (Kadrekar and Kibe, 1972) but also with exchangeable K and HCl soluble K (Pathak et al., 1975).

Submerging a soil resulted in the increase in the available K content of the soils (Ramanathan and Krishnamoorthy, 1973) mainly due to the release of K from the clay minerals which was replaced by Fe^{2+}, Mn^{2+}, Ca^{2+} etc., the concentration of them being increased due to submergence.

Negi et al. (1981) observed increased available K in soils receiving K and such increases were higher under farm yard manure treatment than under K fertilizer treatment alone (Venkatesh Bharadwaj et al., 1982). The available K was about 0.3 per cent of the total K, 2.5 per cent of lattice K and 12.1 per cent of fixed K. The water soluble K and exchangeable K contributed on an average 17.6 and 82.4 per cent towards available K respectively (Singh et al., 1983).

2.4. Methods of Available K Determination

Fertiliser is used, when the nutrient demand of a crop expected to yield at a given level, exceeds the amount of nutrient, which the soil can supply within the growing season. Simple and rapid chemical soil tests are needed to determine the nutrient supplying ability of the soil so that the quantity of fertiliser needed to over come the short coming can be applied. There are many soil testing methods and a great deal of work has been expanded in search for the 'best' method of K determination. So far, however, no method has been accepted as universally applicable.

The determination of K status of the soils is usually carried out by extracting the soils with salt solutions, weak or strong acids, or buffers of acids and their salts. Depending upon their concentration and composition, these solutions extract the loosely bound K and a variable proportion of more tightly bound K from the external and internal surfaces of the soil matrix and the amount extracted more or less approximate with exchangeable.

However, while exchangeable K represents that fraction of adsorbed on external and accessible internal surfaces, it is not directly related to the K flux towards the roots (Grimme et al., 1971 and Nye, 1972). It constitutes only quantity measurements.

Though there are several methods used at different times for different soils and crops, any simple chemical method of K availability index which approaches more closely to the actual amount of K required or taken up by the plants can be considered as a reliable and suitable method (Ramanathan, 1975). Such a method should indicate the immediate K potential in the soil (amount of K available at the immediate moment) and the reserve K and its rate of passage into the soil solution (capacity to maintain the K potential).

Among the several extractants, neutral normal ammonium acetate seems to be suitable under most conditions for most of the soils and crops. It has been reported to be effective for rice soils by Esakkimuthu (1972), Sobulu (1977), Durairaj Muthiah (1986), Chandra Prakash and Singh (1986), Sentran et al. (1987) and Nagarajan et al. (1982) and for bajra by Chandrasekhar Rao et al.(1983),and for sunflower by Nelson (1959). Its suitability has also been reported by Mishra et al. (1970) for alluvial soils and Wood and Burrows (1980) for heavy textured soils.

The other extractants which are reported to be suitable are 6N sulphuric acid by Hunter and Pratt (1957), 0.5 N HCl as comparable with N NH_4OAc by Nelson (1959), 0.5N HNO_3 and Morgan's reagent by Oommon and Iswaran (1962), ammonium lactate-acetic acid by Van Diest (1963), Water and Morgan's reagent by Swami and Lal (1970), Na TPB by Wentworth and Rossi (1972) and Quemener (1974), Morgan's reagent by Pathak et al. (1975), 0.5N HNO_3 by Dubey and Khera (1974), 1N HNO_3 by Ghosh and Ghosh (1976) and Sahu and Gupta (1987), 0.1N HNO_3 by Ramanathan (1977), 0.01M $CaCl_2$ by Perur and Mithyantha (1976) and Grimme and Nemeth (1976), Mehlich's method by Lin (1978), Bray's extractant and exchange resin by Vasco Da Gama (1978) Morgan's reagent for laterite soils by Bolan and Sree Ramulu (1980), water extractable K for maize by Singh et al. (1986), N NH_4OAc-K, 0.75 N HCl and 6N H_2SO_4 by Chandraprakash and Singh (1986), a centrifugal method for extracting soil solution K and a mixed ammonium chloride ion-exchange resin procedure by WimalaDasa and Sinclair (1988) and Electro Ultrafiltration method by Nemeth (1978), Wanasuria et al. (1981a), Wanasuria et al. (1981b), Grimme (1982), Scherer (1982), Sinclair (1982), Ramanathan and Nemeth (1982) and Sentran et al. (1987).

2.5. K Potential Parameters

Since the plants take up K from, or via, soil solution, the K concentration in the latter must be important but, because the composition varies greatly according to soil moisture content, its direct measurement is seldom attempted, though comparison of soils is possible if the measurements are made at standard water content. Ever since Schoefield (1947) and Woodruff (1955) proposed the concept of nutrient potential in terms of ratio law and free energies, several workers have attempted to apply this concept to the study of soil K and its availability. The use of numerous emphirical methods to assess the availability of K in soils have their own limitations and have not been perfected for use under all conditions and soil types. This led number of workers to apply the Q/I relationship based on the concept of Schoefield's ratio law in the study of soil K.

The Q/I relation of soil describes the relation between K availability or intensity (I) and Quantity (Q) present in the soil. Woodruff (1955) proposed the relationship between the activities of K and Ca viz., $a_K/a\sqrt{Ca}$ as an index of K availability in soils. But Beckett (1964a and b) was the first to describe the Q/I parameters as a successful technique to assess the K availability. He concluded that the activity ratio of K (AR_e^K) had the same values for all solutions in equilibrium regardless of Ca+Mg (upto 0.06M) and is a measure of chemical potential of labile K or the intensity factor. He also reported that AR_e^K will not necessarily provide a good measure of K for comparing soils of widely varying Ca ratio. Subsequent to the work, Tinker (1964a and b) proposed a modification to the calculation of Beckett's activity ratio including the activity of aluminium to predict the K status of acid soils and called it as ARu (Unified activity ratio).

According to Ramamoorthy and Paliwal (1965a and b) the KAR (Equilibrium potassium adsorption ratio) had a wider applicability in soils of heterogenous nature. Further, this appeared to be a good index of K availability in paddy soils. Acquaye and McLean (1966) observed that the AR_e^K gave a higher degree of correlation with portions of K derived from exchangeable forms, while the AR_e^K and quantity of K released ($-\Delta K^o$) were much more indicative of total K uptake than AR_e^K alone. The potential buffering capacity of K (PBC^K), ratio of $-\Delta K^o$ to that of AR_e^K, showed some relation to the amount of non-exchangeable K and was well correlated to the clay content of the soil and degree of K fixation (Acquaye and McLean, 1966). The PBC^K was reported to be suitable measure of K availability (Barrow, 1966) and is an useful index of K uptake over a growing period.

Beckett and Nafady (1967) found that the Q/I relation was almost unchanged either by large additions upto 3730 kg $K_2O \cdot ha^{-1}$ and the fixation of upto 1900 kg K_2O ha^{-1} or by the depletion of the soil of both labile and some fixed K equivalent to 5 to 20 years of cropping. Bradfield (1969) concluded that the initial AR_e^K was correlated with K percentage in straw berry leaves, but not with the yield of the crop. The Q/I relationship was also found to be better index of K availability than exchangeable K by RezK and Amer (1969).

According to Zandstra and Mackenzie (1968), the K potential well correlated with crop response than AR_e^K or PBC^K, but Balasundaram (1971) studied two soils of Coimbatore and concluded that the K potential alone could not be relied upon as the sole index of K availability. Narayanan Nambiar (1972) observed that the AR_e^K was significantly related to water soluble K, exchangeable K and Neubauer K, while the PBC^K was not related to any of the these parameters.

A model was presented by Beckett and Clement (1973) based on the short and long term Q/I relations of K in a soil on graphs of K uptake by crop against post uptake K - activity ratio, and the exhaustion value of K activity ratio below which K can no longer be taken up, by means of which, to estimate the amount of labile K in a soil and to compare the contribution of labile and fixed K to plant uptake.

A highly significant correlation was obtained between the activity ratio and the total amount of K fertiliser applied during six years of cropping in the experiments of Bijay Singh et al. (1978). The PBC^K was correlated with K saturation of the total and inorganic cation exchange capacity (Maji and Sengupta, 1982). The K uptake has been well correlated with initial labile K predicted from the Q/I isotherms (Sinclair, 1979; Pchelarova and Milcheva, 1983).

Ghosh and Ghosh (1976) observed that the K^O (Q parameter) was less than total exchangeable K content of the soil, which indicated that part of the exchangeable K did not take part in the ion exchange equilibria of immediate Q/I relationship. They observed no extra advantage in describing K availability in terms of Q/I relationships . Similar conclusions were drawn by Bandhyopadhyay (1976) while working in red and black soils of India. The activity ratio has been reported to be unsatisfactory index of K availability by Zandstra and Mackenzie (1968), Wild et al. (1969), Schuffelen (1972) and Ramanathan (1977) whereas both

AR_e^K and K_L was considered to be better indices of K availability in the salt affected soils of Haryana by Tewatia et al. (1987).

The most serious objections in using activity ratio as an index of K availability are (i) two soils exhibiting the same value of activity ratio may differ in absolute K concentration, (ii) the assumed negative effect of (Ca+Mg) on K uptake has not been fully established (Goswamy and Bandhyopadhyay, 1978). Prediction of K can be successfully done only when factors like Q/I relationship, K binding energy (a clay mineral character), diffusion co-efficient (a complex parameter depending upon factors like soil water status and relatively stable characters of soil like texture and structure) and plant characters are taken into consideration (Balasundaram and Krishnamoorthy, 1974).

The Q/I studies of labile K and Na of an alluvial soil by Narain and Singh (1979) revealed three exchange sites of K viz., planar, edge and inter lattice, which differed markedly with regard to K adsorption. The planar exchange sites were equally accessible to K and Ca while wedge and inter lattice sites showed high degree of specificity for K adsorption.

The thermodynamic concept has also been tried. The ion flux would be from that of higher potential to the lower one. It is to be assumed that the potential level in the plant system remain constant and as long as it remains lower to that in the solution phase, the uptake remains steady and proportional. This assumption was checked by a sand culture experiment by Balasundaram et al. (1980). They reported that in the case of maize, neither the concentration nor the activity ratio correlated well with the uptake, but in onion, the activity ratio was related to uptake and not to the concentration values.

Alias et al. (1980 a, b, c and d) published a series of papers on the relationship between Q/I parameters of K and other soil parameters in Aridisols, Entisols, Mollisols and Inceptisols. The equilibrium activity ratio and other parameters of K availability were found to decrease with depth in all the soils coming under the four orders. In saline soils, the AR_e^K was high through out the profile, but its relationship with other indices of K availability suggested a low rate of release of K from the solid phase of soil and consequently a limited availability to plants. The total labile pool of K was greater than the ammonium acetate extractable K which was greater than the easily exchangeable K. Labile K and its components decreased with increasing profile depth. PBC^K increased with depth and was affected by the amount and type of clay in Aridisol, Mollisol and Inceptisol but not in Entisol.

Negi et al. (1981) opined that the continuous application of K fertilizer resulted in higher AR_e^K than farm yard manure whereas labile K remained unaffected.

Sparks and Liebhardt (1981) concluded that liming resulted in increased K release which was seen with the increase in $-\Delta K^o$. It also increased PBC^K.

There exists a highly positive correlation between the parameters of PBC^K, AR_e^K and K_L and the clay, organic carbon, available K and exchangeable K in the studies of Maji and Sengupta (1982). A very close relationship of r = 0.908 was obtained by Mengel and Busch (1982) between the K buffer power and the critical concentration of the solution. A significant negative correlation between AR_e^K and clay content was observed by Chandrasekar Rao and Prasad Rao (1983) where as Mahendra Singh et al. (1986) inferred that soils having higher NH_4OAc-K did not necessarily yield higher AR_e^K values. The PBC^K and AR_e^K are negatively related in the studies of Dhillon et al. (1986).

The potential buffering capacity of soils was poor in soils low in clay, organic matter and cation exchange capacity as reported by Yadav (1986). Datta and Sastry (1987) while studying the Q/I parameters of the rice growing soils inferred that soils containing montmorillonite clay minerals have more linear buffering capacity than kaolinite and illite soils indicating the higher buffering capacity of soils with montmorillonite clay. It was opined by Rani Perumal and Sonar (1987) that soils having AR_e^K values of less than 2×10^{-3} $(m.l^{-1})^{1/2}$ and above -3500 calories.mol^{-1} of ΔG are considered deficient in K.

2.6. Effect of K on Rice Yield

Eventhough the need of K for rice crop has long been established, there is no definite answer on the need of K application to all the rice soils. There are perhaps equal number of reports for and against the application of K for rice. The changes in the soil characteristics, environmental influence and varietal differences are responsible for such variations in the response of rice to K application.

Arunachalam et al. (1964) observed response to K in all the districts of Tamil Nadu except in parts of Coimbatore and Salem, where K application depressed the yield. According to Mariakulandai et al. (1965) only the second crop of rice responded to K application under the potash scheme experiment in farmer's fields in the districts of Thanjavur, Tiruchy, Tirunelveli and Madurai.

Esakkimuthu (1972) reported increasing yield of rice with K application on Coimbatore soil. According to Sadayappan et al. (1971) rice responded to K application in Mani Muthar tract. Studying the response of high yielding rice varieties (ADT 27, IR 8, IR 5 and Co 33) to K application at Thanjavur, Dhanapalan Mosi et al. (1973) observed that IR 5 alone responded to K application. Vadivelu et al. (1973) found significant response of rice to K application at Coimbatore. Kalyani Kutty and Morachan (1974) observed that Co 33 and ADT 27 responded to K application in Coimbatore.

From the reports of All India Coordinated Agronomic trials project in India, Kanwar (1974) concluded that the response to the application of K was higher in soils low in available K than in the experiments conducted on medium K level. However in alluvial soils of Patna, the response of K was very low and was concluded that the exchangeable K measurement was unsuitable and was a poor indicator of K supplying power of soils.

Response of rice to K application was also reported by Kanwar and Grewal (1966), Kemmler (1972) Singh and Singh (1972), Velly (1972), Feng and Saldana (1973), Ramirez et al. (1975), Esakkimuthu et al. (1975), Singh and Sinha (1975), Von Uexkull (1976), Ali et al. (1976), Ramanathan (1977), Mandal and Des Mahapatra (1982), Nagarajan et al. (1982) and Durairaj Muthiah (1986).

In contrast to these observations, absence of response to K application by rice was reported by several workers. In Coimbatore wetlands, Padma Variety did not respond to K application (Subramanian, 1970). Sadayappan et al. (1971) reported no response of rice to K application in Thamaraparani tract during rabi season, but during Kharif it responded.

Absence of response or negative response of rice to K application was also reported by Gopal Rao (1972), Kolandaisamy et al. (1974), Krishnamoorthy et al. (1974) and Ramasamy and Palaniappan (1974). Sekhon et al. (1988) inferred that a knowledge on the extent and nature of different soil series and soil types within a series may provide better information for making recommendations for K.

2.7. Interaction of Nitrogen and Potassium

Some of the interactions which affect the way in which crops respond to a nutrient such as K are with qualitative factor such as form of fertilizer, method and date of application, crop variety etc. The more important type of interactions is with quantitative variables such as level of other nutrients applied,rate of irrigation, plant spacing etc. Among these, the interaction of K with other nutrients, particularly nitrogen is the most important.

Though the N and K interactions are most prominent in soils, beecause of the similar ionic radii of NH_4^+ and K^+, the extent and nature of interaction is depending upon their concentration, time and mode of application and moisture condition of the soils. Sengupta et al. (1971) reported that the retentiion of N^{15} in soil decreased considerably when K was added prior to the addition of N. The decrease was very little in case of acid soils, while in a calcareous soil there was a slight increase, possibly because of the presence of positive edged charge and Al^{3+} ions which are likely to develop negative charges with phosphate ions where NH_4^+ can be held.

Raju and Mukhopadhyay (1973, 1975b) reported that higher percentage of added nitrogen was fixed in NH_4^+ form in the K added treatment. An opposite trend was observed when relatively high amount of exchangeable Na was present in the clay complex which might have influenced the fixation. The highest fixation of NH_4 resulted when K^+ was added 10 days before the addition of NH_4^+. When both the ions were added simultaneously, more NH_4^+ was fixed firstly because of the higher bonding energy (in the presence of equal amount) over K ion and because of the similarly fixable K ion which prevented the releasee of already fixed NH_4^+ ions. In the treatments where K application was seperated from N application by 2 days, the presence of one of the ions of similar ionic radii and so similar fixability was available in large amounts for the first 3 days, more fixation of that ion resulted leaving least number of sites for the next.

Kar et al. (1975) noted that 46 to 55 per cent of the K^+ added, remained in water soluble form, while in the presence of NH_4^+, water soluble K ranged from 50 to 59 per cent which might be due to lesser fixation of K^+ in the presence of NH_4^+. Addition of K resulted only in marginal increase in exchangeable K in the presence of NH_4^+. K fixation was maximum in the presence of NH_4^+ in the studies of Ramanathan et al. (1977) and Singh and Singh (1979). The K fixation was more when both the elements were applied simultaneously than when K was applied prior to NH_4^+.

Sato et al. (1980) observed an increased concentration of NH_4-N in paddy soils with K application in the early periods and subsequently it was lower than the control. As the amount of K in the soil increased the amount of water soluble NH_4-N also increased. The release rate of K during successive periods was almost constant and not affected by the addition of NH_4 in the studies of Beauchamp (1982).

Mandal and Des Mahapatra (1982) observed that the percentage increase in the yield of rice due to K fertilisation was higher at higher levels of N. The results of Patel and Khatri (1983) showed that the adverse effect of excess K can be reduced with higher application of N and can result in the increased yield of rice.

Though both the NH_4 and K^+ can compete for their fixation sites, their fixation was not only governed by the polarisability of the ions, the NH_4^+ having higher polarisability than the K^+, is preferred in the ion exchange reactions (Sparks, 1987), but also governed by the type of clay minerals that are present in the soils (Bajwa, 1987). He inferred that montmorillonite fixed more amount of NH_4^+ but least K^+, X-ray amorphous clay fixed preferably NH_4^+ over K^+, Vermiculite and beidellite strongly fixed both, hydrous mica, chlorite, halloysite fixed low NH_4^+ as well as K^+.

EXPERIMENTAL DETAILS

CHAPTER 3

EXPERIMENTAL DETAILS

In order to achieve the various objectives catalogued under the Introduction (Chapter I), both field and pot culture experiments were conducted. The details relating to the field and the pot experiments, the soil sample collection and the analytical methods followed are presented in this chapter.

3.1. Details of the Field Experiments

3.1.1. Location

The field experiments were conducted in the Tamil Nadu Rice Research Institute, Aduthurai, Thanjavur district with rice as test crop.

3.1.2. Season and Varieties

The first experiment was conducted during the Samba season (October to February) with a long duration variety CR 1009 (Ponmani). The second field experiment was conducted during the Kuruvai season (June to September) with a short duration variety, ADT 36. The third experiment was conducted during the Thaladi season (October to January) with a medium duration variety, IR 20.

3.1.3. Soils

The soil of the experimental fields belonged to Adanur Series and the results of the analysis of the initial soil are furnished in Table 1.

3.1.4. Design and Layout of the Experiments

The experiments were conducted in a factorial randomised blocks design with three replications.

3.1.5. Treatments Details

There were four levels in each of nitrogen and potassium (0.50, 100 and 150 kg . ha^{-1}) in all possible combinations and replicated thrice. Urea and muriate of potash were the forms of N and K applied respectively. Phosphorus was applied uniformly to all the treatments based on the soil test recommendations in the form of super phosphate. The treatment combinations were as follows:

Treatment No.	Treatment details (kg.ha^{-1})	
	Nitrogen	Potassium (K_2O)
T_1	0	0
T_2	0	50
T_3	0	100
T_4	0	150
T_5	50	0
T_6	50	50
T_7	50	100
T_8	50	150

T_9	100	0
T_{10}	100	50
T_{11}	100	100
T_{12}	100	150
T_{13}	150	0
T_{14}	150	50
T_{15}	150	100
T_{16}	150	150

Nitrogen was applied in three splits, 50 per cent basally, and 25 per cent each at tillering and panicle initiation stages. The entire amounts of P and K were applied basally.

3.1.6. Transplanting and After cultivation

Seedlings were transplanted at their appropriate ages viz., 25 days for the short duration variety (Kuruvai season), 30 days for the medium duration variety (Thaladi) and 35 days for the long duration variety (Samba season). Peizometers for the collection of soil solution samples were placed in each plot at 20 cm depth before transplanting. The short duration variety was planted at a spacing of 15 x 10 cm and the medium and long duration varieties with a spacing of 20 x 10 cm. The seedlings were transplanted at the rate of 2 seedlings per hill. The crop was weeded at the appropriate time. Irrigation was given such that the water level was maintained at 5 cm throughout the crop period till 15 days before harvest. Prophylatic measures were taken up at the appropriate time against pests and diseases.

3.1.7. Collectiion of Soil, Soil Solution and Plant Samples

The composite soil samples were collected before transplanting for the initial analyses. Soil solution samples were collected from the peizometers placed in each plot at the important physiological stages of rice growth viz., tillering and panicle initiation during Samba season. During Kuruvai and Thaladi seasons, soil solution samples were collected at 10 days interval to generate more informations. These samples were analysed immediately or stored in polythene containers with toluene on the surface of the soil solution to avoid transformations. Soil and plant samples were collected at three stages viz., tillering, pancile initiation and harvest. The wet soil samples were collected in aluminium containers and the analyses of the wet soil samples were carried out as outlined in section 3.5. After the estimation of the moisture content of the samples simultaneously, the results were reported on oven dry basis. For determining quantity - intensity (Q/I) relationship of K, the soil samples were dried in shade, gently powdered with wooden mallet and sieved through 50 mesh sieve. The plant samples were dried in an air-oven at 60-70 $^{\circ}$C. The dried samples were powdered in a wiley mill and used for analyses. The grain and straw yields were recorded seperately.

3.2. Details of the Pot Experiments

3.2.1. Details of the Soil Collection

Out of the 22 soil series established in Thanjavur district 10 dominant soil series which constitute more than 80 per cent of the cultivated area were included for the present study. The locations of soil collection and the appropriate classification of the soil series as per the soil Taxonomy are given below.

Details of the soil series collected for the pot experiment

Sl.No.	Soil Series	Sub-group	Location of soil collection
1.	Kondal	Typic chromustert	Alakkudi
2.	Padugai	Typic ustifluent	Kadiramangalam
3.	Valuthalakudi	Typic udipsamment	Thandankulam
4.	Kivalur	Entic chromustert	Kivalur
5.	Nedumbalam	Entic Chromustert	Manali
6.	Sikar	Typic Chromustert	Thiruvarur
7.	Pattukkottai	Ultic haplustalf	Pattukkottai
8.	Madukkur	Aquic haplustalf	Nattuchalai
9.	Adanur	Entic chromustert	TRRI, Aduthurai
10.	Kalathur	Udic Pellustert	Vannakkudi

3.2.2. Season and Varieties

The first experiment was conducted during Kuruvai season (June-September) with a short duration variety, ADT 36. The second experiment was conducted (residual study) during Thaladi season (October to January) with a medium duration variety IR 20.

3.2.3. Preparation of Soil Samples

The soil samples were air dried, gently malleted and the extraneous matters removed by Sieving with 6 mm sieve. The soil passing through 2 mm sieve was used for the initial soil analyses. The wet soil samples were collected, preserved, analysed and values computed on oven dry basis as described in section 3.1.7.

3.2.4. Design and Treatment Details of Pot Experiment

3.2.4.1. First Crop

The experiments were laid out in a factorial randomised Blocks design with two replications. The details of the treatments during Kuruvai were as follows:

N levels : 0, 50, 100 and 150 kg $N.ha^{-1}$

K levels : 0, 50, 100 and 150 kg $K_2O.ha^{-1}$

Soils : 10 dominant soil series of Thanjavur delta as mentioned in section 3:2:1.

P was applied uniformly to all pots at the rate of 50 kg $P_2O_5.ha^{-1}$

3.2.4.2. Residual Crop

For the second season crop (Thaladi crop) N treatments (0, 50, 100, 150 $kg.ha^{-1}$) were alone given along with an uniform dose of P at 50 kg $P_2O_5 \cdot ha^{-1}$ level. Potassium was not applied to the second crop in order to study the residual effect of K. Nitrogen in the form of urea was applied in three splits, 50 per ceent at transplanting along with the entire quantity of P in the form of super phosphate. The remaining 50 per cent of N was applied in two equal splits at tillering and panicle initiation stages.

The pots were filled with seven kg of soil, water was added, mixed properly so as to get an uniform suspension of soil and water. The seedlings pulled out at 25 days and 30 days age, respectively for Kuruvai and Thaladi seasons were transplanted at the rate of 3 hills/pot and 2 seedlings per hill. irrigation was given on alternate days. Prophylaic measures were taken up at the appropriate time against pest and diseases.

3.2.5. Collection of Soil and Plant Samples

The collection and processing of soil samples for chemical analysis and for determining Q/I parameters and plant sampls for computing uptake of nutrients were done as described in 3.1.7.

3.3 Particulars of Soil Analyses

The details of the analyses carried out for determining the soil physical, physico-chemical and fractions of N and K following the standard procedures are described below:

Sl.No.	Parameters	Reference/ Author (s)	Remarks
1.	**Physical parameters**		
1.1	Soil physical constants	Keen and Raczkowski (1921)	Keen-Raczkowski brass cup measurements
1.2	Particle size analysis	Piper(1966)	International pipette method
2.	**Chemical properties**		
2.1	Moisture	A.O.AC(1962)	Gravimetric method
2.2.	Loss on ignition	Piper (1966)	Gravimetric method
2.3	Hydrochloric acid extraction	Piper (1966)	Acid:water ratio 1:1
2.4	Sesqui-oxides	Piper (1966)	Gravimetric method
2.5	Iron-oxide	Piper (1966)	Volumetric method
2.6	Alumina	Piper (1966)	Difference betwe the total sesqui- oxides and iron oxide

2.7.	Total Calcium and Magnesium	Jackson (1973)	Versenate titration
2.8	Total Nitrogen	Jackson (1973)	Kjeldahl digestion
2.9	Total Phosphorus	Pemberton (1945)	Volumetric method
2.10	Total Potassium	Toth and Prince (1960)	Flame photometry method
2.11.	Available Nitrogen	Subbiah and Asija (1956)	Alkaline permanga--nate method
2.12	Available Phosphorus	Olsen et al. (1954)	0.5M Sodium bicarbonate (pH 8.5) extraction
2.13.	Available Potassium	Stanford and English (1949)	Neutral normal ammonium acetate extraction-flame photometry method.
2.14	Available Calcium and Magnesium	Toth and Pince (1960)	Neutral normal ammonium acetate extraction - versenate titraion.
2.15	Organic Carbon	Walkley and Black (1934)	Wet digesttion method
2.16	Soil reaction (pH)	Jackson (1973)	Soil:water ratio 1 : 2

2.7.	Total Calcium and Magnesium	Jackson (1973)	Versenate titration
2.8	Total Nitrogen	Jackson (1973)	Kjeldahl digestion
2.9	Total Phosphorus	Pemberton (1945)	Volumetric method
2.10	Total Potassium	Toth and Prince (1960)	Flame photometry method
2.11.	Available Nitrogen	Subbiah and Asija (1956)	Alkaline permanga- -nate method
2.12	Available Phosphorus	Olsen et al. (1954)	0.5M Sodium bicarbonate (pH 8.5) extraction
2.13.	Available Potassium	Stanford and English (1949)	Neutral normal ammonium acetate extraction-flame photometry method.
2.14	Available Calcium and Magnesium	Toth and Pince (1960)	Neutral normal ammonium acetate extraction - versenate titraion.
2.15	Organic Carbon	Walkley and Black (1934)	Wet digesttion method
2.16	Soil reaction (pH)	Jackson (1973)	Soil:water ratio 1 : 2

2.17.	Electrical conductivity	Jackson (1973)	By using conductivity bridge
2.18	Cation exchange capacity	Schollenberger and Dreibelbis (1930)	Using neutral normal ammonium acetate.
2.19.	Ammoniacal and nitrate nitrogen	Keeney and Bremner (1964)	Steam distillation
2.20	Potassium in soil solution	Toth and Prince (1960)	Flame photometry

3.3.3. Determination of Different Forms of Potassium

3.3.3.1. Water Soluble Potassium

A 10g lot of soil sample was transferred to a centrifuge tube and 25 ml of distilled water was added. The tube was shaken for 10 minutes, centrifuged and the clear supernatent liquid filtered. The filterate was collected in a 100 ml volumetric flask . Three additional extractions were made in the same manner and the combined extract diluted to 100 ml with distilled water. The extract thus obtained was mixed well and potassium determined using flame photometer (Narayanan Nambiar, 1972).

3.3.3.2. Exchangeable Potassium

The method of Pratt (1965) was followed. A 10g lot of soil sample was transferred to a 50 ml centrifuge tube and 25 ml of neutral normal ammonium accetate was added to the tube. The tube was shaken for 10 minutes, centrifuged and the clear supernatent liquid filtered. The filterate was collected in a 100 ml volumetric flask. Three additional extractions were made in the same manner and the combined extracts diluted to 100 ml with neutral normal ammonium acetate. The solution was mixed well and K estimated using flame photometer. The difference between water soluble and the ammonium acetate extractable K was computed as the exchangeable K.

3.3.3.3. Non Exchangeable Potassium

Normal nitric acid extractable potassium was determined by employing the method of Wood and De Turk (1940).

A 2.5 g lot of finely ground soil sample was transferred to a 100 ml flask and 25 ml of normal nitric acid was added. The flask was then heated over a gas burner and the content was made to boil gently for 10 minutes. The content was then cooled, diluted, filtered and the filterate collected in a 100 ml volumetric flask. The soil residue was then washed four times with 15 ml portions of 0.1N HNO_3 and collected in the same volumetric flask, mixed thoroughly and K determined using flame photometer. The difference between the normal nitric acid extractable K and water soluble plus exchangeable K were taken as the non-exchangeable K.

3.3.4. Determination of Available K by Different Methods

Extractant	Weight of soil taken (g)	Volume of extractant (ml)	Shaking time (minutes)	Author(s)
1. Distilled water	5	25	5	Nelson (1959)
2. 0.5N EDTA	5	25	1	Narayananan Nambiar (1972
3. 0.5N NaCl	10	20	1	-do-
4. Neutral Normal Ammonium acetate	5	25	5	Hanway and Heidal(1952)
5. 10 per cent Sodium acetate + 3 per cent acetic acid (pH 4.8)	10	20	1	Morgan (1941)
6. 0.01N HCl	5	25	5	--
7. 0.5 N HCl	5	25	5	Elsokkary (1973)
8. 0.1N HCl	5	25	5	Sobulo (1973)
9. 0.5N HNO_3	5	25	30	Oommen and Iswaran (1962)
10. 0.1N HNO_3	5	25	30	Sobulo (1973)
11. 1N HNO_3	2.5	25	10	Ghosh and Ghosh (1976)
12. 0.01N HNO_3	5	25	5	--
13. 6N H_2SO_4	10	20	30	Hunter and Pratt (1957) method No.2
14. 0.5N NH_4F in 0.025 N HCl	5	25	5	Bray and Kurtz (1945)
15. 0.01M $CaCl_2$	5	25	5	Beckett (1964a)

3.3.5. Quantity-Intensity Relationship of Potassium

The method developed by Beckett (1964a) and as adopted by Palaniappan (1972) was employed for the determination of K potential. To a series of 5g soil samples (passing through 50 mesh sieve) in 100 ml shaking bottles (centrifuge bottles), 40 ml of 0.0125 M $CaCl_2$ was added. In addition, 10 ml portions each of varying KCl concentrations were added to make the final concentration 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 0.5g was also weighed into the centrifuge bottle and 50 ml of 0.01M $CaCl_2$ solution was added. The bottles were shaken in a shaker for 1 hour, kept over night and centrifuged at 2000 RPM for 10 minutes. The supernatent liquid was filtered and analysed for K using flame photometer and for Ca and Mg by the Versenate titration method.

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

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

The ΔK (gain or loss of K), the difference between the amount of K added and recovered in the extracted solution in m.e.100 g^{-1} soil was also calculated.

The AR^K was then plotted against ΔK . For most of the soils typically a curve with linear upper part and a curved lower part was obtained. The linear part of the curve was interpolated to intersect the X-axis and this X-intercept would represent the equilibrium activity ratio (AR^K_e) where ΔK was zero. The linear part was also extrapolated 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 ($-\Delta K^o$).

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. Furthur an extension of the curved lower part of the ΔK axis gives the total amount of K in labile pool (K_L). The potential buffering capacity for K was calculated as follows:

$$PBC^K = \frac{-\Delta K^o}{AR^K_e}$$

Where PBC^K = Potential buffering capacity

$-\Delta K^o$ = 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

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

$$G = RT \ln (AR_e^K)$$

Where R is the gas constant and T is the absolute temperature ΔG, the free energy in calories and ln the natural logaritum.

3.4. Plant analysis

3.4.1. Total Nitrogen

The microkjeldahl method as described by Humphries (1956) was employed to determine the total nitrogen.

3.4.2. Prepqration of TripleAcid Extract

Exactly 0.5g of powdered plant material was digested with 12 ml of triple acid mixture of nitric acid, sulphuric acid and perchloric acid in the ratio of 9:2:1. The extract was made up to known volume and P and K estimated employing the following methods.

3.4.4. Phosphorus

This was estimated in a known aliquot of the triple acid extract by Vanado molybdate method (Jackson, 1967).

3.4.5. Potassium

This was estimated in the triple acid extract using Corning '400' flame photometer.

3.5. Statistical Analysis

The yield and analytical data obtained in the study were subjected to statistical scrutiny for drawing definite conclusions. Simple correlations and multiple regressions were worked out between various soil characters, yield parameters and the nutrient uptake data. Response functions were fitted in between the grain yield and levels of N and K to work optimum dose of these nutrients in the different soil series of Thanjavur delta.

RESULTS

CHAPTER 4

RESULTS

The results of analyses of the soil and plant samples and yield particulars of the experiments conducted as described in Chapter 3 are presented in this chapter.

4.1. The Results of Field Experiments

4.1.1. General Properties of the Soils

The results of initial soil analysis of the experimental fields (K_3C and D_2a) are presented in Table 1. Both the soils of the experimental fields come under Adanur soil series and belonged to the sub group Entic Chromustert as per the Soil Taxonomic classification. The soils of K_3C and D_2a fields were silty clay loam and clay loam in texture respectively, low in available N, medium in available P status and high in available K status.

4.1.2. Availability Indices of K in Soils

The soil samples collected during important physiological stages of rice crop viz., active tillering (S1), panicle initiation (S2) and post-harvest stages were extracted with different extractants numbering 15 to find out the most suitable extractant to predict K availability and the results of the statistical analysis of the data are presented in Tables 2-16.

Table 1. Results of the initial soil analysis of the field experiments

Properties	Field Numbers K_3C	D_2a
I. Mechanical analysis		
i) Clay (%)	30.91	42.15
ii) Silt (%)	35.12	30.18
iii) Fine sand (%)	15.87	18.11
iv) Coarse sand (%)	8.01	7.15
Loss (by difference)	2.09	2.41
Texture	Silty clay loam	Clay loam
II. Physical constants		
i) Apparent density $kg.m^{-3}$	1070	1120
ii) Absolute specific gravity $kg.m^{-3}$	2180	2280
iii) Pore space (%)	38.91	45.82
iv) Water holding capacity (%)	42.15	48.91
v) Volume expansion on wetting (%)	28.81	33.10
III. Chemical analysis		
i) Moisture (%)	2.15	3.59
ii) Loss on Ignition (%)	3.89	4.42
iii) Iron Oxide (Fe_2O_3 %)	5.12	6.89
iv) Alumina (Al_2O_3 %)	8.91	9.57
v) Total N (%)	0.108	0.142
vi) Available N (ppm)	84.0	92.0

(Contd.,)

Table 1. (Contd.,)

vii)	Total P (%)	0.092	0.115
viii)	Available P (Olsen's) (ppm)	15.2	16.8
ix)	Total K (%)	0.29	0.35
x)	Available K (NH_4OAc-K) (ppm)	214	202
xi)	Total Ca (%)	0.52	0.40
xii)	Available Ca (ppm)	1960	3080
xiii)	Total magnesium (%)	0.39	0.42
xiv)	Available Mg (ppm)	289	313
xv)	Organic carbon (%)	0.42	0.61
xvi)	Soil pH (1:2 soil:water suspension)	6.30	7.10
xvii)	Electrical conductivity ($ds.m^{-1}$)	0.39	0.17
VI.	<u>Cation exchange properties</u> ($m.e.100\ g^{-1}$)		
1.	Cation exchange capacity	15.8	25.2
2.	Exchangeable K	0.34	0.39
3.	Exchangeable Ca	9.80	15.40
4.	Exchangeable Mg	2.41	2.61
V.	<u>K Potential parameters</u>		
1.	$AR_e^K \times 10^{-3}$ (moles $litre^{-1})^{1/2}$	2.29	2.23
2.	$-\Delta K^o$ ($m\ e\ 100\ g^{-1}$)	0.25	0.245
3.	PBC^K	109	97
4.	ΔG (- calories)	3637	3577
5.	K_L	0.436	0.428
6.	K_X	0.186	0.183

4.1.2.1. Water Extractable K (Table 2)

Application of N, increased the water extractable K in all the three seasons, the levels being comparable but superior over control during Samba season. The levels N_{100} and N_{50} recorded the highest value during Kuruvai and Thaladi seasons respectively. The same trend of results was observed at all levels of K during Kuruvai season and in all the stages of sampling during Thaladi season. The water extractable K consistently increased with every increase in the levels of K in all the three seasons. During Kuruvai season alone, the water extractable K increased with increasing levels of N, where as at N_{150} level the effect of K was not pronounced. With the advancement of crop growth, the water extractable K in soils decreased. This was true irrespective of the levels of N during Thaladi season.

4.1.2.2. N NH_4OAc-K (Table 3)

The NH_4OAc-K increased with every increase in the levels of N during Thaladi season, whereas during Samba and Kuruvai seasons the higher levels were comparable but superior over the lower levels of N which were again on a par. This was true at all stages of sampling during Thaladi season. Application of K increased the NH_4OAc-K in all the seasons, the levels K_{150} and K_{100} being on a par during Samba and Kuruvai seasons. This result was also observed during Samba season at tillering stage, whereas at the latter stages of sampling, the effect of K was not marked. The NH_4OAc-K decreased with the advancement of sampling in

Table 2. Results of the statistical analysis of the water extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
17.23	21.33	20.92	20.92	0.88	1.78

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
16.44	19.50	21.81	22.65	0.88	1.78

3. Stages

S_1	S_2	S_3	SE_D	CD
24.14	18.39	17.77	0.76	1.54

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
10.46	11.71	13.89	11.47	0.44	0.89

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
9.57	11.46	12.76	13.73	0.44	0.89

(Contd.,)

Table 2. (Contd.,)

4) Nitrogen x Stages interaction

	S_1	S_2	S_3	SE_D	CD
N_0	16.07	14.20	10.64	0.97	1.96
N_{50}	18.41	16.36	13.70		
N_{100}	17.44	13.75	13.11		
N_{150}	19.72	12.60	11.71		

Table 3. Results of the statistical analysis of the NH_4OAc extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
183	191	206	211	5.00	10

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
180	193	205	214	5.00	10

3. Stages

S_1	S_2	S_3	SE_D	CD
253	186	155	4.3	9

4. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	222	168	149	8.6	17
K_{50}	246	180	152		
K_{100}	270	191	153		
K_{150}	272	204	165		

(Contd.,)

Table 3. (Contd.,)

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
160	164	170	172	2.2	4

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
159	164	170	173	2.2	4

3. Stages

S_1	S_2	S_3	SE_D	CD
175	170	155	1.9	4

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE	CD
186	193	199	208	1.25	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE	CD
185	192	200	203	1.2	2

(Contd.,)

Table 3. (Contd.,)

3. <u>Stages</u>

S_1	S_2	S_3	SE_D	CD
215	200	174	0.97	2

4. <u>Nitrogen x Stage interaction</u>

	S_1	S_2	S_3	SE_D	CD
N_0	209	189	161	1.95	4
N_{50}	211	198	170		
N_{100}	215	205	176		
N_{150}	225	209	191		

all the seasons and at all levels of N during Thaladi season. This was also true irrespective of the levels of K during Samba season.

4.1.2.3. 0.01N HCl-K (Table 4)

Application of N increased the 0.01N HCl-K in all the three seasons. This was well pronounced during Kuruvai and Thaladi seasons and in Samba season N_{50} was superior over the rest of the levels which were comparable. The increase in the 0.01N HCl-K with every increase in the levels of K was observed in all the seasons. The 0.01N HCl-K decreased as the stages of sampling advanced.

4.1.2.4. 0.1N HCl-K (Table 5)

Nitrogen application consistently increased the 0.1N HCl-K during Kuruvai and Thaladi seasons, whereas in Samba season, this effect was not well pronounced. Application of K progressively increased the 0.1N HCl-K in all the seasons. It also decreased with the advancement of sampling irrespective of the seasons.

4.1.2.5. 0.5N HCl-K (Table 6)

Increase in the 0.5N HCl-K was observed with increase in the levels of N during Kuruvai and Thaladi seasons. The level N_{100} was on a par with N_{50} and registered

Table 4. Results of the statistical analysis of the 0.01N HCl extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
49.3	56.8	47.6	46.0	2.1	4.3

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
40.7	48.0	53.2	57.7	2.1	4.3

3. Stages

S_1	S_2	S_3	SE_D	CD
65.0	50.9	33.9	1.9	3.7

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
37.1	40.6	43.1	46.8	1.18	2.4

(Contd.,)

Table 4. (Contd.,)

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
37.8	40.3	43.5	46.2	1.18	2.4

3. Stages

S_1	S_2	S_3	SE_D	CD
47.8	42.3	35.6	1.02	2.0

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
45.3	49.7	58.1	61.1	2.19	4.4

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
42.4	51.1	55.3	65.3	2.19	4.4

3. Stages

S_1	S_2	S_3	SE_D	CD
75.0	48.5	37.2	1.9	3.8

Table 5. Results of the statistical analysis of the 0.1N HCl extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
119	124	111	103	4.8	10

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
97	108	121	131	4.8	10

3. Stages

S_1	S_2	S_3		SE_D	CD
129	117	98		4.2	8

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
68	72	73	78	1.5	3

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
68	71	74	79	1.5	3

(Contd.,)

Table 5. (Contd.,)

3. Stages

S_1	S_2	S_3		SE_D	CD
84	71	63		1.3	3

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
72	81	94	101	2.6	5

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
71	82	92	104	2.6	5

3. Stages

S_1	S_2	S_3		SE_D	CD
110	86	66		2.2	5

Table 6. Results of the statistical analysis of the 0.5N HCl extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
187	197	203	175	3.9	8

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
172	185	197	209	3.9	8

3. Stages

S_1	S_2	S_3	SE_D	CD
207	189	175	3.4	7

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	207	193	162	6.7	14
N_{50}	219	191	181		
N_{100}	223	193	193		
N_{150}	181	178	166		

(Contd.,)

Table 6. (Contd.,)

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	184	168	164	6.7	14
K_{50}	200	177	177		
K_{100}	216	202	172		
K_{150}	229	212	185		

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
145	153	161	167	1.8	4

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
150	154	159	163	1.8	4

3. Stages

S_1	S_2	S_3	SE_D	CD
180	155	135	1.6	3

(Contd.,)

Table 6. (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
152	161	171	183	2.7	5

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
147	160	172	188	2.7	5

3. Stages

S_1	S_2	S_3	SE_D	CD
204	164	133	2.3	5

4. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	177	144	121	4.7	9
K_{50}	193	158	129		
K_{100}	211	169	136		
K_{150}	234	185	145		

higher value than the rest during Samba season and this was true at all the stages of sampling. Application of K correspondingly increased the 0.5N HCl-K in all the seasons. During Samba and Thaladi seasons, this trend was observed at the tillering and panicle initiation stages also, where as at post-harvest stage alone the effect of K was not pronounced. With the advancement of sampling, 0.5N HCl-K decreased in all the seasons and at all levels of N and K during Samba and Thaladi seasons.

4.1.2.6. 0.1N HNO_3-K (Table 7)

The results of 0.1N HNO_3-K followed the same trend with the application of N, K and with the advancement of sampling, as observed in the 0.5N HCl-K.

4.1.2.7. 0.5N HNO_3-K (Table 8)

Application of N progressively increased the 0.5N HNO_3-K during Kuruvai and Thaladi seasons and in all the stages of sampling of the Kuruvai crop. During Samba season, N_{50} level registered the highest value followed by N_{100}, N_{150} and N_0, the latter two being on a par. The increase in 0.5N HNO_3-K with every increase in K application was observed in all the seasons. This trend was observed in all the stages of sampling during Kuruvai season, though the levels K_{150} and K_{100} were comparable but superior over control. The 0.5N HNO_3-K decreased with the advancement of

Table 7. Results of the statistical analysis of 0.1N HNO_3 extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
202	213	224	200	3.3	7

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
194	205	217	223	3.3	7

3. Stages

S_1	S_2	S_3	SE_D	CD
333	210	170	2.9	6

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	244	208	155	5.6	12
N_{50}	250	215	174		
N_{100}	270	217	184		
N_{150}	236	198	167		

(Contd.,)

Table 7. (Contd.,)

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	233	187	161	5.6	12
K_{50}	247	203	166		
K_{100}	258	218	176		
K_{150}	262	230	177		

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
170	175	184	194	1.8	4

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
174	179	182	188	1.8	4

3. Stages

S_1	S_2	S_3	SE_D	CD
207	174	162	1.6	3

(Contd.,)

Table 7. (Contd.,)

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	187	168	154	3.2	6
N_{50}	199	170	157		
N_{100}	215	175	162		
N_{150}	226	183	173		

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
167	174	178	189	3.1	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
164	172	182	191	3.1	6

3. Stages

S_1	S_2	S_3	SE_D	CD
218	165	148	2.7	5

Table 8. Results of the statistical analysis of the 0.5N HNO_3 extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
253	255	274	287	2.9	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
249	261	273	285	2.9	6

3. Stages

S_1	S_2	S_3	SE_D	CD
302	299	200	2.5	5

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	292	268	200	5.1	10
N_{50}	322	321	217		
N_{100}	314	307	200		
N_{150}	294	287	183		

(Contd.,)

Table 8. (Contd.,)

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
162	226	233	242	1.7	3

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
223	228	233	235	1.7	3

3. Stages

S_1	S_2	S_3	SE_D	CD
256	227	207	1.5	3

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	242	217	196	2.9	6
N_{50}	251	226	202		
N_{100}	259	227	214		
N_{150}	272	237	217		

(Contd.,)

Table 8. (Contd.,)

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	251	218	202	2.9	6
K_{50}	256	221	207		
K_{100}	258	233	207		
K_{150}	259	235	212		

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
228	235	244	251	2.8	6

2. Potassium levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
225	236	243	254	2.8	6

3. Stages

S_1	S_2	S_3	SE_D	CD
273	240	206	2.5	5

sampling in all the seasons irrespective of the levels of N during Samba and Kuruvai and at all levels of K during Kuruvai season alone.

4.1.2.8. 1N HNO_3-K (Table 9)

The influence of N and K in increasing the 1N HNO_3-K was pronounced in all the seasons. During Kuruvai season alone the same effect of N was also seen at all stages of sampling. As the stages of sampling advanced to maturity, the 1N HNO_3-K decreased and this was true irrespective of the levels of N during Kuruvai season alone.

4.1.2.9. 0.01N HNO_3-K (Table 10)

The effect of N and K application and the advancement of sampling followed similar trend of results as observed in 0.5N HNO_3-K for 0.01N HNO_3-K also. The individual effect of N and K application was also observed at all stages sampling during Samba and Thaladi seasons respectively.

4.1.2.10. 6N H_2SO_4-K (Table 11)

The 6N H_2SO_4-K followed the same trend as observed with 0.5N HNO_3-K excepting that during Samba season, all the treatments and their interactions were insignificant.

Table 9. Results of the statistical analysis of the 1N HNO_3 extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
333	348	374	391	7.9	16

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
318	353	378	396	7.9	16

3. Stages

S_1	S_2	S_3	SE_D	CD
410	366	308	6.8	14

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
250	265	274	289	2.9	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
261	266	272	278	2.9	6

(Contd.,)

Table 9. (Contd.,)

3. Stages

	S_1	S_2	S_3	SE_D	CD
	310	288	211	2.5	5

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	287	270	191	5.0	10
N_{50}	298	282	214		
N_{100}	318	291	215		
N_{150}	336	307	224		

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
259	263	274	283	2.9	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
251	265	275	289	2.9	6

3. Stages

	S_1	S_2	S_3	SE_D	CD
	317	272	220	2.5	5

Table 10. Results of the statistical analysis of 0.01N HNO_3 extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
147	155	157	162	4.0	8

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
135	152	163	171	4.0	8

3. Stages

S_1	S_2	S_3	SE_D	CD
176	148	141	3.5	7

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	177	140	133	7.0	14
N_{50}	183	156	147		
N_{100}	166	158	140		
N_{150}	178	156	137		

(Contd.,)

Table 10. (Contd.,)

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
135	137	148	154	2.3	5

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
134	139	146	155	2.3	5

3. Stages

S_1	S_2	S_3	SE_D	CD
171	140	120	2.0	4

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
114	120	126	135	2.4	5

(contd.,)

Table 10. (Contd.,)

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
109	119	128	139	2.4	5

3. Stages

S_1	S_2	S_3	SE_D	CD
153	120	98	2.1	4

4. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	134	104	89	5.9	12
K_{50}	147	114	95		
K_{100}	158	126	100		
K_{150}	173	138	107		

Table 11. Results of the statistical analysis of 6N H_2SO_4 extractable K in soil (ppm)

I. Samba crop: Treatments are not significant.

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
225	233	241	251	2.7	5

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
225	233	241	252	2.7	5

3. Stages

S_1	S_2	S_3	SE_D	CD
274	228	211	2.3	5

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
239	246	251	259	3.2	6

(Contd.,)

Table 11. (Contd.,)

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
232	243	254	265	3.2	6

3. Stages

S_1	S_2	S_3	SE_D	CD
284	242	220	2.8	5.0

4. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	262	223	211	7.8	16
K_{50}	275	237	218		
K_{100}	292	247	223		
K_{150}	308	259	228		

4.1.2.11. 0.5N EDTA-K (Table 12)

Application of N did not show marked changes in the 0.5N EDTA-K in all the seasons. Increasing levels of K correspondingly increased the 0.5N EDTA-K in Kuruvai and Thaladi seasons, but during Samba season, the levels of K were comparable but superior to control. This was true at all stages of sampling during Thaladi season.

4.1.2.12. 0.5N NaCl-K (Table 13)

The individual effects of N and K application in increasing the 0.5N NaCl-K and the decrease in its value with the stage advancement was similar to the trend observed in the 0.5N HCl-K.

4.1.2.13. 0.01M $CaCl_2$-K (Table 14)

Application of N increased the 0.01M $CaCl_2$-K in all the seasons, the level N_{50} recording the highest value followed by N_{100} and N_{150}, the latter being on a par with N_0. Increased 0.01M $CaCl_2$-K was observed with every increase in the levels of K irrespective of the season of experimentation. The 0.01M $CaCl_2$-K decreased with the advancement of sampling in all the seasons.

4.1.2.14. Bray's-K (Table 15)

Increasing levels of N application increased the Bray's-K during Kuruvai and Thaladi seasons, whereas during

Table 12. (Contd.,)

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	76	59	49	2.2	4
N_{50}	83	65	56		
N_{100}	76	64	51		
N_{150}	74	70	54		

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	76	58	47	2.2	4
K_{50}	77	61	51		
K_{100}	75	67	53		
K_{150}	81	72	60		

III. Thaladi crop

1. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
56	62	70	76	2.0	4

(Contd.,)

Table 12. (Contd.,)

2. Stages

S_1	S_2	S_3	SE_D	CD
95	65	38	1.7	3

3. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	81	54	32	3.4	7
K_{50}	89	61	37		
K_{100}	102	69	40		
K_{150}	109	75	45		

Table 13. Results of the statistical analysis of the 0.5N NaCl extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
77	82	88	80	2.7	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
70	81	84	91	2.7	6

3. Stages

S_1	S_2	S_3	SE_D	CD
97	85	63	2.4	5

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
53	57	65	69	2.7	5

(contd.,)

Table 13. (Contd.,)

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
53	58	64	69	2.7	5

3. Stages

S_1	S_2	S_3	SE_D	CD
76	63	45	2.3	5

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
79	88	92	101	2.0	4

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
77	86	93	104	2.0	4

3. Stages

S_1	S_2	S_3	SE_D	CD
119	90	61	1.7	4

Table 14. Results of the statistical analysis of 0.01M $CaCl_2$ extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
81	103	90	86	3.2	7

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
70	84	95	110	3.2	7

3. Stages

S_1	S_2	S_3	SE_D	CD
120	77	73	2.8	6

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
60	68	64	60	1.5	3

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
55	61	65	71	1.5	3.4

(Contd.,)

Table 14. (Contd.,)

3. Stages

S_1	S_2	S_3	SE_D	CD
75	62	52	1.3	3

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
76	90	83	80	2.3	5

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
73	80	85	91	2.3	5

3. Stages

S_1	S_2	S_3	SE_D	CD
108	85	54	2.0	4

Table 15. Results of the statistical analysis of the Bray's reagent extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
67	84	70	67	4.7	10

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
59	68	74	86	4.7	10

3. Stages

S_1	S_2	S_3	SE_D	CD
93	74	49	4.0	8

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
45	48	56	59	1.4	3

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
46	50	54	59	1.4	3

(Contd.,)

Table 15. (Contd.,)

3. Stages

S_1	S_2	S_3	SE_D	CD
61	51	45	1.2	2

4. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	52	43	42	2.4	5
K_{50}	57	48	43		
K_{100}	63	53	46		
K_{150}	70	59	48		

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
52	60	66	76	1.8	4

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
52	59	67	75	1.8	4

(Contd.,)

Table 16. Results of the statistical analysis of the Morgan's reagent extractable K in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
53	62	52	56	1.7	3

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
41	54	60	67	1.7	3

3. Stages

S_1	S_2	S_3	SE_D	CD
67	60	39	1.5	3

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	17	50	37	2.9	6
N_{50}	74	71	40		
N_{100}	60	59	36		
N_{150}	64	61	42		

(Contd.,)

Table 16. (Contd.,)

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
29	34	38	42	1.4	3

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
30	34	38	41.0	1.40	3

3. Stages

S_1	S_2	S_3	SE_D	CD
41	35	31	1.2	2

III. Thaladi

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
55	62	67	73	2.0	4

(Contd.,)

Table 16. (Contd.,)

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
54	62	67	74	2.0	4

3. Stages

S_1	S_2	S_3	SE_D	Cd
87	63	43	1.7	4

4. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	73	52	38	3.4	7
N_{50}	82	61	43		
N_{100}	91	66	44		
N_{150}	102	73	48		

Samba season, N_{50} level was superior over the rest of the levels which were on a par. Application of K correspondingly increased the Bray's-K in all the seasons. This was also true in the tillering and panicle initiation stages of the Thaladi crop. In post-harvest stage, the differences between the levels were not marked.

4.1.2.15. Morgan's-K (Table 16)

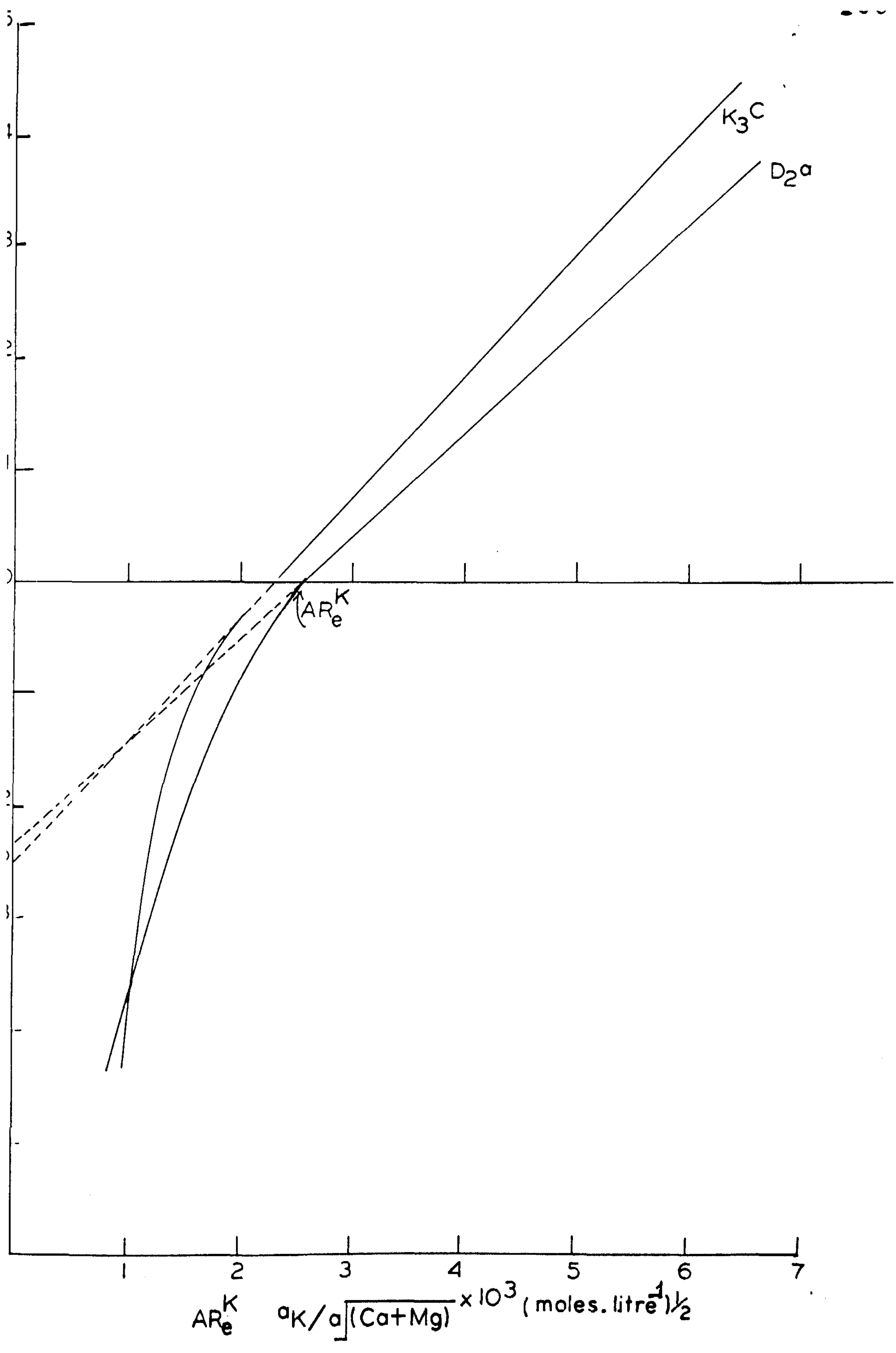
The results of Morgan's-K indicated similar trend of results as observed in Bray's-K.

4.1.3. Quantity/Intensity Parameters

The Q/I curves of the initial soil samples are presented in Fig.1. The results of the statistical analysis of the Q/I parameters as influenced by N and K application are presented in Tables 17-20.

4.13.1. Equilibrium Activity Ratio of K (AR_e^K) (Table 17)

Application of N at lower levels (N_{50} and N_{100}) being on a par with N_0, registered the highest AR_e^K value and the least was at N_{150}. This trend was also seen during Samba season at higher levels of K , whereas at K_{50} level,the K_{100} and N_0 levels were comparable but superior over N_{150} and N_{50} levels which were on a par.



K3C
D2a
ARe K
1
2
3
4
5
6
7
ARe K   aK/a√(Ca+Mg) x 10^3 (moles. litre^-1)^1/2

Table 17. Results of the statistical analysis of the AR_e^K values of soil in different seasons $(\text{moles}\cdot\text{litre}^{-1})^{1/2} \times 10^{-3}$

I. Samba

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
3.49	3.51	3.42	2.92	0.09	0.20

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
2.63	3.05	3.80	3.87	0.09	0.20

3. Stages

S_1	S_2	SE_D	CD
3.48	3.20	0.06	0.14

4. Nitrogen x Potassium interactions

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	2.65	3.22	3.82	4.25	0.18	0.41
N_{50}	2.60	2.72	4.10	4.62		
N_{100}	2.82	3.50	3.50	3.87		
N_{150}	2.45	2.75	3.10	3.40		

(Contd.,)

Table 17. (Contd.,)

5. Nitrogen x Stage interaction

	S_1	S_2	SE_D	CD
N_0	3.61	3.36	0.128	0.29
N_{50}	3.76	3.26		
N_{100}	3.70	3.15		
N_{150}	3.01	2.84		

6. Potassium x Stage interaction

	S_1	S_2	SE_D	CD
K_0	2.75	2.51	0.128	0.29
K_{50}	3.45	2.65		
K_{100}	3.82	3.77		
K_{150}	3.89	3.85		

III. Kuruvai and Thaladi crops

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
2.88	2.89	2.65	2.52	0.14	0.30

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
2.39	2.61	2.96	2.98	0.14	0.30

3. Stages

S_1	S_2	S_3	SE_D	CD
3.00	2.75	2.46	0.12	0.26

In the absence of K, application of N did not show any changes in AR_e^K values. Application of K increased the AR_e^K values (Fig.2) consistently during Samba season whereas during Kuruvai and Thaladi seasons, the levels of K_{150} and K_{100} were comparable but superior over K_{50} and K_0 which were on a par. Almost the same result could be seen during Samba season irrespective of the stages of sampling and at lower levels of N, whereas at higher levels of N, the levels of K were comparable. The AR_e^K values decreased with advancement of sampling. This was also observed at N_{50} and N_{100} levels and in the rest of the levels, the difference was not marked. The AR_e^K values decreased from 3.48 to 3.20 x 10^{-3} (moles · $litre^{-1})^{½}$ during Samba season and from 3.00 to 2.75 x 10^{-3}(moles. $litre^{-1}$)^{½} after Kuruvai crop and to 2.46 x 10^{-3} (moles.$litre^{-1}$) after the Thaladi crop.

4.1.3.2. Labile K (-ΔK^o) (Table 18)

Increasing levels of N application showed decreasing trend in the - ΔK^o values of the soil during Kuruvai and Thaladi seasons. Application of K increased the -ΔK^o values (Fig.2), the levels being comparable but superior over control in this season. The - ΔK^o values decreased from 0.412 to 0.291 m.e.100 g^{-1} after Samba crop and from 0.369 to 0.344 m.e.100 g^{-1} after Kuruvai crop, which was not markedly different and was significantly reduced to 0.293 m.e.100 g^{-1} after Thaladi crop.

... ON Q/I PARAMETER

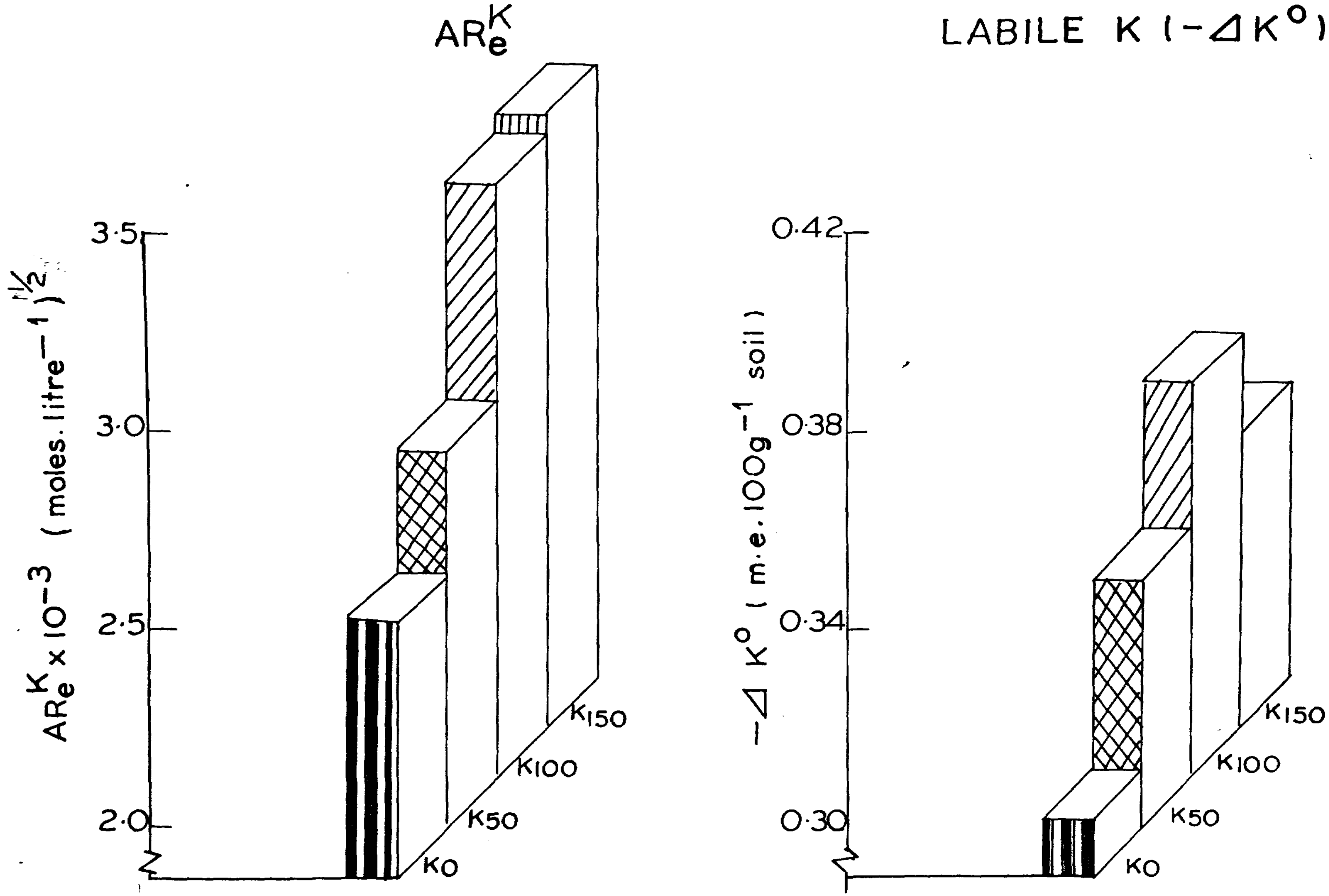


Table 18. Results of the statistical analysis of the $-\Delta K^{o}$ (labile K) in different seasons (m e 100^{-1})

I. Samba crop

1. Stages

S_1	S_2	SE_D	CD
0.412	0.291	0.016	0.036

II. Kuruvai and Thaladi crops

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.372	0.360	0.320	0.290	0.017	0.036

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.295	0.360	0.320	0.290	0.017	0.036

3. Stages

S_1	S_2	S_3	SE_D	CD
0.369	0.344	0.293	0.015	0.031

4.1.3.3. Potential Buffering Capacity of K (PBC^K) (Table 19)

During Samba season alone, application of K at 50 $kg.ha^{-1}$ level and control registered higher PBC^K values than the levels K_{100} and K_{150} which were comparable. The PBC^K values decreased with the advancement of the crop growth during Samba season alone. The treatmental effect was not pronounced during Kuruvai and Thaladi seasons.

4.1.3.4. Woodruff's Free Energy (ΔG) (Table 20)

Application of N at 150 $kg.ha^{-1}$ level recorded the highest ΔG value followed by the rest of the levels which were on a par during Samba season alone. This was true at both the stages of sampling and at higher levels of K during this season. At lower levels of K, this level (N_{150}) was comparable with N_{50}. The values of ΔG decreased markedly with the application of K in all the seasons and at all stages of sampling and at all levels of N during Samba season. In Kuruvai and Thaladi seasons, the ΔG increased with the advancement of sampling.

4.1.4. Results of Correlation Studies made among the K Extracted by Different Extractants and Q/I Parameters

The results of the correlation studies made to find out the relationship among the K extracted by different extractants are presented in Table 21, and their relationship

Table 19. Results of the statistical analysis of the Potential Buffering Capacity of Potassium (PBC^K) in different seasons

I. Samba crop

1. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
119	115	99	94	6.23	14

2. Stages

S_1	S_2	SE_D	CD
121	94	4.4	10

Table 20. Results of the statistical analysis of the free energy change (ΔG) of potassium in different seasons (-calories)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
3396	3401	3403	3458	14.2	32

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
3556	3474	3336	3331	14.2	32

3. Stages

S_1	S_2	SE_D	CD
3398	3450	10.1	23

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	3550	3438	3336	3267	28.4	64
N_{50}	3561	3536	3290	3217		
N_{100}	3575	3390	3383	3322		
N_{150}	3596	3529	3458	3401		

(Contd.,)

Table 20. (Contd.,)

5. Nitrogen x Stage interaction

	S_1	S_2	SE_D	CD
N_0	3370	3422	20.1	46
N_{50}	3358	3445		
N_{100}	3352	3453		
N_{150}	3480	3512		

6. Potassium x Stage interaction

	S_1	S_2	SE_D	CD
K_0	3530	3581	20.1	46
K_{50}	3396	3551		
N_{100}	3333	3318		
N_{150}	3332	3330		

II. Kuruvai and Thaladi crops

1. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
3620	3566	3489	3489	36.7	77

2. Stages

S_1	S_2	S_3	SE_D	CD
3479	3536	3608	31.8	67

with Q/I parameters are presented in Table 22. The relationship among the different Q/I parameters are presented in Table 23.

The results have clearly indicated a large number of relationships among the K extracted by different extractants. The AR_e^K values were correlated with the K extracted by most of the extractants, except N NH_4OAc-K, 0.01N HCl-K, 0.5N NaCl-K and Morgan's-K. The K extracted by N NH_4OAc and 0.5N NaCl-K was correlated with labile K (ΔK^o) values whereas the PBC^K values were negatively related to the K extracted by all the extractants. The free energy values (ΔG) showed negative relationships with most of the extractants except NH_4OAc-K, 0.01N HCl-K, 0.5N NaCl-K and Morgan's-K.

Among the Q/I parameters, the AR_e^K values were related to $-\Delta K^o$ values, but negatively to PBC^K and ΔG values. The $-\Delta K^o$ values showed negative correlation with ΔG values. The PBC^K value was positively related to ΔG values.

4.1.5. Fraction of K

4.1.5.1. Water Soluble K (Table 24)

Application of increasing levels of N increased the water soluble K during Samba season. During Kuruvai and Thaladi seasons, the level N_{50} was superior over the rest of the levels which were comparable. During Thaladi season, this trend was also observed at K_{150} level, whereas at the rest of the K levels, N_{50} was comparable with N_0 and N_{100}. In the absence of K, N application did not show marked changes. Application of K correspondingly increased the

Table 21. Results of the correlation studies among the K extracted by different extractants (n = 48)

Sl. No.	Extractants	H_2O-K	NH_4OAc-K	0.01 N HCl-K	0.1N HCl-K	0.5N HCl-K	0.1N HNO_3-K	0.5N HNO_3-K	1N HNO_3-K	0.01N HNO_3 -K	6N H_2SO_4 K	0.5N EDTA K	0.5N NaCl K	0.01M $CaCl_2$ K	Bray's K	Morgan's K
1.	H_2O-K	1														
2.	NH_4OAc-K	0.77**	1													
3.	0.01N HCl-K	0.56**	0.55**	1												
4.	0.1N HCl-K	0.85**	0.70**	0.72**	1											
5.	0.5N HCl-K	0.82**	0.71**	0.75**	0.94**	1										
6.	0.1N HNO_3-K	0.80**	0.26^{NS}	0.51**	0.86**	0.93**	1									
7.	0.5N HNO_3-K	0.87**	0.70**	0.69**	0.93**	0.95**	0.92**	1								
8.	1N HNO_3-K	0.87**	0.66**	0.36**	0.80**	0.79**	0.88**	0.83**	1							
9.	0.01N HNO_3-K	0.63**	0.34*	0.40*	0.65**	0.72**	0.85**	0.74**	0.77**	1						
10.	6N H_2SO_4-K	0.93**	0.70**	0.49**	0.89**	0.86**	0.96**	0.93**	0.96**	0.75**	1					
11.	0.5N EDTA -K	0.89**	0.52**	0.42**	0.87**	0.80**	0.84**	0.35**	0.98**	0.68**	0.94**	1				
12.	0.5N NaCl-K	0.63**	0.89**	0.89**	0.66**	0.72**	0.49**	0.54**	0.40*	0.20^{NS}	0.51*	0.38*	1			
13.	0.01M CaCl - K	0.86**	0.71**	0.71**	0.75**	0.76**	6.64**	0.81**	0.53**	0.45**	0.76**	0.73**	0.73**	1		
14.	Brays - K	0.78**	0.77**	0.85**	0.88**	0.89**	0.78**	0.91**	0.67**	0.64**	0.78**	0.69**	0.77**	0.83**	1	
15.	Morgan's-K	0.62**	0.87**	0.90**	0.67**	0.65**	0.41**	0.63**	0.39*	0.18^{NS}	0.50**	0.41**	0.94**	0.94**	0.79**	1

Table 22. Results of the correlation studies among the K extracted by different extractants and the Q/I Parameters

(n=48)

Independant variables	Dependant variables			
	AR^K_e	$-\Delta K^o$	PBC^K	ΔG
1. Water extractable K	0.591^{**}	0.180^{NS}	-0.679^{**}	-0.470^{**}
2. NH_4OAc-K	0.300^{NS}	0.301^{*}	-0.470^{**}	0.230^{NS}
3. 0.01N HCl-K	0.150^{NS}	0.170^{NS}	-0.340^{*}	-0.200^{NS}
4. 0.1N HCl-K	0.500^{**}	0.180^{NS}	-0.565^{**}	-0.447^{**}
5. 0.5N HCl-K	0.481^{**}	0.215^{NS}	-0.588^{**}	-0.439^{**}
6. 0.1N HNO_3-K	0.377^{*}	0.184^{NS}	-0.618^{**}	-0.498^{**}
7. 0.5N HNO_3-K	0.500^{**}	0.256^{NS}	-0.634^{**}	-0.300^{**}
8. 1N HNO_3-K	0.558^{**}	0.230^{NS}	-0.670^{**}	-0.433^{**}
9. 0.01N HNO_3-K	0.598^{**}	0.030^{NS}	-0.486^{**}	-0.577^{**}
10. 6N H_2SO_4-K	0.551^{**}	0.250^{NS}	-0.660^{**}	-0.513^{**}
11. 0.5N EDTA-K	0.674^{**}	0.040^{NS}	-0.652^{**}	-0.642^{**}
12. 0.5N NaCl-K	0.115^{NS}	0.330^{*}	-0.357^{*}	-0.080^{NS}
13. 0.01M $CaCl_2$-K	0.529^{**}	0.126^{NS}	-0.540^{**}	-0.405^{**}
14. Bray's-K	0.397^{**}	0.172^{NS}	-0.460^{**}	-0.340^{**}
15. Morgan's K	0.12^{NS}	0.277^{NS}	-0.310^{*}	-0.080^{NS}

Table 23. Results of the correlation studies between the different Q/I Parameters

(n=48)

	AR_e^K	$-\Delta K^o$	PBC^K	ΔG
AR_e^K	1.000			
$-\Delta K^o$	0.385^{**}	1.000		
PBC^K	-0.615^{**}	0.060^{NS}	1.000	
ΔG	-0.984^{**}	-0.418^{**}	0.597^{**}	1.000

Table 24. Results of the statistical analysis of the water soluble K fraction in soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
15.4	18.2	19.4	20.3	0.54	1.1

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
16.7	18.0	18.8	19.7	0.54	1.1

3. Stages

S_1	S_2	S_3	SE_D	CD
21.8	18.8	14.3	0.47	0.9

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
11.4	12.9	11.5	11.3	0.39	0.8

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
13.3	12.3	11.6	10.0	0.39	0.8

(Contd.,)

Table 24. (Contd.,)

3. <u>Stages</u>

S_1	S_2	S_3	SE_D	CD
15.1	11.4	8.8	0.34	0.7

III. <u>Thaladi crop</u>

1. <u>Nitrogen levels</u>

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
8.3	9.2	7.9	7.1	0.32	0.6

2. <u>Potassium levels</u>

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
6.4	7.6	8.6	9.9	0.32	0.6

3. <u>Stages</u>

S_1	S_2	S_3	SE_D	CD
11.5	7.8	5.1	0.28	0.6

4. <u>Nitrogen x Potassium interaction</u>

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	5.9	7.7	8.9	10.5	0.5	1.1
N_{50}	6.8	8.1	10.0	11.9		
N_{100}	6.7	7.4	8.5	9.1		
N_{150}	6.3	7.0	7.1	8.0		

(Contd.,)

Table 24. (Contd.,)

5. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	9.0	6.1	4.2	0.6	1.3
K_{50}	11.1	6.8	4.8		
K_{100}	12.1	8.3	5.4		
K_{150}	13.8	10.0	5.8		

water soluble K during Kuruvai and Thaladi seasons whereas during Samba season, the levels were comparable but superior to control. The increase in water soluble K with every increase in K level was observed during Thaladi season at lower levels of N, whereas at higher levels, this effect was less marked. At all the stages of sampling, K application increased the water soluble K and this was more pronounced during tillering and panicle initiation stages than during post harvest stage. With the advancement of sampling, water soluble K decreased in all the seasons and this was also true irrespective of the levels of K during Thaladi season.

4.1.5.2. Exchangeable K (Table 25)

increase in the exchangeable K fraction of the soil was observed with the application of N in all the seasons. However the levels 100 and 150 kg $N \cdot ha^{-1}$ were comparable during Samba and Kuruvai seasons. Increasing levels of K application increased the exchangeable K fraction, more significantly during Thaladi season, whereas during Kuruvai and Samba seasons, the results followed almost the same trend. There was marked reduction in the exchangeable K with the advancement of sampling in all the seasons and at all levels of K. During Thaladi season alone, the exchangeable K decreased with the stages of crop growth irrespective of the levels of K and an increasing trend of exchangeable K with increasing levels of K irrespective of the stages.

Table 25. Results of the statistical analysis of the exchangeabl K fraction of soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
215	217	232	231	4.9	10

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
207	223	229	236	4.9	10

3. Stages

S_1	S_2	S_3	SE_D	CD
244	234	194	4.3	9

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
174	182	189	184	2.7	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
167	197	189	198	2.7	6

(Contd.,)

Table 25. (Contd.,)

3. Stages

S_1	S_2	S_3	SE_D	CD
210	182	156	2.4	5

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
153	161	165	176	3.1	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
146	158	168	183	3.1	6

3. Stages

S_1	S_2	S_3	SE_D	CD
199	165	128	2.7	5

4. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	167	147	125	5.4	11
K_{50}	188	164	124		
K_{100}	207	172	127		
K_{150}	233	178	137		

4.1.5.3. Non-exchangeable K (Table 26)

Application of N at 150 $kg \cdot ha^{-1}$ level recorded the highest non-exchangeable K during Thaladi season followed by the rest, which were almost comparable. During Samba and Kuruvai seasons, the higher levels of N (N_{150} and N_{100}) being comparable were superior to the rest.

The non-exchangeable K fraction was the highest with the application of K, the K_{150} being superior over the rest of the levels during Samba but comparable with K_{100} during Thaladi season followed by the rest. Non-exchangeable K fraction decreased with the advancement of sampling during Kuruvai and Thaladi seasons but not markedly during Samba season.

4.1.6. Fractions of N in Soil

4.1.6.1. NH_4-N (Table 27; Fig.3)

Increase in the levels of N progressively increased the NH_4-N in all the seasons. During Thaladi season alone, this was true at the tillering stage of sampling, whereas in the latter stages, this was not well pronounced. Application of K increased the NH_4-N during Samba and Kuruvai seasons. During Thaladi season no definite trend, could be seen. There was marked reduction in NH_4-N with the advancement of sampling in all the seasons and at all levels of N during Thaladi season.

FIG. [illegible] EFFECT OF N AND K LEVELS ON
THE NH_4-N CONTENT OF SOILS

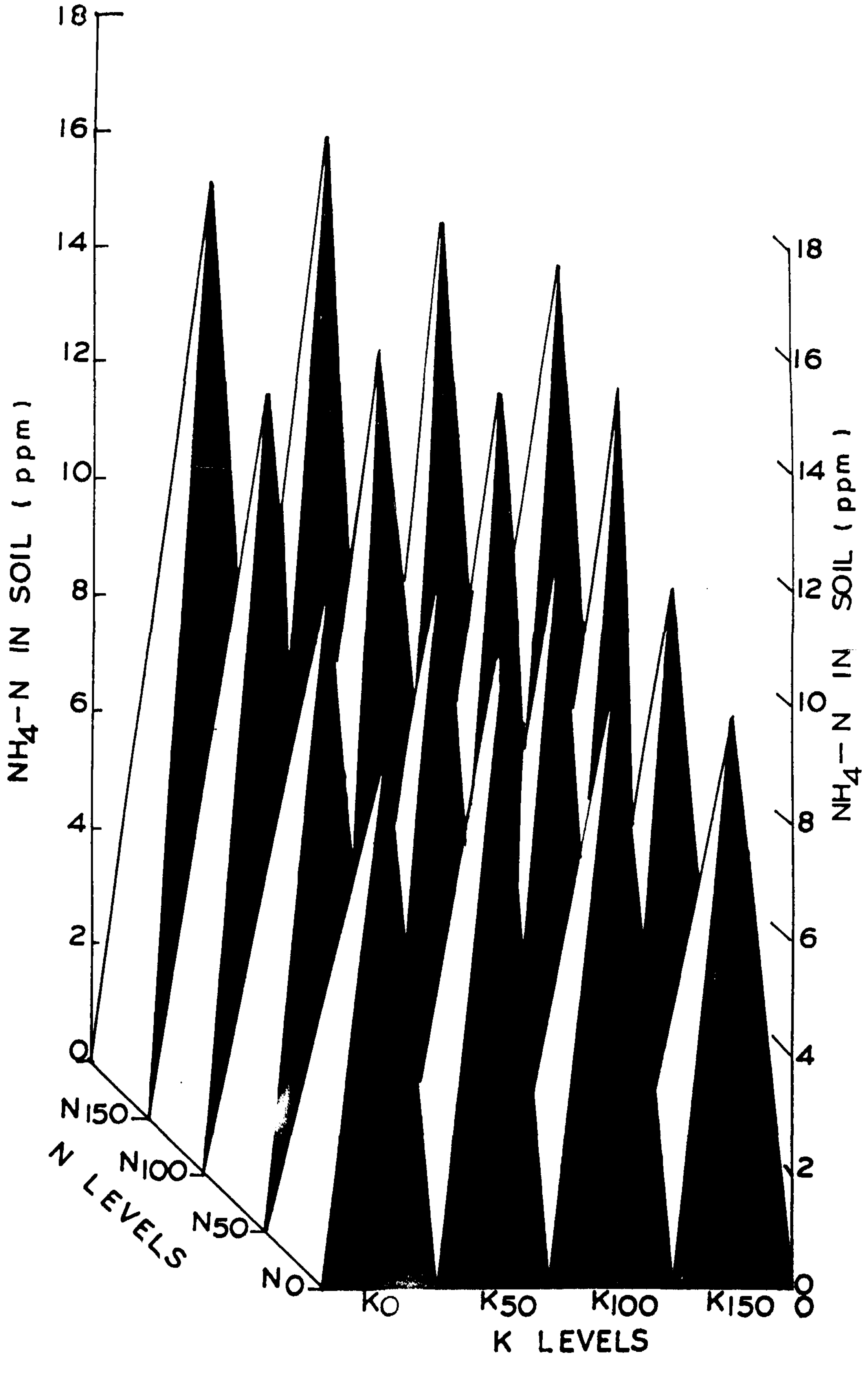


Table 26. Results of the statistical analysis of the non-exchangeable K fraction of the soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
1049	1052	1081	1097	8.3	17

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
1054	1063	1071	1089	8.3	17

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
962	967	979	983	6.85	14

2. Stages

S_1	S_2	S_3	SE_D	CD
993	974	951	5.9	12

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
891	906	918	937	8.2	16

(Contd.,)

Table 26. (Contd.,)

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
887	910	926	931	8.2	16

3. Stages

S_1	S_2	S_3	SE_D	CD
947	903	890	7.1	14

Table 27. Results of the statistical analysis of the NH_4-N content of the soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
24.62	28.24	29.63	31.85	0.87	1.74

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
25.32	27.77	29.40	31.85	0.87	1.74

3. Stages

S_1	S_2	S_3	SE_D	CD
37.10	25.64	23.01	0.75	1.51

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
29.62	35.47	42.30	49.36	1.10	2.22

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
36.15	39.56	39.96	41.04	1.10	2.22

(Contd.,)

Table 27. (Contd.,)

3. Stages

S_1	S_2	S_3	SE_D	CD
43.93	40.15	33.50	0.96	1.92

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
16.84	19.40	19.90	22.40	1.07	2.15

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
19.15	21.38	19.55	18.51	1.07	2.15

3. Stages

S_1	S_2	S_3	SE_D	CD
32.75	19.72	6.49	0.65	1.32

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	26.46	18.61	5.41	1.31	2.64
N_{50}	31.66	19.71	6.90		
N_{100}	32.92	19.75	7.04		
N_{150}	39.95	20.79	6.59		

4.1.6.2. NO_3-N (Table 28)

Application of N progressively increased the NO_3-N content in all the three seasons and at all stages of sampling during Thaladi season. The NO_3-N content was increased with K application, the levels being comparable but superior over control during Samba season. During Thaladi season, K_{50} recorded highest NO_3-N content followed by K_0, K_{100} and K150, the latter two being on a par. The same trend of results was also observed with the stages of sampling. There was reduction in NO_3-N content with the advancement of sampling during Kuruvai season, whereas during Samba and Thaladi seasons, higher NO_3-N content was recorded at the post-harvest stage followed by tillering stage. The lowest NO_3-N content was observed at the panicle initiation stage. This was also true at all levels of N and K during Thaladi season.

4.1.7. Available Nutrient Status of Soils

4.1.7.1. Available K (Table 29)

Increasing levels of N application correspondingly increased the available N status of the soil in all the three seasons irrespective of the stages of sampling during Kuruvai and Thaladi seasons but not during Samba season. In all the seasons, application of K increased the available K, the level K_{50} registering higher value followed by K_{100},

Table 28. Results of the statistical analysis of the NO_3-N content of soil (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
6.91	8.19	8.61	9.58	0.33	0.65

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
7.64	8.51	8.64	8.76	0.33	0.65

3. Stages

S_1	S_2	S_3	SE_D	CD
8.48	7.47	9.03	0.28	0.57

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
3.62	4.90	5.54	6.91	0.51	1.02

2. stages

S_1	S_2	S_3	SE_D	CD
7.31	4.56	3.85	0.44	0.89

(Contd.,)

Table 28. (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
5.43	6.43	7.16	7.77	0.20	0.41

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
6.78	7.68	6.30	6.03	0.20	0.41

3. Stages

S_1	S_2	S_3	SE_D	CD
5.95	3.77	10.37	0.10	0.36

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	4.55	2.96	8.77	0.35	0.71
N_{50}	6.06	3.27	9.95		
N_{100}	6.47	4.43	10.57		
N_{150}	6.70	4.43	12.17		

(Contd.,)

Table 28. (Contd.,)

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	6.26	3.68	10.41	0.35	0.71
K_{50}	6.85	4.36	11.81		
K_{100}	5.56	3.51	9.83		
K_{150}	5.12	3.55	9.41		

Table 29. Results of the statistical analysis of the available N content of the soil ($kg \cdot ha^{-1}$)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
186	213	248	253	4.95	10

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
215	235	226	223	4.95	10

3. Stages

S_1	S_2	S_3	SE_D	CD
271	221	184	4.29	9

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
182	193	214	233	3.4	7

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
199	216	207	201	3.4	7

(Contd.,)

Table 29. (Contd.,)

3. Stages

	S_1	S_2	S_3	SE_D	CD
	231	207	179	2.9	6

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	204	180	162	5.9	12
N_{50}	213	196	170		
N_{100}	238	219	184		
N_{150}	267	232	201		

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
167	182	199	216	3.2	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
187	197	190	190	3.2	6

(Contd.,)

Table 29. (Contd.,)

3. Stages

S_1	S_2	S_3	SE_D	CD
233	196	144	2.6	5

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	200	165	136	5.52	11
N_{50}	218	183	146		
N_{100}	243	208	147		
N_{150}	272	229	148		

K_{150} and K_0 which were comparable. There was a steady decrease in the available N status as the crop growth advanced, in all the seasons and at all levels of N during Kuruvai and Thaladi seasons.

4.1.7.2. Available P (Table 30)

Increase in the available P content with the application of N was observed during Kuruvai and Thaladi seasons, but not during Samba season where in the effect was not pronounced. This trend was also observed at all stages of sampling during Thaladi season. Application of K did not result in any conclusive trend in the available P status of the soil. With the advancement of sampling, the available P decreased in all the three seasons and at all levels of N during Thaladi season.

4.1.7.3. Available K (Table 31)

Application of N increased the available K content of the soil consistently during Thaladi season whereas during the other two seasons, the higher levels of N were comparable but superior over the lower levels which were on a par. At all stages of sampling during Thaladi season, application of N increased the available K content. The available K content was increased with every increase in the levels of K in all the seasons. This was true at the tillering stage of sampling during Samba season, whereas at

Table 30. Results of the statistical analysis of the available P content of the soil ($kg \cdot ha^{-1}$)

I. Samba crop

1. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
51	47	45	43	2.35	5

2. Stages

S_2	S_2	S_3	SE_D	CD
55	43	41	2.0	4

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
39	43	45	49	1.15	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
42	43	45	46	1.15	2

3. Stages

S_1	S_2	S_3	SE_D	CD
52	46	34	1.0	2

(Contd.,)

Table 30. (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
28	31	32	35	0.6	1

2. Stages

S_1	S_2	S_3	SE_D	CD
45	28	23	0.5	1

3. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	39	26	20	1.07	2
N_{50}	43	26	23		
N_{100}	44	27	25		
N_{150}	51	32	23		

Table 31. Results of the statistical analysis of the available K content of the soil (kg·ha^{-1})

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
409	426	462	482	11.3	23

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
402	431	459	489	11.3	23

3. Stages

S_1	S_2	S_3	SE_D	CD
573	417	345	9.8	20

4. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	497	377	330	195	39
K_{50}	549	402	340		
K_{100}	606	429	343		
K_{150}	640	460	366		

(Contd.,)

Table 31. (Contd.,)

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
393	403	416	421	5.6	11

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
390	402	416	423	5.6	11

3. Stages

S_1	S_2	S_3	SE_D	CD
428	416	380	4.8	10

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
418	432	445	467	2.5	5

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
415	432	449	466	2.5	5

(Contd.,)

Table 31. (Contd.,)

3. Stages

S_1	S_2	S_3	SE_D	CD
482	449	391	2.2	4

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	468	424	361	4.4	9
N_{50}	474	443	380		
N_{100}	482	459	394		
N_{150}	504	468	428		

the latter stages, this effect was less pronounced. The available K was steadily decreased with the advancement of sampling irrespective of the levels of N during Thaladi season and levels of K during Samba season.

4.1.8. Analysis of Soil Solution

4.1.8.1. pH (Table 32)

The pH of the soil solution, increased with the application of N during Kuruvai season, the levels N_{150} and N_{100} were comparable but superior over the rest of the levels which were on a par. This increase was observed only upto 20 days after transplanting of Kuruvai crop, after which, the effect was not pronounced. During Samba season, the levels N_{50} and N_{150} were comparable but markedly different from the rest of the levels. Almost the same result was observed at all levels of K, except K_{150} where in, the differnece between the levels of N were not marked. Application of K increased the pH of soil solution only during Kuruvai season, its effect being insignificant in the other two seasons. With the advancement of sampling, the pH of soil solution tended to turn towards neutrality irrespective of the levels of N during Kuruvai season.

4.1.8.2. Electrical Conductivity (Table 33)

Application of N increased the EC of the soil solution. This was more prononuced during Kuruvai and

Table 32. Results of the statistical analysis of the pH of the soil solution

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
7.51	7.76	7.38	7.74	0.087	0.17

2. Stages

S_1	S_2	S_3	SE_D	CD
7.54	7.98	7.29	0.075	0.15

3. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	7.27	7.36	7.81	7.61	0.174	0.35
N_{50}	7.87	8.08	7.66	8.08		
N_{100}	7.24	7.29	7.38	7.62		
N_{150}	7.83	7.59	7.85	7.67		

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
7.38	7.37	7.48	7.51	0.032	0.06

(Contd.,)

Table 32. (Contd.,)

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
7.35	7.43	7.46	7.52	0.032	0.06

3. Stages

S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
8.00	7.69	7.39	7.24	7.20	7.12	0.04	0.08

4. Nitrogen x Stage

	S_1	S_2	S_3	S_4	S_5	S_5	SE_D	CD
N_0	7.82	7.49	7.40	7.31	7.18	7.10	0.08	0.15
N_{50}	7.85	7.57	7.33	7.22	7.11	7.16		
N_{100}	8.16	7.75	7.40	7.23	7.24	7.10		
N_{150}	8.15	7.95	7.42	7.18	7.25	7.12		

III. Thaladi crop

1. Stages

S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
7.35	7.23	7.19	7.17	7.05	7.07	0.03	0.06

Table 33. Results of the statistical analysis of the electrical conductivity of the soil solution (ds.m^{-1})

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.244	0.244	0.268	0.209	0.013	0.026

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.227	0.272	0.252	0.214	0.013	0.026

3. Stages

S_1	S_2	S_3	SE_D	CD
0.295	0.272	0.157	0.011	0.022

4. Potasium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	0.216	0.304	0.161	0.045	0.022
K_{50}	0.310	0.320	0.190		
K_{100}	0.325	0.282	0.147		
K_{150}	0.24	0.272	0.129		

(Contd.,)

Table 33. (Contd.,)

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.42	0.47	0.52	0.57	0.01	0.03

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.43	0.49	0.52	0.54	0.01	0.03

3. Stages

S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
0.53	0.69	0.48	0.60	0.40	0.28	0.02	0.04

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.25	0.32	0.39	0.43	0.02	0.04

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.29	0.33	0.36	0.41	0.02	0.04

3. Stages

S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
0.45	0.40	0.47	0.33	0.24	0.19	0.03	0.05

Thaladi seasons than during Samba season. The EC increased with the increase in the levels of K, more significantly during Kuruvai and Thaladi than during Samba season. The EC of the soil solution was the highest at panicle initiation stage of Samba crop. During Kuruvai and Thaladi seasons, EC measured at 20 and 30 days after transplanting recorded higher values than the rest of the stages.

4.1.8.3. NH_4-N (Table 34)

The NH_4-N content increased with the application of N in all the seasons. This was well pronounced in all the stages of sampling during Kuruvai season, whereas during Samba and Thaladi seasons, the levels were almost comparable. Application of K increased the NH_4-N content of the soil solution during Kuruvai season whereas its effect was not pronounced during Thaladi season. During Samba season K_{50} was superior over the rest of the levels which were on a par. During Samba season, the NH_4-N content decreaseed with the advancement of sampling at all levels of N and K. During Kuruvai and Thaladi seasons, the highest NH_4-N was registered at 20th and 30th day of transplanting respectively. Almost the same trend could be seen in these seasons at different levels of N. In the absence of N, the difference was not marked.

Table 34. Results of the statistical analysis of the NH_4-N content of soil solution (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
3.50	4.26	5.19	4.05	0.19	0.38

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
3.91	4.96	4.11	4.02	0.19	0.38

3. Stages

S_1	S_2	S_3	SE_D	CD
5.64	4.16	2.95	0.16	0.33

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	4.81	3.15	2.54	0.33	0.66
N_{50}	5.25	4.46	3.06		
N_{100}	7.17	5.07	3.32		
N_{150}	5.34	3.94	2.89		

(Contd.,)

Table 34. (Contd.,)

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	4.90	4.02	2.80	0.33	0.66
K_{50}	7.09	4.64	3.15		
K_{100}	5.34	4.02	2.97		
K_{150}	5.25	3.94	2.89		

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
8.72	10.95	13.68	15.99	0.27	0.54

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
11.27	12.40	12.63	13.04	0.27	0.54

3. Stages

S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
13.69	14.83	12.43	14.37	10.51	8.18	0.34	0.6

(Contd.,)

Table 34. (Contd.,)

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
N_0	9.45	11.29	8.40	10.24	7.17	5.77	0.67	1.33
N_{50}	11.72	12.25	11.20	13.21	9.61	7.70		
N_{100}	15.66	16.27	14.35	15.39	11.55	8.84		
N_{150}	17.94	19.51	15.77	18.64	13.60	10.41		

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
4.05	6.98	8.33	9.23	0.53	1.05

2. Stages

S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
6.62	7.37	9.17	7.00	6.66	6.08	0.65	1.28

3. Nitrogen x Stage interaction

	S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
N_0	3.67	4.81	2.71	4.90	4.46	3.76	1.29	2.57
N_{50}	6.12	7.17	8.97	7.86	5.81	5.95		
N_{100}	7.70	7.79	11.60	8.63	7.87	6.39		
N_{150}	8.97	9.71	13.39	6.61	8.49	8.22		

Table 35. Results of the statistical analysis of the NO_3-N content of the soil solution (ppm)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.43	0.48	0.61	0.51	0.02	0.05

2. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	0.46	0.46	0.38	0.04	0.08
N_{50}	0.42	0.52	0.49		
N_{100}	0.71	0.60	0.53		
N_{150}	0.52	0.48	0.52		

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
1.38	1.99	2.33	2.82	0.07	0.14

2. Stages

S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
1.58	2.43	2.15	2.47	2.04	1.83	0.09	0.17

(Contd.,)

Table 35. (Contd.,)

3. Nitrogen x Stage interaction

	S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
N_0	1.14	1.40	1.53	1.79	1.27	1.18	0.17	0.35
N_{50}	1.71	2.10	2.19	2.49	1.71	1.71		
N_{100}	2.01	2.80	2.23	2.67	2.36	1.88		
N_{150}	2.54	3.41	2.67	2.93	2.84	2.54		

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
1.41	1.82	2.21	2.33	0.09	0.17

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
2.07	2.87	1.82	1.65	0.09	0.17

3. Stages

S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
3.46	2.38	1.89	1.58	1.31	1.03	0.11	0.21

(Contd.,)

Table 35. (Contd.,)

4. Potassium x Nitrogen interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
N_0	1.22	1.84	2.36	2.71	0.21	0.42
N_{50}	1.60	2.22	2.54	2.68		
N_{100}	1.37	1.78	1.10	2.04		
N_{150}	1.43	1.46	1.81	1.89		

5. Nitrogen x Stage interaction

	S_1	S_2	S_3	S_4	S_5	S_6	SE_D	CD
N_0	2.27	1.92	1.37	1.05	0.83	0.79	0.21	0.42
N_{50}	2.93	2.58	1.79	1.62	1.18	0.83		
N_{100}	3.94	2.62	2.19	1.79	1.62	1.09		
N_{150}	4.68	2.41	2.01	1.88	1.62	1.39		

4.1.8.4. NO_3-N (Table 35)

The NO_3-N content consistently increased with the application of N during Kuruvai and Thaladi seasons, whereas during Samba season, N_{100} level recorded the highest NO_3-N followed by N_{150} and N_{50}, which were comparable but superior over control. Almost the same results were also observed at all levels of K during Thaladi season and irrespective of the stages of sampling of all the seasons. Application of K increased the NO_3-N content only during Thaladi season, the level K_{50} registering the highest value followed by K_0, K_{100} and K_{150}, the latter two levels were on a par. The NO_3-N content decreased with the advancement of stages of sampling during Thaladi season. This trend was also seen irrespective of the levels of N. During Kuruvai season, the NO_3-N content was higher at 40 and 20 days after transplanting, which were comparable and the least was observed on 10th and 60th day of transplanting.

4.1.9. Drymatter Production and Yield of Rice

The results of the drymatter production are presented in Table 36 and the grain and straw yield data are presented in Table 37 and 38 respectively.

4.1.9.1. Drymatter Production (Table 36)

Increase in the levels of N correspondingly increased the drymatter production in all the seasons. This trend was true only at harvest stage of sampling, whereas at

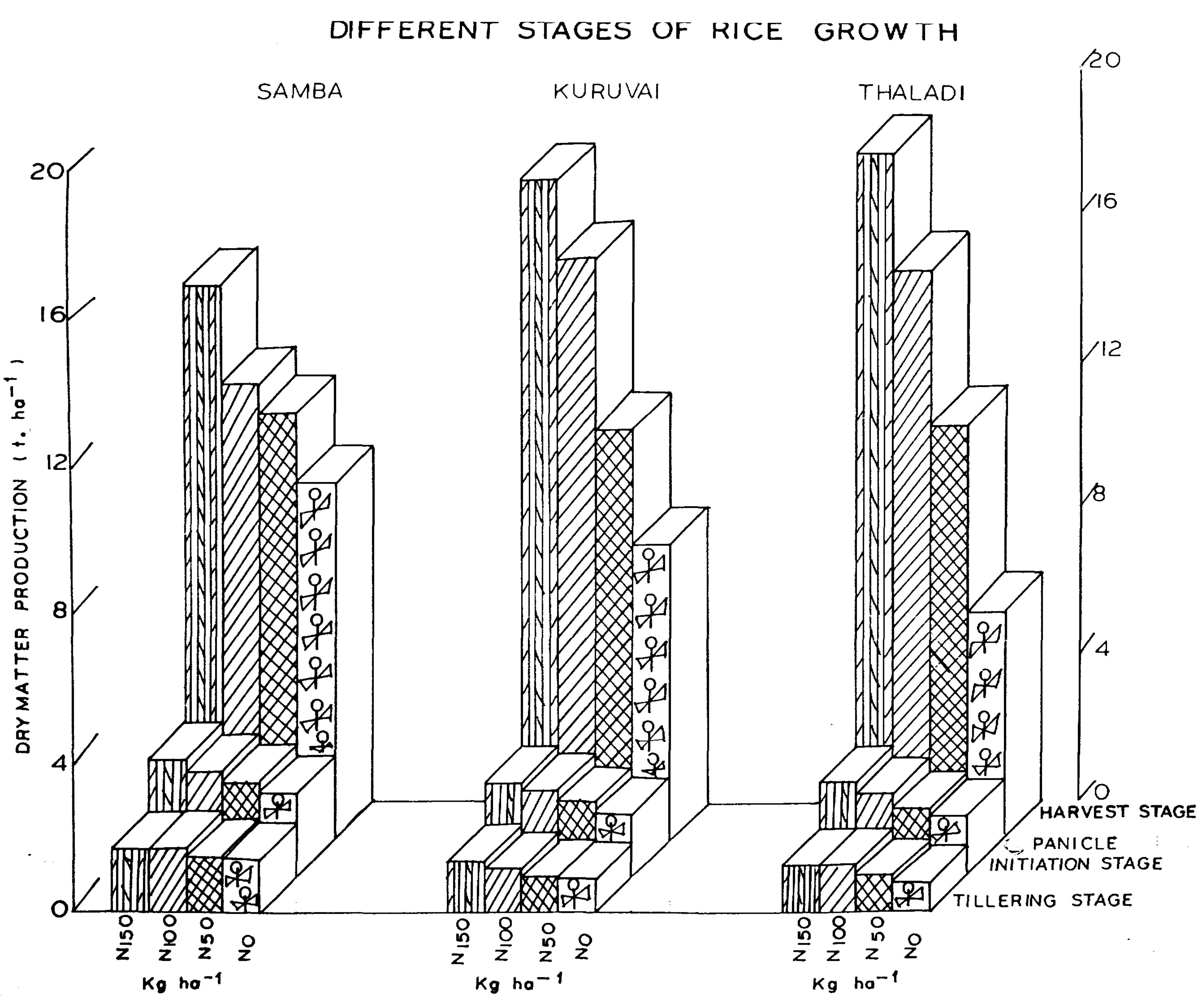

DIFFERENT STAGES OF RICE GROWTH
SAMBA
KURUVAI
THALADI
DRYMATTER PRODUCTION (t. ha^{-1})
0
4
8
12
16
20
N150
N100
N50
NO
Kg ha^{-1}
HARVEST STAGE
PANICLE INITIATION STAGE
TILLERING STAGE

Table 36. Results of the statistical analysis of the dry matter production in different seasons ($kg \cdot ha^{-1}$)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
4381	5174	5590	6277	152	307

2. Stages

S_1	S_2	S_3	SE_D	CD
1545	2649	11873	132	265

3. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	1376	2200	9567	264	531
N_{50}	1456	2526	11536		
N_{100}	1665	2797	12307		
N_{150}	1682	3067	14083		

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
3556	4689	6376	7239	257	518

(Contd.,)

Table 36. (Contd.,)

2. Stages

S_1	S_2	S_3	SE_D	CD
1118	2123	13153	223	448

3. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	918	1725	8026	446	896
N_{50}	991	2200	11095		
N_{100}	1180	2258	15659		
N_{150}	1351	2510	17854		

III. Thaladi crop

1. Nitrogen levels

NO	N_{50}	N_{100}	N_{150}	SE_D	CD
2857	4634	6281	7480	182	365

2. Stages

S_1	S_2	S_3	SE_D	CD
1088	2007	12843	157	317

(Contd.,)

Table 36. (Contd.,)

3. <u>Nitrogen x Stage interaction</u>

	S_1	S_2	S_3	SE_D	CD
N_0	796	1556	6218	315	633
N_{50}	966	1773	11164		
N_{100}	1253	2228	15361		
N_{150}	1339	2472	18627		

panicle initiation stage, higher levels of N registered higher drymatter yield than the lower levels of N. At tillering stage, N application was not pronounced (Fig.4). Application of K did not influence the drymatter production in all the three seasons. There was a steady increase in the drymatter production with the advancement of sampling irrespective of the seasons and N levels.

4.1.9.2. Grain and Straw Yield (Tables 37 and 38)

The yield of grain and straw increasd with each increment in the levels of N in all the three seasons. The effect of K application on the yield of rice was not pronounced in all the seasons except during Samba, where in, application of K_{50} and K_{100} recorded higher straw yield than control.

4.1.10. Response Functions of N with Grain Yield

The results of the response functions of grain yield and levels of N for different seasons are presented in Table 39 and at varying levels of K are presented in Tables 40 to 42.

The results indicated that the response function of N was linear during Samba season and was quadratic during Kuruvai and Thaladi seasons. To find out the influence of K application on the performance of N, response functions of N

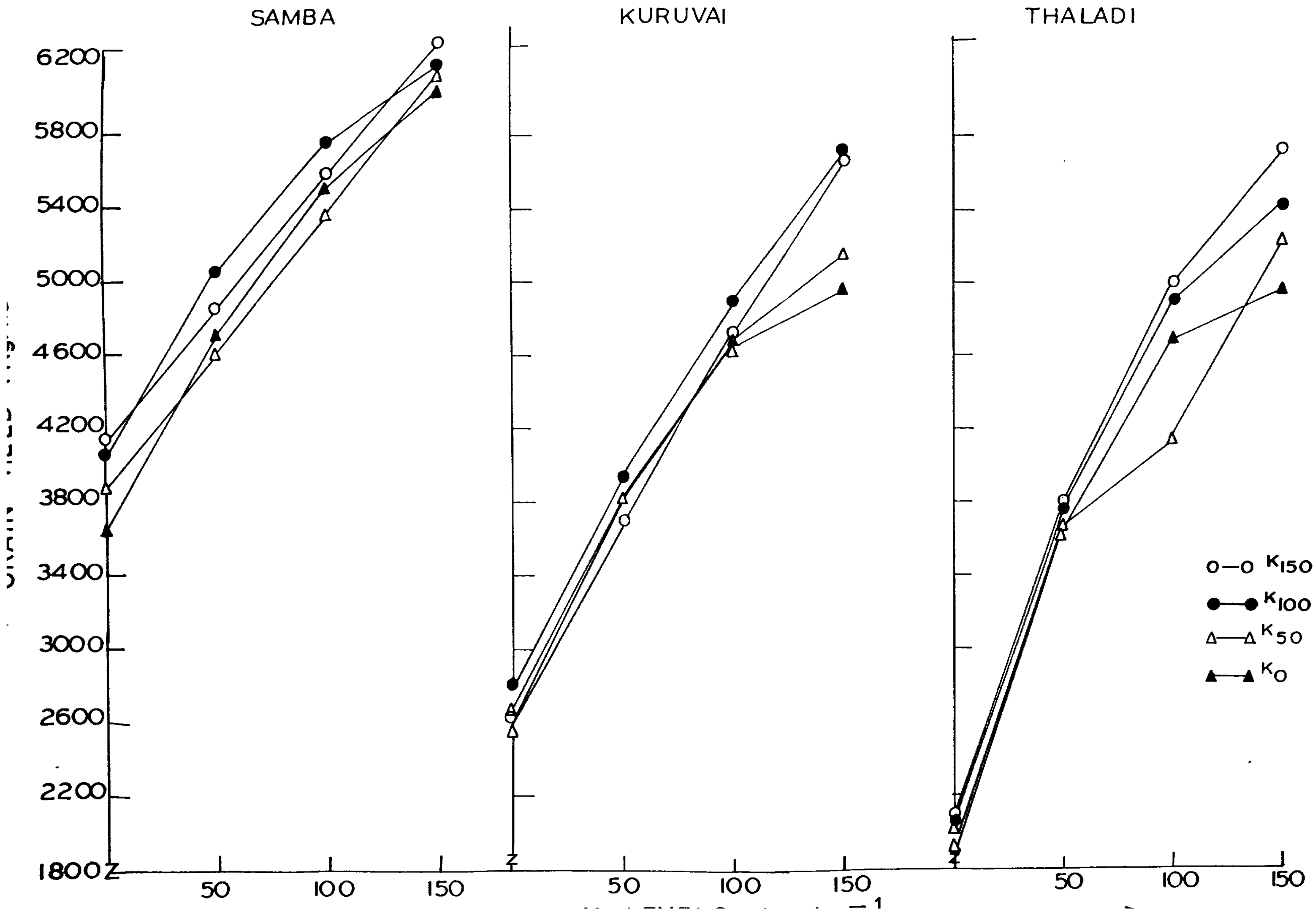

SAMBA
KURUVAI
THALADI
6200
5800
5400
5000
4600
4200
3800
3400
3000
2600
2200
1800
50
100
150
K150
K100
K50
K0

Table 37. Results of the statistical analysis of the grain yield of rice (kg.ha^{-1})

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
3913	4999	5234	6318	181	370

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
2718	3644	4919	5310	126	258

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
1933	3953	4582	5418	109	222

Table 38. Results of the statistical analysis of the straw yield of rice ($kg \cdot ha^{-1}$)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
5654	6537	7037	7766	186	381

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
6379	6750	6934	6967	186	381

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
5190	7508	10912	12569	371	759

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
4284	7211	10779	13209	340	696

Table 39. Results of the response function equation between grain yield (kg·ha^{-1}) and levels of N (kg·ha^{-1}) during different seasons

Season	Best fit	Response equation	Physical optimum	Economic optimum		Actual yield	Predict yiel
Samba	Linear	$\hat{Y} = 3998+14.9x$	--	--	N_0	3913	3998
					N_{50}	4999	4743
					N_{100}	5234	5488
					N_{150}	6318	6233
Kuruvai	Quadratic	$\hat{Y} = 2656+26.13x - 0.0535x^2$	244	222	N_0	2718	2656
					N_{50}	3644	3829
					N_{100}	4919	4734
					N_{150}	5310	5372
Thaladi	Quadratic	$\hat{Y} = 2013+39.9x - 0.118\ x^2$	169	159	N_0	1933	2013
					N_{50}	3953	3713
					N_{100}	4582	4823
					N_{150}	5418	5343

Table 40. Results of the response function equation between grain yield ($kg.ha^{-1}$) and levels of N ($kg.ha^{-1}$) at varying levels of K during Samba season

Levels of K	Best fit	Response equation	Physical optimum	Economic optimum		Actual yield	Predicted yield
K_0	Quadratic	$\hat{Y} = 3646+24.26x -0.0551x^2$	220	198	N_0	3470	3646
					N_{50}	5250	4721
					N_{100}	4993	5521
					N_{150}	6222	6045
K_{50}	Linear	$\hat{Y} = 3874 + 15.11x$	--	--	N_0	3751	3874
					N_{50}	5046	4629
					N_{100}	4920	5385
					N_{150}	6312	6141
K_{100}	Quadratic	$\hat{Y} = 4016 + 22.7x$ $0.0576\ x^2$	197	176	N_0	4144	4061
					N_{50}	4804	5052
					N_{100}	6003	5755
					N_{150}	6087	6170
K_{150}	Linear	$\hat{Y} = 4130 + 14.44\ x$	--	--	N_0	4286	4130
					N_{50}	4894	4852
					N_{100}	5020	5573
					N_{150}	6650	6295

Table 41. Results of the response function equation between grain yield ($kg.ha^{-1}$) and levels of N ($kg.ha^{-1}$) at varying levels of K during Kuruvai season

Levels of K	Best fit	Response equation	Physical optimum	Economic optimum		Actual yield	Predicted yield
K_0	Quadratic	$\hat{Y} = 2555 + 30.4x - 0.096\ x^2$	158	145	N_0	2600	2555
					N_{50}	3700	3834
					N_{100}	4767	4633
					N_{150}	4905	4950
K_{50}	Quadratic	$\hat{Y} = 2638 + 27.6x - 0.0716\ x^2$	193	176	N_0	2750	2638
					N_{50}	3505	3839
					N_{100}	5017	4682
					N_{150}	5056	5167
K_{100}	Quadratic	$\hat{Y} = 2779 + 24.9\ x - 0.0367\ x^2$	340	307	N_0	2844	2779
					N_{50}	3739	3934
					N_{100}	5100	4905
					N_{150}	5628	5693
K_{150}	Linear	$\hat{Y} = 2677 + 20.15\ x$	--	--	N_0	2678	2677
					N_{50}	3633	3685
					N_{100}	4794	4693
					N_{150}	5650	5700

Table 42. Results of the response function equation between grain yield (kg.ha^{-1}) and levels of N (kg.ha^{-1}) at varying levels of K during Thaladi season

Levels of K	Best fit	Response equation	Physical optimum	Economic optimum		Actual yield	Predicted yield
K_0	Quadratic	$\hat{Y} = 1921 + 41.93\,x - 0.1442\,x^2$	145	137	N_0	1854	1921
					N_{50}	3857	3657
					N_{100}	4472	4672
					N_{150}	5033	4966
K_{50}	Quadratic	$\hat{Y} = 2057 + 37.37\,x - 0.1079\,x^2$	173	162	N_0	1951	2057
					N_{50}	3975	3656
					N_{100}	4397	4115
					N_{150}	5342	5235
K_{100}	Quadratic	$\hat{Y} = 2032 + 40.67\,x - 0.1204\,x^2$	169	159	N_0	1976	2032
					N_{50}	3931	3764
					N_{100}	4728	4895
					N_{150}	5479	5423
K_{150}	Quadratic	$\hat{Y} = 2044 + 39.69\,x - 0.1008x^2$	197	185	N_0	1953	2044
					N_{50}	4048	3776
					N_{100}	4733	5005
					N_{150}	5820	5729

were fitted at varying levels of K (Fig.5). The results of the analysis revealed that application of K had increased the response of the crop to N application, as could be seen from the physical and economic optimum values, more clearly during Kuruvai and Thaladi season than during Samba season. During Kuruvai season, the quadratic function of N in the absence of K, was linear at K_{150} level. The physical and economic optimum values of N during Thaladi season was 145 and 137 $kg.ha^{-1}$ at K_0 level which rose up to 197 and 185 $kg.ha^{-1}$ respectively at K_{150} level.

4.1.11. Nutrient Content of the Grain and Straw

4.1.11.1. Nutrient Content of the Grain

4.1.11.1.1. Nitrogen Content in Grain (Table 43)

Application of N at 150 $kg.ha^{-1}$ level recorded the highest grain N content during Kuruvai and Thaladi seasons, this level being comparable with N_{100} during Samba season and the least was in control. The increase in the N content of the grain with every increase in the levels of N applied irrespective of the levels of K was observed during Thaladi season. The N content of the grain increased with every increase in the levels of K during Kuruvai and Thaladi seasons and during Thaladi season alone, this was true irrespective of the levels of N. During Samba season higher levels of K being comparable were superior to the lower levels.

Table 43. Results of the statistical analysis of the N content of the grain (%)

I. <u>Samba crop</u>

1. <u>Nitrogen levels</u>

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
2.12	2.31	2.50	2.63	0.06	0.14

2. <u>Potassium levels</u>

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
2.24	2.33	2.49	2.51	0.06	0.14

II. <u>Kuruvai crop</u>

1. <u>Nitrogen levels</u>

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
2.13	2.31	2.27	2.59	0.02	0.05

2. <u>Potassium levels</u>

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
2.18	2.27	2.36	2.48	0.02	0.05

(Contd.,)

Table 43. (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	Cd
1.90	2.03	2.17	2.43	0.02	0.04

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
1.99	2.10	2.19	2.25	0.02	0.04

3. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	1.78	1.92	1.92	1.96	0.07	0.02
N_{50}	1.85	1.99	2.13	2.13		
N_{100}	1.99	2.10	2.24	2.34		
N_{150}	2.34	2.38	2.45	2.55		

4.1.11.1.2. Phosphorus Content in Grain (Table 44)

Application of N increased the grain P content during Kuruvai and Thaladi seasons. Increasing levels of K also showed an increasing trend in the P content of the grain.

4.1.11.1.3. Potassium Content in Grain (Table 45)

Application of N enhanced the grain K content in all the seasons, the increase almost corresponding with every increase in the N levels. Increased grain K content was observed with increasing levels of K during Samba season whereas in Kuruvai and Thaladi seasons, the levels of K being on a par recorded higher grain K than control. During Thaladi season alone, the K content of the grain increased due to K application at lower levels of N and due to N at lower levels of K.

4.1.11.2. Nutrient Content of Straw

4.1.11.2.1. Nitrogen Content in Straw (Table 46)

Increasing levels of N application increased the N content of the straw at all stages of sampling during Kuruvai and Thaladi seasons, but during Samba season, the effect of N was not pronounced. The N content of the straw increased with every increase in the level of K application during Kuruvai and Thaladi seasons. This was true at tillering stage of Kuruvai season, whereas at later stages,

Table 44. Results of the statistical analysis of the P content of the grain (%)

I. Samba crop

Treatments are not significant.

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.262	0.299	0.349	0.381	0.016	0.033

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.284	0.304	0.341	0.362	0.016	0.033

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.316	0.356	0.386	0.389	0.018	0.038

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.309	0.354	0.372	0.412	0.018	0.038

Table 45. Results of the statistical analysis of the K content of the grain (%)

1. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.350	0.365	0.389	0.417	0.009	0.02

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.339	0.375	0.390	0.417	0.009	0.02

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.422	0.467	0.505	0.522	0.02	0.042

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.449	0.469	0.495	0.505	0.02	0.042

(Contd.,)

Table 45. (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.371	0.392	0.419	0.429	0.007	0.015

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.369	0.406	0.411	0.425	0.007	0.015

3. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	0.310	0.375	0.395	0.405	0.014	0.030
N_{50}	0.335	0.395	0.405	0.435		
N_{100}	0.450	0.425	0.415	0.430		
N_{150}	0.425	0.430	0.430	0.430		

Table 46. Results of the statistical analysis of the N content of the straw (%)

I. Samba crop

Treatments are not significant.

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
1.91	2.03	2.19	2.31	0.02	0.05

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
2.20	2.07	2.16	2.22	0.02	0.05

3. Stages

S_1	S_2	S_3	SE_D	CD
2.60	2.18	1.56	0.02	0.04

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	2.41	1.94	1.38	0.04	0.08
N_{50}	2.53	2.13	1.43		
N_{100}	2.75	2.25	1.58		
N_{150}	2.71	2.38	1.84		

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	2.41	2.09	1.49	0.04	0.08
K_{50}	2.55	2.17	1.50		
K_{100}	2.67	2.20	1.60		
K_{150}	2.76	2.24	1.64		

(Contd.,)

Table 46 (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
1.93	1.73	1.85	1.98	0.03	0.05

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
1.66	1.73	1.83	1.88	0.03	0.05

3. Stages

S_1	S_2	S_3	SE_D	CD
2.27	1.74	1.32	0.18	0.36

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	1.97	1.60	1.08	0.04	0.09
N_{50}	2.25	1.71	1.22		
N_{100}	2.29	1.76	1.43		
N_{150}	2.53	1.89	1.53		

the higher levels were comparable and superior to control. The N content of the straw decreased with the advancement of the crop growth in Kuruvai and Thaladi seasons.

4.1.11.2.2. Phosphorus Content in Straw (Table 47)

Increasing levels of N application proportionately increased the P content of the straw in all the seasons and at all levels of K during Kuruvai season. This result was the same at tillering stage of sampling during Samba and Thaladi seasons, but at later stages, the levels N_{100} and N_{150} were on a par and superior over N_{50} and N_0 which were comparable. Increased P content was observed during Kuruvai and Thaladi seasons with the application of K and irrespective of the levels of N during Kuruvai season. In all the seasons, the P content of the straw declined as the crop attained maturity and it was also ture irrespective of the levels of N during Samba and Thaladi seasons.

4.1.11.2.3. Potassium Content in Straw (Table 48)

Increased straw K content was observed with the enhancement of N levels in all the seasons. During Kuruvai and Thaladi seasons, the same trend was noticed in all the stages of crop growth. The straw K content progressively increased with the levels of K in all the three seasons. During Kuruvai season, this trend could be seen during

Table 47. Results of the statistical analysis of the P content of the straw (%)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.14	0.16	0.20	0.22	0.07	0.01

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.19	0.18	0.18	0.18	0.007	0.01

3. Stages

S_1	S_2	S_3	SE_D	CD
0.26	0.16	0.12	0.006	0.01

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	0.19	0.14	0.09	0.01	0.02
N_{50}	0.24	0.15	0.10		
N_{100}	0.29	0.16	0.14		
N_{150}	0.33	0.19	0.13		

(Contd.,)

Table 47. (Contd.,)

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.15	0.19	0.21	0.25	0.007	0.01

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.18	0.19	0.21	0.22	0.007	0.01

3. Stages

S_1	S_2	S_3	SE_D	CD
0.31	0.17	0.13	0.006	0.01

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	0.125	0.133	0.177	0.163	0.012	0.024
N_{50}	0.182	0.165	0.190	0.218		
N_{100}	0.168	0.218	0.237	0.240		
N_{150}	0.232	0.242	0.252	0.272		

(Contd.,)

Table 47. (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.18	0.22	0.25	0.28	0.007	0.01

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.20	0.23	0.24	0.26	0.007	0.01

3. Stages

S_1	S_2	S_3	SE_D	CD
0.34	0.22	0.13	0.006	0.01

4. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	0.259	0.179	0.097	0.012	0.025
N_{50}	0.342	0.196	0.115		
N_{100}	0.354	0.250	0.146		
N_{150}	0.404	0.272	0.166		

Table 48. Results of the statistical analysis of K content of the straw (%)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.76	0.86	0.98	0.99	0.028	0.06

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.75	0.85	0.94	1.05	0.28	0.06

3. Stages

S_1	S_2	S_3	SE_D	CD
1.06	0.88	0.76	0.06	0.12

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.998	1.080	1.167	1.277	0.022	0.044

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
1.021	1.082	1.166	1.261	0.022	0.044

(Contd.,)

Table 48. (Contd.,)

3. <u>Stages</u>

S_1	S_2	S_3	SE_D	CD
1.388	1.052	0.958	0.019	0.038

4. <u>Nitrogen x Stage interaction</u>

	S_1	S_2	S_3	SE_D	CD
N_0	1.32	0.95	0.73	0.035	0.070
N_{50}	1.39	0.95	0.92		
N_{100}	1.38	1.06	1.06		
N_{150}	1.46	1.25	1.12		

5. <u>Potassium x Stage interaction</u>

	S_1	S_2	S_3	SE_D	CD
K_0	1.23	0.92	0.92	0.035	0.07
K_{50}	1.29	1.03	0.93		
K_{100}	1.46	1.07	0.96		
K_{150}	1.57	1.18	1.03		

(Contd.,)

Table 48. (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.92	1.03	1.10	1.20	0.01	0.02

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.97	1.04	1.10	1.14	0.01	0.02

3. Stages

S_1	S_2	S_3	SE_D	CD
1.29	1.02	0.88	0.01	0.02

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	1.19	0.84	0.73	0.02	0.04
N_{50}	1.26	0.98	0.85		
N_{100}	1.31	1.06	0.93		
N_{150}	1.38	1.19	1.02		

tillering and panicle initiation stages. In the post-harvest stage, the levels of K were almost comparable with the control. In all the seasons, reduction in straw K content was observed as the crop matured. In Kuruvai and Thaladi seasons, this was seen at all levels of N and in Kuruvai season alone this was true irrespective of the levels of K.

4.1.12. Uptake of Nutrients by Grain and Straw

4.1.12.1. Uptake of Nutrients by Grain

4.1.12.1.1. Uptake of N by Grain (Table 49)

Increasing levels of N correspondingly increase the uptake of N in grain in all the seasons. Increasing levels of K increased the grain N uptake during Kuruvai and Thaladi seasons, whereas during Samba season, higher levels of K increased the uptake of N compared to the lower levels.

4.1.12.1.2. Uptake of P by the Grain (Tabel 50)

The uptake of P increased with each increment in the levels of N irrespective of the seasons. Higher uptake of P by the grain was observed with the application of K during Kuruvai and Thaladi seasons but not during Samba season.

Table 49. Results of the statistical analysis of the N uptake by the grain ($kg \cdot ha^{-1}$)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
80	114	129	157	7.3	16

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
109	119	123	130	7.3	16

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
57	85	110	137	3.0	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
91	91	102	104	3.0	6

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
38	83	102	131	3.2	7

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
80	85	90	98	3.2	7

Table 50. Results of the statistical analysis of the P uptake by the grain ($kg \cdot ha^{-1}$)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
10.1	13.4	14.7	18.9	1.2	2.6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
14.0	14.8	14.8	13.5	1.2	2.6

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
6.99	11.01	16.87	20.10	0.75	1.59

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
12.25	12.56	14.93	15.24	0.75	1.59

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
6.29	14.60	18.20	20.81	0.88	1.87

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
12.6	14.4	15.2	17.7	0.88	1.9

4.1.12.1.3. Uptake of K by the Grain (Table 51)

Application of N at increasing levels increased the uptake of K by the grain in all the seasons except during Samba where in the levels N_{100} and N_{50} were on a par. The uptake of K showed increasing trend with increasing levels of K during Kuruvai and Thaladi seasons. During Samba season, the levels being on a par were superior over control.

4.1.12.2. Uptake of Nutrients by Straw

4.1.12.2.1. Uptake of N (Table 52)

The uptake of N by straw linearly increased with increasing levels of N in all the seasons. This trend was observed in the post-harvest stage of sampling, whereas in the earlier stages of sampling, the levels of N were comparable. Application of K increased the N uptake in all the seasons, the levels being on a par were superior to control. The N uptake in straw increased with K application at post-harvest stage whereas at earlier stages its effect was not pronounced. The uptake of N increased with the advancement of sampling irrespective of the seasons and levels of N and K.

4.1.12.2.2. Uptake of P (Table 53)

The P uptake of the straw was progressively increased with increase in the levels of N irrespective of the seasons. This was true during the post-harvest stages of

Table 51. Results of the statistical analysis of the K uptake by the grain ($kg \cdot ha^{-1}$)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
13.21	18.13	20.09	25.52	1.06	2.26

2. Potassium levels

K_0	k_{50}	K_{100}	K_{150}	SE_D	CD
16.40	19.12	20.30	21.13	1.06	2.26

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
11.27	17.24	24.44	27.52	0.81	1.73

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
18.9	19.0	21.1	21.5	0.81	1.73

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
7.39	15.99	19.55	22.93	0.51	1.09

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
14.93	16.37	16.59	17.95	0.51	1.09

Table 52. Results of the statistical analysis of the N uptake by straw ($kg.ha^{-1}$)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
62	89	106	120	2.5	5

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
83	98	99	100	2.5	5

3. Stages

S_1	S_2	S_3	SE_D	CD
38	49	195	2.2	4

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	29	37	119	4.3	9
N_{50}	35	44	188		
N_{100}	42	53	222		
N_{150}	46	61	253		

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	33	45	171	4.3	9
K_{50}	37	49	198		
K_{100}	39	51	207		
K_{150}	43	52	205		

Table 52. (Contd.,)

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
57	75	109	141	5.8	12

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
89	90	101	102	5.8	12

3. Stages

S_1	S_2	S_3	SE_D	CD
29	47	211	5.0	10

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	21	34	114	10.0	20
N_{50}	24	42	158		
N_{100}	33	51	244		
N_{150}	36	60	327		

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	25	43	199	10	20
K_{50}	28	46	195		
K_{100}	32	48	223		
K_{150}	32	50	225		

(Contd.,)

Table 52. (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
36	62	96	121	2.8	6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
71	78	81	86	2.8	6

3. Stages

S_1	S_2	S_3	SE_D	CD
26	35	175	2.4	5

4. Stages x Nitrogen interaction

	S_1	S_2	S_3	SE_D	CD
N_0	17	25	66	4.8	10
N_{50}	22	30	134		
N_{100}	31	39	218		
N_{150}	36	47	282		

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	23	31	158	4.8	10
K_{50}	26	36	173		
K_{100}	28	35	179		
K_{150}	29	39	190		

Table 53. Results of the statistical analysis of the P uptake by the straw ($kg \cdot ha^{-1}$)

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
4.63	6.10	8.98	9.89	0.52	1.05

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
7.24	7.44	7.46	7.46	0.52	1.05

3. Stages

S_1	S_2	S_3	SE_D	CD
4.20	4.20	13.8	0.45	0.91

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	2.71	3.02	8.14	0.90	1.82
N_{50}	3.58	3.64	11.10		
N_{100}	4.49	4.99	17.46		
N_{150}	5.50	5.63	18.56		

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
3.72	6.40	10.10	13.40	0.78	1.58

(Contd.,)

Table 53. (Contd.,)

2. Potassium levels

K_0	K_{50}	K_{100}	k_{150}	SE_D	CD
6.68	7.76	9.39	9.79	0.78	1.5

3. Stages

S_1	S_2	S_3	SE_D	CD
3.53	3.63	18.05	0.68	1.37

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	2.21	2.30	6.66	1.36	2.7
N_{50}	2.85	3.00	13.34		
N_{100}	3.96	4.01	21.98		
N_{150}	4.97	5.35	29.86		

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	2.92	3.09	14.04	1.36	2.7
K_{50}	3.16	3.40	16.71		
K_{100}	3.87	3.94	20.37		
K_{150}	3.94	4.38	21.09		

(Contd.,)

Table 53. (Contd.,)

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
3.66	6.49	10.92	14.40	0.65	1.31

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
6.97	8.73	9.05	10.72	0.65	1.31

3. Stages

S_1	S_2	S_3	SE_D	CD
4.01	4.61	17.97	0.55	1.10

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	2.21	2.82	5.96	1.13	2.28
N_{50}	3.40	3.44	12.65		
N_{100}	4.69	5.50	22.56		
N_{150}	5.70	6.73	30.73		

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	3.27	4.05	13.58	1.13	2.28
K_{50}	4.06	4.54	17.55		
K_{100}	4.31	4.55	18.28		
K_{150}	4.39	5.32	22.44		

all the seasons. During the earlier stages of crop growth, the levels were almost comparable with control. During Kuruvai and Thaladi seasons, P uptake was enhanced with the application of K, but in Samba season its effect was not conspicuous. Almost the same result was observed during the post-harvest stage of the Kuruvai crop alone. In other stages and seasons this effect was not marked. Highest P uptake was observed at the post harvest stage of crop growth followed by the rest of the stages which were comparable. The same result could be seen irrespective of the levels of N during all the seasons and at all levels of K during Kuruvai and Thaladi seasons.

4.1.12.2.3. Uptake of K (Table 54)

The uptake of K by the straw increased with every increase in the levels of N in all the three seasons. This trend could be seen at panicle initiation and post-harvest stages in all these seasons. At tillering stage, the levels were almost comparable. Increasing levels of K application increased the K uptake in all the seasons and only in the post-harvest stages of Samba and Thaladi seasons. In the earlier stages its effect was not marked. There was a progressive increase in the uptake values in all the seasons with the advancement of crop growth. Irrespective of the seasons and levels of N, the highest K uptake was registered

Table 54. Results of the statistical analysis of the K uptake by the straw (kg.ha^{-1})

I. Samba crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
30.0	41.4	48.0	54.2	2.0	4.0

2. Potassium levels

K_0	k_{50}	K_{100}	K_{150}	SE_D	CD
34.6	42.2	47.1	49.6	2.0	4.0

3. Stages

S_1	S_2	S_3	SE_D	CD
16.8	23.2	90.1	1.7	3.5

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	12.5	15.8	61.4	3.5	7.0
N_{50}	15.2	20.5	88.3		
N_{100}	19.7	27.6	96.8		
N_{150}	19.9	29.0	113.8		

5. Potassiumx Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	12.70	18.3	72.4	3.5	7.0
K_{50}	15.4	22.2	89.0		
K_{100}	17.9	24.3	99.2		
K_{150}	21.3	21.6	100.0		

(Contd.,)

Table 54. (Contd.,)

II. Kuruvai crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
29.5	44.7	67.5	83.4	2.6	5.2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
52.1	52.2	59.0	61.7	2.6	5.2

3. Stages

S_1	S_2	S_3	SE_D	CD
15.6	22.8	130.4	2.2	4.5

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	12.5	16.9	59.3	4.5	9.0
N_{50}	13.5	19.0	101.5		
N_{100}	16.8	23.8	161.8		
N_{150}	19.7	31.6	198.8		

III. Thaladi crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
22.6	41.1	61.2	78.7	1.6	3.3

(Contd.,)

Table 54. (Contd.,)

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
42.9	57.0	52.8	57.0	1.62	3.3

3. Stages

S_1	S_2	S_3	SE_D	CD
14.9	20.7	117.1	1.4	2.8

4. Nitrogen x Stage interaction

	S_1	S_2	S_3	SE_D	CD
N_0	10.2	13.2	44.6	2.8	5.6
N_{50}	12.7	17.0	92.6		
N_{100}	17.4	23.3	143.1		
N_{150}	19.5	29.5	187.2		

5. Potassium x Stage interaction

	S_1	S_2	S_3	SE_D	CD
K_0	13.0	18.0	97.6	2.8	5.6
K_{50}	14.5	27.2	117.4		
K_{100}	15.6	21.0	121.7		
K_{150}	16.5	22.8	131.8		

by the post-harvest stage of sampling followed by the panicle initiation and tillering stages which were comparable at lower levels of N only. In Samba and Thaladi seasons, the K uptake increaseed with the stage advancement, the earlier two stages being comparable almost at all levels of K.

4.1.13. Correlation and Multiple Regression Analysis

4.1.13.1. Simple Correlation Studies

The results of the statistical analysis of the simple correlation studies made among the K availability indices during tillering, panicle initiation and post-harvest stages and yield parameters and K uptake values at harvest are presented in Table 55, 56 and 57 respectively.

4.1.13.1.1. Availability Indices of K Vs Grain Yield

The results of the simple correlation studies revealed that the K extracted by most of the extractants at different stages were related to the grain yield. However, the highest correlation co-efficients of 0.641^{**}, 0.631^{**} and 0.635^{**} were obtained between the grain yield and the K extracted by 1N HNO_3-K, during tillering, panicle initiation and post-harvest stages respectively. Among the Q/I parameters - ΔK^{o} at post-harvet stage was positively related to grain yield whereas PBC^{K} was negatively related. All the fractions of K were related to grain yields, except the water soluble K at post-harvest stage.

Table 55. Results of the correlation studies made among the K availability during tillering stage and yield parameters and K uptake values (n=48)

Sl. No.	K availability indices	Grain yield	Straw yield	Dry matter yield	Grain K uptake	Straw K uptake	Total K uptake
1.	H_2O-K	0.556**	NS	NS	0.304*	NS	NS
2.	N NH_4OAc-K	0.455**	NS	NS	NS	NS	NS
3.	0.01N HCl-K	0.299*	NS	0.316*	NS	NS	NS
4.	0.1N HCl-K	0.432**	NS	NS	NS	NS	NS
5.	0.5N HCl-K	0.359*	NS	0.298*	NS	NS	NS
6.	0.1N HNO_3-K	0.604**	NS	0.293*	0.400**	NS	NS
7.	0.5N HNO_3-K	0.447**	NS	NS	NS	NS	NS
8.	1N HNO_3-K	0.641**	NS	NS	0.422**	NS	NS
9.	0.01N HNO_3-K	0.456**	NS	0.294*	0.484**	0.323*	0.345*
10.	6N H_2SO_4-K	0.575**	NS	NS	0.407**	NS	NS
11.	0.5N EDTA-K	NS	NS	NS	NS	NS	NS
12.	0.5N NaCl-K	NS	0.315*	0.337*	NS	0.296*	NS
13.	0.01M $CaCl_2$-K	NS	NS	NS	NS	NS	NS
14.	Bray-K	0.403**	NS	NS	NS	NS	NS
15.	Morgan's-K	NS	NS	NS	NS	NS	NS
16.	$-\Delta K^o$	NS	0.572**	0.526**	0.316*	0.511**	0.498**
17.	PBC^K	-0.381**	-0.299*	NS	NS	NS	NS
18.	AR_e^K	NS	-0.340*	-0.399**	-0.382**	-0.367*	-0.376**
19.	ΔG	NS	-0.289*	NS	NS	NS	NS
20.	Water soluble-K	0.318*	NS	NS	NS	NS	NS
21.	Exchangeable K	0.581**	NS	NS	0.505**	NS	NS
22.	Non-exchangeable K	0.587**	NS	NS	0.427**	NS	NS

Table 56. Results of the correlation studies made among the K availability indices during panicle initiation stage and yield parameters and K uptake values (n = 48)

Sl. No.	K availability indices	Grain yield	Straw yield	Dry matter yield	Grain K uptake	Straw K uptake	Total K uptake
1.	H_2O-K	0.349*	NS	NS	NS	NS	NS
2.	N NH_4OAc-K	0.363*	0.302*	0.356*	0.294*	0.322*	0.324*
3.	0.01N HCl-K	0.437**	0.292*	0.374**	0.356*	0.351*	0.359*
4.	0.1N HCl-K	0.433**	NS	NS	NS	NS	NS
5.	0.5N HCl-K	0.501**	NS	NS	0.343*	NS	NS
6.	0.1N HNO_3-K	0.449**	NS	NS	NS	NS	NS
7.	0.5N HNO_3-K	0.444**	NS	NS	0.285*	NS	NS
8.	1N HNO_3-K	0.631**	NS	NS	0.412**	NS	NS
9.	0.01N HNO_3-K	0.496**	NS	0.359*	0.582**	0.403**	0.428**
10.	6N H_2SO_4-K	0.516**	NS	NS	NS	NS	NS
11.	0.5N EDTA-K	0.304*	NS	NS	NS	NS	NS
12.	0.5N NaCl-K	0.405**	NS	0.352*	NS	NS	0.305*
13.	0.01M $CaCl_2$-K	NS	NS	NS	NS	NS	NS
14.	Bray-K	0.607**	NS	0.359*	0.402**	NS	0.288*
15.	Morgan's-K	0.377**	NS	NS	NS	NS	NS
16.	Water soluble K	0.478**	NS	NS	NS	NS	NS
17.	Exchangeable K	0.534**	NS	NS	0.315*	NS	NS
18.	Non-exchangeable K	0.560**	NS	NS	0.363*	NS	NS

Table 57. Results of the correlation studies made among the K availability indices during post-harvest stage and yield parameters and K uptake values (n=48)

Sl. No.	K availability indices	Grain yield	Straw yield	Dry matter yield	Grain K uptake	Straw K uptake	Total K uptake
1.	H_2O-K	0.499**	NS	0.287*	0.298*	NS	NS
2.	N NH_4OAc-K	0.503**	0.368**	0.405**	0.304*	0.401**	0.396**
3.	0.01N HCl-K	0.367*	NS	NS	NS	NS	NS
4.	0.1N HCl-K	0.491**	NS	NS	0.365*	NS	NS
5.	0.5N HCl-K	0.554**	NS	NS	0.451**	NS	NS
6.	0.1N HNO_3-K	0.597**	NS	NS	0.364*	NS	NS
7.	0.5N HNO_3-K	0.579**	NS	NS	0.395**	NS	NS
8.	1N HNO_3-K	0.635**	NS	0.327*	0.581**	0.317*	0.350*
9.	0.01N HNO_3-K	0.464**	NS	NS	0.320*	NS	NS
10.	6N H_2SO_4-K	0.579**	NS	NS	NS	NS	NS
11.	0.5N EDTA-K	0.379**	NS	0.348*	NS	0.294*	0.293*
12.	0.5N NaCl-K	0.391**	NS	NS	NS	NS	NS
13.	0.01M $CaCl_2$-K	NS	NS	0.369**	0.388**	0.300*	0.314*
14.	Bray - K	0.543**	NS	NS	NS	NS	NS
15.	Morgan's - K	0.330*	NS	NS	NS	NS	NS
16.	$-\Delta K^o$	0.418**	0.290*	0.357*	0.326*	NS	0.289*
17.	AR_e^K	NS	-0.384**	-0.295*	NS	NS	NS
18.	PBC^K	-0.338*	NS	NS	NS	NS	NS
19.	ΔG	NS	-0.359*	-0.291*	NS	NS	NS
20.	Watersoluble K	NS	0.295*	0.356*	0.401**	NS	0.312*
21.	Exchangeable K	0.473**	0.567**	0.401**	0.392**	0.447**	0.403**
22.	Non-exchangeable K	0.357*	NS	0.296*	NS	NS	0.297*

4.1.13.1.2. Availability Indices of K Vs Straw Yield

The straw yield of paddy was not related to most of the K availability indices excepting with 0.5N NaCl-K at tillering stage, 0.01N HCl-K and NH_4OAc-K (highest 'r' value) during panicle initiation stage and with NH_4OAc-K at post-harvest stage. Among the Q/I parameters, - ΔK^o was related to straw yield and AR_e^K, PBC^K and ΔG were negatively related. The water soluble and exchangeable K at post-harvest stage were related to straw yield.

4.1.13.1.3. Availability Indices of K Vs Drymatter Production

The drymatter yield was related to the K extracted by 0.01N and 0.5N HCl, 0.1 and 0.01N HNO_3 and 0.5N NaCl during tillering stage, NH_4OAc, 0.01N HCl, 0.01N HNO_3, 0.5N NaCl and Bray's reagent during panicle initiation stage and to the K extracted by H_2O, N NH_4OAc, 1N HNO_3, 0.5N EDTA and 0.01M $CaCl_2$ during post-harvest stage. The highest 'r' values among these being reecorded by 0.5N NaCl, 0.01N HCl and NH_4OAc-K druing these stages respectively. The - ΔK^o was also related to dry matter yield, whereas AR_e^K and ΔG values were negatively releated.

4.1.13.1.4. Availability Indices of K Vs Grain K Uptake

The K extracted by water, 0.1N HNO_3, 1N HNO_3, 0.01N HNO_3 and 6N H_2SO_4 during tillering stage, N NH_4 OAc, 0.01N HCl, 0.5N HCl, 0.5N HNO_3, 1N HNO_3, 0.01N HNO_3 and Bray's reagent during panicle initiation stage and water, N NH_4OAc, 0.1N HCl, 0.5N HCl, 0.1N HNO_3, 0.5N HNO_3, 1N HNO_3, 0.01N HNO_3 , and 0.01M $CaCl_2$ during post-harvest stage were related to grain K uptake. Among these, during tillering and panicle initiation stages 0.01N HNO_3-K, had the highest 'r' value (0.582^{**}) whereas 1N HNO_3-K at post-harvest stage had the highest 'r' value (0.581^{**}). The $-\Delta K^o$ during tillering stage was also related to uptake of K by the grain, whereas AR_e^K was negatively related. The fractions of K were also related to grain K uptake.

4.1.13.1.5. Availability Indices of K Vs Straw K Uptake

The straw K uptake was related to the 0.01N HNO_3 and 0.5N NaCl extractable K during tillering stage, N HN_4OAc-K, 0.01N HCl-K and 0.01N HNO_3-K during panicle initiation stage and N NH_4OAc-K, 1N HNO_3 -K, 0.5N EDTA-K and 0.01M $CaCl_2$-K during post-harvest stage. Among these, the K extracted by 0.01N HNO_3-K at tillering (0.323^{*}) and panicle initiation (0.403^{**}) stages showed the highest correlation co-efficient and at post-harvest stage, NH_4OAc-K had the highest 'r' value (0.401^{**}). The $-\Delta K^o$ values at tillering stage were related to straw K uptake, whereas AR_e^K was negatively related.

4.1.13.1.6. Availability Indices of K Vs Total K Uptake

The total K uptake was related only to 0.01N HNO_3-K at tillering stage, N NH_4OAc-K, 0.01N HCl-K, 0.01N HNO_3-K, 0.5N NaCl-K and Bray-K during panicle initiation stage and with NH_4OAc-K, 1N HNO_3-K, 0.5N EDTA-K and 0.01M $CaCl_2$-K at post-harvest stage. The highest 'r' values were registered by the K extracted by 0.01N HNO_3 at tillering (0.345^{*}) and panicle initiation (0.428^{**}) and by NH_4OAc-K (0.396) during post-harvest stage. The $-\Delta K^{o}$ at tillering and post-harvest stages was related to total K uptake. AR_e^K at tillering stage was negatively related to K uptake.

4.1.13.2. Multiple Regression Analysis

The results of the simple correlation studies made indicated that out of the 15 extractants compared for their relative performance to predict the yield parameters of rice and K uptake values, the grain yield and K uptake values were more closely related to 1N HNO_3-K and 0.01N HNO_3-K respectively. To confirm these results, multiple regression analysis were worked out and the results of which are presented in tables 58, 59 and 60 respectively for tillering, panicle initiation and post-harvest stages.

4.1.13.2.1. Tillering Stage (Table 58)

Among the different extractnts tried, the K extracted by 1N HNO_3 and 0.01N HNO_3 at tillering stage had

Table 58. Results of the statistical analysis of the multiple regression of the K availability indices during tillering stages (x parameter) and yield attributes and K uptake values. (n=48)

Sl. No.	K availability indices	't' values					
		Grain yield	Straw yield	Dry matter yield	Grain K uptake	Straw K uptake	Total K uptake
1.	H_2O-K	2.996**	NS	NS	2.741*	NS	NS
2.	NH_4OAc-K	-2.444*	-3.798**	-3.514**	-4.731**	-3.282**	-3.454**
3.	0.01N HCl-K	NS	NS	NS	NS	NS	NS
4.	0.1N HCl-K	NS	NS	NS	NS	NS	NS
5.	0.5N HCl-K	-3.023**	NS	NS	-2.487*	NS	NS
6.	0.1N HNO_3-K	NS	NS	NS	NS	NS	NS
7.	0.5N HNO_3-K	2.547*	NS	NS	NS	NS	NS
8.	1N HNO_3-K	3.832**	3.682**	3.865**	4.825**	3.790**	4.032**
9.	0.01N HNO_3-K	2.936*	2.587*	2.828*	3.271**	3.195**	3.281**
10.	6N H_2SO_4 -K	-2.618*	NS	NS	NS	NS	NS
11.	0.5N EDTA-K	-3.472**	-4.617**	-2.570*	-3.739**	-3.403**	-3.449**
12.	0.5N NaCl-K	NS	NS	NS	NS	NS	NS
13.	0.01N $CaCl_2$-K	NS	NS	NS	NS	NS	NS
14.	Bray-K	NS	NS	NS	NS	NS	NS
15.	Morgan's-K	2.872*	3.913**	3.722**	3.297**	3.690**	3.762**
	R^2 values	0.830	0.835	0.825	0.860	0.858	0.859

significant 't' values with all the yield attributes. The R^2 values ranged from 0.82 to 0.86.

4.1.13.2.2. Panicle Initiation Stage (Table 59)

The results of multiple regression analysis indicated that out of 15 extractants tried, the K extracted by 1N HNO_3 at panicle initiation stage showed significant values with only grain yield and the 0.01N HNO_3-K had significant 't' values with the K uptake in grain and straw and total K uptake. The R^2 values of this regression analysis ranged from 0.66 to 0.73.

4.1.13.2.3. Post-harvest Stage (Table 60)

The K extracted by 1N HNO_3-K had significant 't' values with all the yield attributes whereas 0.01N HNO_3-K had relationship with K uptake in grain and straw and total K uptake. The R^2 values ranged from 0.81 to 0.90.

The results of the simple correlation and multiple regression analysis indicated that out of the 15 extractants tried and various K potential parameters investigated, 1N HNO_3 was found to be the best extractant for predicting the grain yield of rice. The K extracted by 0.01N HNO_3-K showed higher 'r' values in the simple correlation and significant 't' values in the multiple regression analysis with that of the K uptake values of grain, straw and total K uptake indicating that it would be the best extractant for predicting the uptake of K.

Table 59. Results of the statistical analysis of the multiple regression of the K availability indices during panicle initiation stage (x parameter) and yield attributes and K uptake values (n = 48)

Sl. No.	K availability indices	't' values					
		Grain yield	Straw yield	Dry matter yield	Grain K uptake	Straw K uptake	Total K uptake
1.	H_2O-K	NS	NS	NS	NS	NS	NS
2.	N NH_4OAc-K	NS	NS	NS	NS	NS	NS
3.	0.01N HCl-K	NS	NS	NS	NS	NS	NS
4.	0.1N HCl-K	NS	NS	NS	NS	NS	NS
5.	0.5N HCl-K	NS	NS	NS	NS	NS	NS
6.	0.1N HNO_3-K	NS	NS	NS	NS	NS	NS
7.	0.5N HNO_3-K	NS	NS	NS	NS	NS	NS
8.	1N HNO_3-K	2.688*	NS	NS	NS	NS	NS
9.	0.01N HNO_3-K	NS	NS	NS	2.905**	3.003**	3.005**
10.	6N H_2SO_4-K	NS	NS	NS	NS	-2.191*	NS
11.	0.5N EDTA-K	NS	NS	NS	NS	NS	NS
12.	0.5N NaCl-K	NS	NS	NS	NS	NS	NS
13.	0.01M $CaCl_2$-K	NS	NS	NS	NS	NS	NS
14.	Bray - K	NS	NS	NS	NS	NS	NS
15.	Morgans - K	NS	NS	NS	NS	NS	NS
	R^2 values	0.713	0.693	0.665	0.682	0.727	0.720

Table 60. Results of the statistical analysis of the multiple regression of the K availability indices during post-harvest stage (x parameter) and yield attributes and K uptake values (n = 48)

Sl. No.	K availability indices	't' values					
		Grain yield	Straw yield	Dry matter yield	Grain K uptake	Straw K uptake	Total K uptake
1.	H_2O-K	NS	NS	NS	NS	NS	NS
2.	N NH_4OAc-K	-2.306*	-2.789*	-2.743*	-3.390**	-3.198**	-3.264**
3.	0.01N HCl-K	NS	NS	NS	NS	NS	NS
4.	0.1N HCl-K	NS	NS	NS	NS	NS	NS
5.	0.5N HCl-K	NS	NS	NS	NS	NS	NS
6.	0.1N HNO_3-K	NS	NS	NS	NS	NS	NS
7.	0.5N HNO_3-K	NS	NS	NS	NS	NS	NS
8.	1N HNO_3-K	3.834**	4.042**	4.060**	4.400**	4.279**	4.349**
9.	0.01N HNO_3-K	NS	NS	NS	2.670*	2.966*	2.962*
10.	6N H_2SO_4-K	NS	NS	NS	NS	NS	NS
11.	0.5N EDTA-K	-2.545*	-3.725**	-3.664**	-4.079**	-3.482**	-3.487**
12.	0.5N NaCl-K	NS	NS	NS	NS	NS	NS
13.	0.01M $CaCl_2$-K	-2.521*	-3.164**	-3.206**	NS	-3.867**	-2.934*
14.	Bray-K	NS	NS	NS	NS	NS	NS
15.	Morgan's - K	NS	2.571*	2.361*	2.216*	3.058**	2.980**
.	R^2 values	0.808	0.871	0.848	0.833	0.896	0.889

4.2. Results of the Pot Culture Experiments

The results of the pot culture experiments conducted during Kuruvai and Thaladi seasons using the ten major soil series of Thanjavur delta are presented below.

4.2.1. General Properties of the Soils (Table 61)

The general properties of the soils chosen for the pot culture experiment are described hereunder.

4.2.1.1. Kondal soil series (Typic chromustert)

The soil of Kondal series (Knd) was sandy clayey in texture, low in available N, medium in available P and K. The soil was neutral in soil reaction.

4.2.1.2. Padugai soil series (Typic ustifluent)

The soil coming under Padugai soil series (Pdg) was clayey loam in texture, low in available N, medium in available P and K status. It was neutral in soil reaction.

4.2.1.3. Valuthalakudi Soil Series (Typic Udipsamment)

The Valuthalakudi soil was sandy loam in texture and poor in its fertility status. The available, N and P contents were low and the K status was medium. It was slightly acidic in reaction.

Table 61. Results of the initial analysis of the soils used for the pot culture experiment

Sl. No.	Soil series	Particle size analysis				Physical constants				
		Clay %	Silt %	Fine sand %	Coarse sand %	App. density $kg.m^{-3}$	Sp. gr $kg.m^{-3}$	Pore space %	WHC %	Vol. on exp. %
1.	Kondal	34.28	22.72	15.51	23.50	1090	2120	41.17	44.15	39.82
2.	Padugai	38.51	25.82	15.41	20.10	1180	2200	39.82	42.81	35.11
3.	Valuthalakudi	18.82	19.50	32.81	25.87	1410	2480	25.11	15.18	22.41
4.	Sikar	31.87	17.81	29.10	16.89	1150	2190	35.52	32.61	27.11
5.	Nedumbalam	42.80	12.23	22.41	19.61	1220	2270	39.31	33.81	31.52
6.	Kivalur	28.91	32.80	29.17	7.81	1290	2310	36.15	29.80	22.13
7.	Madukkur	35.71	14.82	22.11	20.02	1310	2280	30.50	33.31	27.71
8.	Pattukkottai	18.12	8.90	28.52	38.50	1120	2080	38.15	29.11	26.64
9.	Kalathur	52.81	20.11	10.50	12.33	1020	2100	51.18	60.81	47.18
10.	Adanur	31.82	28.14	18.82	15.14	1170	2220	38.15	42.11	33.00

Table 61. (Contd.,)

Sl. No.	Soil series	Chemical properties								
		Moisture (%)	Loss on ignition (%)	Fe_2O_3 (%)	Al_2O_3 (%)	Total N(%)	Avail. N (ppm)	Total P (%)	Avail. P (ppm)	Total K(%
1.	Kondal	4.41	2.15	4.41	5.85	0.121	72	0.040	6.7	1.2
2.	Padugai	5.82	2.81	5.10	7.81	0.108	80	0.029	8.0	1.2
3.	Valuthalakudi	2.11	1.15	3.85	4.44	0.087	58	0.071	3.2	0.8
4.	Sikar	3.14	2.85	4.21	3.82	0.092	68	0.015	5.1	1.3
5.	Nedumbalam	3.41	3.50	6.82	8.50	0.100	70	0.044	7.2	1.2
6.	Kivalur	5.12	3.15	4.82	9.10	0.102	62	0.011	5.4	1.6
7.	Madukkur	4.81	2.10	3.51	2.55	0.132	95	0.021	8.9	1.2
8.	Pattukkottai	4.10	1.81	3.22	6.40	0.093	84	0.077	9.8	1.4
9.	Kalathur	5.81	2.20	7.19	8.56	0.131	98	0.051	8.5	2.4
10.	Adanur	4.11	4.58	6.12	9.00	0.120	87	0.071	8.0	1.8

Table 61. (Contd.,)

Sl. No.	Soil series	Chemical properties							
		Avail. K (ppm)	Total Ca(%)	Avail. Ca(ppm)	Total Mg (%)	Avail. Mg (ppm)	Org. C (%)	pH	EC $ds \cdot m^{-1}$
1.	Kondal	132	0.231	2800	0.182	181	0.32	6.82	0.23
2.	Padugai	109	0.425	3250	0.285	215	0.38	6.95	0.45
3.	Valuthalakudi	62	0.151	620	0.135	112	0.13	6.38	0.18
4.	Sikar	212	0.225	4200	0.251	145	0.56	7.10	0.28
5.	Nedumbalam	200	0.314	3800	0.189	99	0.44	6.52	0.11
6.	Kivalur	241	0.442	2410	0.320	165	0.81	7.21	0.31
7.	Madukkur	101	0.380	890	0.210	112	0.58	6.15	0.15
8.	Pattukkottai	105	0.283	1020	0.184	145	0.38	6.22	0.18
9.	Kalathur	232	0.650	4850	0.410	282	0.91	7.41	0.37
10.	Adanur	215	0.585	3280	0.315	255	0.87	7.59	0.30

Table 61. (Contd.,)

Sl. No.	Soil series	Q/I parameters						Cation exchange properti (m.e.100 g^{-1})			
		AR_e^K x 10^{-3} $(m.l^{-1})^{1/2}$	$-\Delta K^o$ m.e. $100g^{-1}$	PBC^K	ΔG -Calories	K_L m.e. $100g^{-1}$	K_x m.e. $100g^{-1}$	CEC	Exch. K	Exch. Ca	Exch. Mg
1.	Kondal	3.25	0.470	145	3427	0.569	0.099	21.82	0.415	14.00	1.51
2.	Padugai	3.70	0.415	112	3350	0.428	0.013	24.11	0.470	16.25	1.79
3.	Valuthalakudi	5.20	0.190	36	3145	0.428	0.298	7.52	0.287	3.10	0.93
4.	Sikar	4.75	0.420	88	3200	0.569	0.149	25.62	0.544	21.00	1.21
5.	Nedumbalam	5.00	0.280	57	3169	0.428	0.148	28.11	0.513	19.00	0.83
6.	Kivalur	6.50	0.420	65	3032	0.595	0.175	18.58	0.618	12.05	1.38
7.	Madukkur	4.90	0.320	66	3182	0.428	0.108	11.56	0.362	4.45	0.93
8.	Pattukottai	6.00	0.220	37	3060	0.428	0.208	13.85	0.400	5.10	1.21
9.	Kalathur	3.30	0.620	189	3418	0.728	0.108	32.56	0.595	24.25	2.35
10.	Adanur	3.40	0.400	119	3400	0.428	0.028	25.13	0.553	16.40	2.12

4.2.1.4. Sikar Soil Series (Typic chromustert)

The texture of the Sikar soil series (Skr) was sandy clay loam. The soil was low in available N, medium in available P and high in available K status. It was neutral in reaction.

4.2.1.5. Nedumbalam Soil Series (Entic chromustert)

The soil classified under Nedumbalam soil series (Ndb) was sandy clayey in texture with low status of available N, medium level of available P and high status of available K. It was slightly acidic in soil reaction.

4.2.1.6. Kivalur Soil Series (Entic Chromustert)

The Kivalur soil (Kvr) was clayey loam in texture, low in available N, medium in available P and high in available K status. The soil was neutral in reaction.

4.2.1.7. Madukkur Soil Series (Aquic haplustalf)

The soil of Madukkur series (Mdk) was lateritic in nature and was acidic in reaction. It was low in its available N medium in available P and K contents and was clay loamy in texture.

4.2.1.8. Pattukkottai Soil Series (Ultic haplustalf)

The soil of Pattukkottai series (Pkt) was sandy loam in texture with a low status of N and medium status of available P and K. It was also lateritic with acidic soil reaction.

4.2.1.9. Kalathur Soil Series (Udic Pellustert)

The Kalathur soil (Klt) was clayey in texture and neutral in reaction. It was low in available N, medium in available P and high in available K.

4.2.1.10. Adanur Soil Series (Entic chromustert)

The soil of Adanur series (Adn) was clayey loam in texture with low level of N, medium level of P and high level of available K. The soil reaction was neutral.

4.2.2. Availability Indices of K in Soils

All the extractants used to extract K from soil of the field experiments (section 3.3.4) were also used in the pot culture experiment.

4.2.2.1. Water Extractable K

4.2.2.1.1. First Crop (Table 62)

The water extractable K increased with the application of N, N_{50} registering the highest value

Table 62. Results of the statistical analysis of the water extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
7.80	8.85	8.47	8.11	0.13	0.26

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
6.98	7.96	8.66	9.60	0.13	0.26

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
7.53	8.06	7.04	8.41	8.02	0.2	0.41
Kvr	Mdk	Pkt	Klt	Adn		
12.67	6.76	8.02	8.29	8.22		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	6.14	7.52	8.39	9.21	0.26	0.52
N_{50}	7.20	8.32	9.17	10.63		
N_{100}	7.33	8.27	8.68	9.62		
N_{150}	7.27	7.75	8.44	8.97		

(Contd.,)

Table 62. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	7.64	8.02	6.90	7.56	0.41	0.82
Pdg	7.81	9.00	7.86	7.56		
Vld	5.69	7.98	7.03	7.45		
Skr	8.02	8.79	8.58	8.27		
Ndb	7.57	7.95	8.87	7.72		
Kvr	11.58	13.54	13.20	12.36		
Mdk	6.26	7.16	7.20	6.44		
Pkt	7.40	8.19	8.47	8.00		
Klt	8.16	8.75	8.53	7.70		
Adn	7.93	8.87	8.08	7.99		

Table 63. Results of the statistical analysis of the water extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
4.95	5.38	5.40	5.13	0.07	0.14

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
4.83	5.11	5.35	5.56	0.07	0.14

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
5.70	5.60	3.95	5.08	5.02	0.11	0.22
Kvr	Mdk	Pkt	Klt	Adn		
8.20	4.10	4.92	4.75	4.84		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	4.42	4.92	5.03	5.43	0.14	0.27
N_{50}	4.82	5.13	5.61	5.97		
N_{100}	5.27	5.28	5.50	5.53		
N_{150}	4.81	5.13	5.25	5.35		

(Contd.,)

Table 63. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	5.10	5.23	6.62	6.42	0.22	0.43
Pdg	5.42	5.67	5.62	5.67		
Vld	3.47	3.97	3.99	3.95		
Skr	4.70	5.36	5.27	4.97		
Ndb	4.44	5.03	5.67	4.93		
Kvr	8.11	8.72	8.20	7.77		
Mdk	3.47	4.47	3.99	4.44		
Pkt	4.86	5.48	4.86	4.48		
Klt	4.74	4.94	4.95	4.36		
Adn	4.77	4.96	4.91	4.74		

followed by N_{100} and N_{150}. The control pots registered the lowest values. Almost the same trend could be seen at all levels of K and in almost all the soil series. Application of K in increasing levels increased the water extractable K at all levels of N. The Kivalur soil series registered the highest water extractable K, irrespective of the N levels. The Valuthalakudi and Madukkur soils being on a par recorded the lowest value. The other soil series were in between.

4.2.2.1.2. Residual Crop (Table 63)

Application of N increased the water extractable K, the levels N_{100} and N_{50} being on a par recorded the highest value followed by N_{100} and N_0. This trend was observed in almost all the soils except Padugai and Adanur soils, where in the effect of N was not marked. Increasing levels of K correspondingly increased the water extractable K and also at lower levels of N. At higher levels of N, the levels of K were almost comparable. The Kivalur soil series recorded the highest water extractable K and the lowest values were registered in Valuthalakudi and Madukkur soils, which could be seen also at all levels of N.

4.2.2.2. NH_4OAc-K

4.2.2.2.1. First Crop (Table 64)

Increase in NH_4OAc-K was observed with every increase in the levels of N. In five out of ten soils, the

Table 64. Results of the statistical analysis of the N-NH_4OAc extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
167	170	171	174	1.02	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
165	169	173	175	1.02	2

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
159	169	119	197	189	1.6	3
Kvr	Mdk	Pkt	Klt	Adn		
209	127	139	192	208		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	155	156	161	164	3.2	6
Pdg	164	165	171	177		
Vld	104	109	110	133		
Skr	197	197	190	192		
Ndb	185	189	190	192		
Kvr	206	211	210	209		
Mdk	125	129	127	129		
Pkt	135	141	141	140		
Klt	190	192	194	191		
Adn	204	211	211	208		

Table 65. Results of the statistical analysis of the N-NH_4OAc extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
129	133	133	132	0.5	1

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
128	131	133	135	0.5	1

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
128	135	75	169	109	0.78	2
Kvr	Mdk	Pkt	Klt	Adn		
176	99	107	155	164		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	125	128	129	134	0.98	2
N_{50}	126	132	135	138		
N_{100}	130	132	133	135		
N_{150}	130	133	133	133		

Table 65. (Contd.,)

5. Nitrogen x soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	126	129	129	129	1.55	3
Pdg	132	138	136	135		
Vld	71	77	77	75		
Skr	167	170	168	171		
Ndb	107	109	109	111		
Kvr	174	180	175	174		
Mdk	95	100	101	99		
Pkt	107	108	107	107		
Klt	153	156	156	154		
Adn	160	160	168	166		

NH_4 OAc-K increased with N application whereas in Kivalur, Sikar, Pattukkottai, Madukkur and Kalathur soils, the effect of N was not marked. Application of K increased the NH_4OAc-K correspondingly. The Kivalur and Adanur soils being comparable registered higher NH_4OAc-K than the rest of the soils and the lowest was observed in Valuthalakudi soils. At all the levels of N, this trend was observed.

4.2.2.2.2. Residual Crop (Table 65)

Increasing NH_4OAc-K with every increase in the levels of K was observed. Application of N tended to increase the NH_4OAc-K and also at all levels of K and in all soils except Kondal and Pattukkottai, where in the effect of N was not pronounced. Kivalur soil series registered the highest value and the lowest was recorded by Valuthalakudi. The rest of the soils were in between. This was true at all levels of N. At lower levels of N, K application increased the NH_4OAc-K consistently but at higher levels, the levels of K were not different.

4.2.2.3. 0.1N HCl-K

4.2.2.3.1. First Crop (Table 66)

Application of K increased the 0.1N HCl-K, though the levels of N were comparable but superior over control. The K extracted by 0.1N HCl increased with every increase in the K levels at all levels of N. The Kivalur and Valuthalakudi soils registered the highest and lowest 0.1N HCl-K respectively which was also true at all levels of N. Increased 0.1N HCl-K was recorded with N application at all levels of K excepting K_{150}, where in N_{50} recorded the highest value. In Kondal, Sikar and Pattukkottai soils, N application did not result in marked changes. In the rest of the soils 0.1N HCl-K tended to increase with the levels of N.

4.2.2.3.2. Residual Crop (Table 67)

The individual effects of N and K in increasing 0.1N HCl-K followed the same trend as in the first crop. The Kivalur and Sikar soil series being on a par recorded higher 0.1N HCl-K than the rest of the soils and the lowest was observed at Valuthalakudi soil. This was true also at all levels of N. In Valuthalakudi, Pattukkottai, Madukkur and Kalathur soils, 0.1N HCl-K was not altered with N application, whereas in the rest of the soils, it tended to increase.

4.2.2.4. 0.5N HCl-K

4.2.2.4.1. First Crop (Table 68)

Application of N increased the 0.5N HCl-K, the levels being on a par but superior to control. This trend was almost seen at all levels of K and in most of the soils. In Kivalur, Sikar, Nedumbalam and Madukkur soils, 0.5N HCl-K was not changed with N application. Increased values

Table 66. Results of the statistical analysis of the 0.1N HCl extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
87	89	89	90	0.53	1

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
82	87	91	95	0.53	1

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
83	92	57	94	84	0.83	2
Kvr	Mdk	Pkt	Klt	Adn		
119	73	75	106	100		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	79	84	89	95	1.06	2
N_{50}	82	86	92	97		
N_{100}	83	88	90	93		
N_{150}	85	88	91	83		

(Contd.,)

Table 66. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	82	84	83	84	1.67	3
Pdg	91	92	95	92		
Vld	54	58	58	60		
Skr	93	94	95	94		
Ndb	86	84	81	87		
Kvr	117	120	120	120		
Mdk	68	76	74	73		
Pkt	75	77	76	74		
Klt	102	108	106	108		
Adn	97	102	97	104		

Table 67. Results of the statistical analysis of the 0.1N HCl extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
67	69	68	68	0.49	1

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
65	68	69	70	0.49	1

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
62	74	44	85	68	0.78	2
Kvr	Mdk	Pkt	Klt	Adn		
87	55	56	83	67		

4. Nitrogen x soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	59	64	61	62	1.56	3
Pdg	71	74	74	76		
Vld	42	44	45	45		
Skr	84	83	86	88		
Ndb	65	69	71	67		
Kvr	85	86	88	89		
Mdk	52	53	54	53		
Pkt	56	56	56	57		
Klt	83	83	83	84		
Adn	72	74	62	62		

of 0.5N HCl-K were observed with every increase in K levels and at all levels of N. Among the soils, the Kivalur soil recorded the highest 0.5N HCl-K and the lowest value was observed in Valuthalakudi soil and the rest of the soils were in between. Almost similar trend of results were also observed at all levels of N.

4.2.2.4.2. Residual Crop (Table 69)

Increased 0.5N HCl-K was registered with N application, the highest being recorded by N_{50}, followed by N_{150} and N_{100} which were comparable. The control pots registered the lowest. This was also observed at K_{100} and K_{150} whereas at lower levels of K, the levels of N were not markedly different. The variation among the soils and the effect of K application individually and at different levels of N followed the same trend as observed in the first crop.

4.2.2.5. 0.01N HCl

4.2.2.5.1. First Crop (Table 70)

Application of N increased 0.01N HCl-K. At lower levels of K, this trend was true whereas at K_{150}, N_{50} recorded the highest value followed by, N_0 and N_{100} and N_{150} which were on par. The 0.01N HCl-K increased with every increase in the K levels and this was also observed irrespective of the soils and N levls. The Kilvalur soil

Table 68. Results of the statistical analysis of 0.5N HCl extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
153	157	157	156	0.8	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
148	155	159	163	0.8	2

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
164	171	126	153	146	1.3	3
Kvr	Mdk	Pkt	Klt	Adn		
199	140	135	173	155		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	144	150	156	163	1.6	3
N_{50}	146	154	160	167		
N_{100}	150	158	159	162		
N_{150}	151	156	159	160		

(Contd.,)

Table 68. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	157	162	168	167	2.6	5
Pdg	166	170	168	176		
Vld	120	125	130	128		
Skr	151	155	151	152		
Ndb	145	148	145	145		
Kvr	198	199	201	197		
Mdk	139	139	143	140		
Pkt	134	136	140	132		
Klt	169	177	171	176		
Adn	154	158	157	152		

Table 69. Results of the statistical analysis of the 0.5N HCl extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
124	128	126	126	0.71	1

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
122	124	127	131	0.71	1

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
128	131	97	129	120	1.13	2
Kvr	Mdk	Pkt	Klt	Adn		
159	110	109	149	128		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	120	120	126	131	1.4	3
N_{50}	121	127	130	134		
N_{100}	122	126	127	129		
N_{150}	124	126	126	130		

series recorded the highest 0.01N HCl-K and lower value was observed in Valuthalakudi soils at all levels of N and K. The N x soils series interaction also revealed that the 0.01N HCl-K increased with N application in Valuthalakudi, Sikar, Nedumbalam, Kalathur and Adanur soils. In the rest of the soil, the effect was not pronounced.

4.2.2.5.2. Residual Crop (Table 71)

Application of N increased the 0.01N HCl-K, the levels N_{100} and N_{150} being on a par were superior to the rest. Almost the same trend of result was observed in all the soils. The 0.01N HCl-K increased progrssively with the increase in the levels of K. The highest and the lowest 0.01N HCl-K were observed in the Kivalur and Valuthalakudi soils respectively and also at all levels of N.

4.2.2.6. 0.1N HNO_3-k

4.2.2.6.1. First Crop (Table 72)

Application of N increased the 0.1N HNO_3-K, the levels N_{50} and N_{100} being comparable were superior to control. At lower levels of K, N_{100} and N_{150} were comparable but superior to the rest, but at higher levels of K, N_{50} registered the highest 0.1N HNO_3-K. Increased 0.1N HNO_3-K with N application was observed in all soils excepting Padugai, where in the levels of N were not different. The 0.1 N HNO_3-K proportionately increased with increasing

Table 70. Results of the statistical analysis of the 0.01N HCl extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
34.76	35.57	35.54	35.65	0.23	0.45

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
32.85	34.41	36.23	38.43	0.23	0.45

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
30.66	42.91	22.76	37.84	36.67	0.36	0.72
Kvr	Mdk	Pkt	Klt	Adn		
49.25	27.53	29.60	43.01	34.57		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	31.60	32.62	35.98	38.85	0.45	0.91
N_{50}	32.56	34.72	36.61	39.98		
N_{100}	33.61	34.96	36.14	37.46		
N_{150}	33.63	35.33	36.20	37.43		

(Contd.,)

Table 70. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	31.45	31.35	30.20	29.62	0.72	1.40
Pdg	43.45	42.62	42.75	42.85		
Vld	22.37	24.05	22.62	21.97		
Skr	37.02	39.47	36.62	38.22		
Ndb	35.35	35.90	37.20	38.22		
Kvr	49.07	49.80	49.67	48.45		
Mdk	27.30	27.90	27.25	27.67		
Pkt	29.30	29.72	29.22	30.15		
Klt	38.85	44.10	44.00	45.10		
Adn	33.45	34.75	35.87	34.20		

6. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	27.77	29.67	31.67	33.50	0.72	1.40
Pdg	40.22	42.25	43.80	45.40		
Vld	20.65	21.17	23.80	25.40		
Skr	35.90	36.00	38.50	40.95		
Ndb	34.75	35.77	36.10	40.05		
Kvr	44.42	48.87	50.35	53.35		
Mdk	24.77	26.75	28.55	30.05		
Pkt	27.10	28.70	30.55	32.05		
Klt	40.90	41.60	43.35	46.20		
Adn	32.00	33.27	35.65	37.35		

Table 71. Results of the statistical analysis of the 0.01N HCl extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
21.58	21.67	22.55	22.17	0.20	0.40

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
21.27	21.85	22.01	22.84	0.2	0.40

3. Soil series

Knd	Pdg	Vld	Skr	Mdb	SE_D	CD
19.21	22.32	14.11	25.42	23.14	0.31	0.62
Kvr	Mdk	Pkt	Klt	Adn		
33.76	15.82	17.36	25.89	22.89		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	18.75	19.77	19.47	18.85	0.62	1.24
Pdg	23.12	21.72	23.20	21.25		
Vld	12.87	13.75	14.85	14.95		
Skr	24.75	24.92	26.05	25.95		
Mdb	22.35	23.17	23.35	23.70		
Kvr	33.75	32.75	35.05	33.47		
Mdk	15.35	16.70	16.00	15.22		
Pkt	15.80	16.52	18.92	18.20		
Klt	26.62	25.80	24.95	26.20		
Adn	22.40	21.62	23.67	23.87		

levels of K. This was true at all levels of N and in all soils. The Kivalur and Kalathur soils which were on a par, recorded higher 0.1N HNO_3 than the rest of the soils. The lowest was observed in Valuthalakudi soil. This was also true at all levels of N and K.

4.2.2.6.2. Residual Crop (Table 73)

Application of N at 150 $kg.ha^{-1}$ level recorded the highest 0.1N HNO_3-K followed by N_{50}, N_{100} and N_0 levels which were almost comparable. This was true in Pattukkottai soil alone. In the rest of the soils, except Padugai and Sikar soils, N application tended to increase 0.1N HNO_3-K. In Padugai and Sikar soils, the effect was not pronounced. The 0.1N HNO_3-K increased with every increase in the levels of K. This was almost true in Padugai, Valuthalakudi, Kivalur, Nedumbalam and Adanur soils. In the rest of the soils, the levels were comparable but superior to control. The Kivalur and Kalathur soils being on a par recorded the highest 0.1N HNO_3-K whereas the lowest value was observed in Valuthalakudi soils. This was also observed at all levels of N and K.

4.2.2.7. 0.5N HNO_3-K

4.2.2.7.1. First Crop (Table 74)

The straight effects of N, K and soils as well as the N x K and N x soils interaction followed almost the same trend of results as that of the 0.1N HNO_3-K.

Table 72. Results of the statistical analysis of the 0.1N HNO_3 extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
216	221	220	219	0.6	1

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
210	216	222	227	0.6	1

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
189	213	149	245	230	0.96	2
Kvr	Mdk	Pkt	Klt	Adn		
272	171	187	271	259		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	205	211	219	227	1.2	2
N_{50}	209	215	225	233		
N_{100}	214	218	222	225		
N_{150}	213	219	220	224		

(Contd.,)

Table 72. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	185	187	189	194	1.9	4
Pdg	212	213	215	213		
Vld	147	148	147	152		
Skr	234	246	254	245		
Ndb	227	233	227	237		
Kvr	272	275	270	270		
Mdk	170	174	172	170		
Pkt	182	198	187	185		
Klt	271	272	273	268		
Adn	254	261	262	260		

6. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	185	188	189	194	1.9	4
Pdg	206	212	216	218		
Vld	139	146	151	158		
Skr	239	239	248	254		
Ndb	219	226	232	241		
Kvr	263	268	277	283		
Mdk	161	169	176	179		
Pkt	178	184	190	195		
Klt	260	267	277	281		
Adn	250	255	263	269		

Table 73. Results of the statistical analysis of the 0.1N HNO_3 extractable K of soil in residual crop

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
154	156	155	157	0.61	1

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
151	155	157	160	0.61	1

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
120	128	84	180	170	1.2	3
Kvr	Mdk	Pkt	Klt	Adn		
215	112	138	212	197		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	117	122	118	123	2.5	5
Pdg	126	127	128	128		
Vld	85	81	84	86		
Skr	179	179	183	179		
Ndb	165	171	170	173		
Kvr	214	218	211	216		
Mdk	115	1112	109	114		
Pkt	137	136	134	145		
Klt	204	214	215	216		
Adn	194	197	201	195		

(Contd.,)

Table 73. (Contd.,)

5. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	113	119	122	126	2.5	5
Pdg	124	124	131	130		
Vld	81	81	84	89		
Skr	174	180	184	183		
Ndb	163	171	169	177		
Kvr	210	212	219	219		
Mdk	108	110	115	117		
Pkt	133	142	138	139		
Klt	207	212	211	216		
Adn	195	192	197	202		

4.2.2.7.2. Residual Crop (Table 75)

The 0.5N HNO_3-K increased with N application, the N_{150} registered the highest followed by N_{50} and N_{100} which were on a par and N_0. In Valuthalakudi, Kivalur, Sikar and Kalathur soils, this trend was seen whereas in the rest of the soils, its effect was not pronounced. Application of K in increasing levels increased the 0.5N HNO_3-K. The Kivalur and Valuthalakudi soils registered the highest and lowest values respectively at all levels of N.

4.2.2.8. 1N HNO_3-K

4.2.2.8.1. First crop (Table 76)

Application of N increased the 1N HNO_3-K, the levels being comparable but superior to control. This was also true to K_0 and K_{50} levels of application whereas at K_{150} level, N_{50} was superior over the rest of the levels. In Valuthalakudi, Kivalur, Madukkur and kalathur soils, N application increased the 1N HNO_3-K, whereas in Sikar , Nedumbalam and Adanur soils 50 kg level registered marginally higher values than the rest of the levels. In other soils, N application did not show any marked changes. Increasing levels of K increased and 1N HNO_3-K which was seen also at all levels of N. The Kivalur and Valuthalakudi soils registered the highest and lowest 1N HNO_3-K respectively. This was true at all levels of N.

Table 74. Results of the statistical analysis of the 0.5N HNO_3 extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
249	235	253	252	0.84	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
243	249	256	262	0.84	2

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
216	260	178	273	266	1.3	3
Kvr	Mdk	Pkt	Klt	Adn		
321	203	228	298	281		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	239	243	254	260	1.68	4
N_{50}	243	250	260	268		
N_{100}	244	251	257	263		
N_{150}	246	250	254	257		

Table 74. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	209	209	221	226	2.6	5
Pdg	256	266	261	257		
Vld	176	179	180	179		
Skr	262	272	279	277		
Ndb	267	267	265	265		
Kvr	319	325	319	320		
Mdk	196	210	204	202		
Pkt	221	228	232	228		
Klt	301	304	295	293		
Adn	280	292	277	277		

Table 75. Results of the statistical analysis of the 0.5N HNO_3 extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
179	181	181	183	0.9	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
177	181	182	185	0.9	2

3. Soils series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
131	172	118	194	192	1.4	8
Kvr	Mdk	Pkt	Klt	Adn		
249	135	148	235	236		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	133	134	128	129	2.8	6
Pdg	170	174	172	171		
Vld	115	117	117	123		
Skr	191	193	194	200		
Ndb	190	193	193	193		
Kvr	244	246	251	254		
Mdk	133	137	136	133		
Pkt	146	146	151	149		
Klt	232	236	231	240		
Adn	234	236	236	239		

4.2.2.8.2. Residual Crop (Table 77)

The levels of N being comparable registered higher 1N HNO_3-K than N_0 which however was on a par with N_{50}. The 1N HNO_3-K increased with K application, the levels being almost comparable. Among the soils, Kalathur and Kivalur soils, being on a par registered higher 1N HNO_3-K than the rest of the soils and the lowest value was observed in Valuthalakudi soil. This was also true at all levels of N. In Kondal, Kivalur, Nedumbalam and Adanur soils, N application did not show marked changes in 1N HNO_3-K, whereas in the rest of the soils it increased with the application of N.

4.2.2.9. 0.01N HNO_3-K

4.2.2.9.1. First Crop (Table 78)

Application of N_{50} recorded the highest 0.01N HNO_3-K followed by N_{100} and N_{150} which were comparable and N_0 registered the lowest value. Almost the same trend was observed at all levels of K and in all soils. In the absence of K, N_{150} recorded numerically higher 0.01N HNO_3-K than the rest of the levels. Application of K consistently increased the 0.01N HNO_3-K and this was true irrespective of the levels of N. Kalathur series registered the highest 0.01N HNO_3-K, whereas the lowest values were recorded in Madukkur and Valuthalakudi soils which were comparable. This was seen also at all the levels of N.

Table 76. Resulsts of the statistical analysis of the 1N HNO_3 extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
282	287	285	286	0.9	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
277	282	288	293	0.9	2

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
230	292	202	295	302	1.5	3
Kvr	Mdk	Pkt	Klt	Adn		
364	231	253	354	329		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	273	276	287	292	1.9	4
N_{50}	277	284	290	296		
N_{100}	278	284	288	291		
N_{150}	280	285	287	291		

(Contd.,)

Table 76. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	234	232	227	226	3.0	6
Pdg	291	290	292	295		
Vld	197	203	202	205		
Skr	295	300	292	293		
Ndb	290	309	307	300		
Kvr	362	366	367	360		
Mdk	232	228	227	237		
Pkt	251	254	253	255		
Klt	341	356	361	358		
Adn	329	332	325	328		

Table 77. Results of the statistical analysis of the 1N HNO_3 extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
203	205	206	208	1.54	3

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
203	204	206	208	1.54	3

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
159	202	135	215	217	2.4	5
Kvr	Mdk	Pkt	Klt	Adn		
269	156	180	269	252		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	157	160	158	160	4.9	10
Pdg	195	197	203	212		
Vld	132	149	130	127		
Skr	218	221	211	209		
Ndb	219	218	213	217		
Kvr	267	271	265	271		
Mdk	219	218	213	217		
Pkt	171	172	187	191		
Klt	264	262	274	277		
Adn	255	247	257	250		

Table 78. Results of the statistical analysis of the $0.01N\ HNO_3$ extractable K of soil in first crop (pp

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
93	98	97	96	0.65	1

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
91	95	98	101	0.65	1

3. Soils series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
93	97	68	105	100	1.0	2
Kvr	Mdk	Pkt	Klt	Adn		
115	66	69	127	118		

4. Nitrogen x potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	89	91	94	99	1.3	3
N_{50}	90	97	100	105		
N_{100}	91	96	99	99		
N_{150}	92	92	97	99		

(Contd.,)

Table 78. (Contd.,)

5. <u>Nitrogen x Soils interaction</u>

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	92	89	95	95	2.1	4
Pdg	96	97	101	95		
Vld	60	69	68	75		
Skr	104	111	105	102		
Ndb	97	104	100	98		
Kvr	108	118	118	118		
Mdk	63	69	63	65		
Pkt	76	70	64	67		
Klt	123	129	128	129		
Adn	113	123	118	117		

Table 79. Results of the statistical analysis of the 0.01N HNC extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
69.0	69.4	72.5	71.5	0.3	0.6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
68.3	69.4	72.3	72.6	0.3	0.60

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
65.9	79.6	43.4	76.6	75.5	0.9	1.7
Kvr	Mdk	Pkt	Klt	Adn		
84.8	48.7	56.2	96.0	79,6		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	67.0	68.1	69.7	71.4	1.1	2.2
N_{50}	67.8	67,8	70.4	71.8		
N_{100}	68.6	70.6	74.5	76.3		
N_{150}	69.6	71.0	72.4	73.1		

(Contd.,)

Table 79. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	63.5	65.5	65.5	69.5	1.7	3.5
Pdg	74.3	78.8	82.5	82.8		
Vld	40.3	47.8	45.5	40.3		
Skr	76.8	75.3	79.3	75.3		
Ndb	76.0	73.8	77.8	74.5		
Kvr	79.5	83.8	88.3	87.5		
Mdk	50.0	45.8	51.8	47.3		
Pkt	57.3	55.0	57.8	54.8		
Klt	93.3	93.8	96.0	101.0		
Adn	79.8	75.3	80.8	82.8		

6. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	64.3	64.5	68.0	67.0	1.7	3.5
Pdg	75.5	78.3	82.0	82.0		
Vld	40.5	39.5	46.0	47.8		
Skr	72.8	78.5	76.3	79.0		
Ndb	71.5	74.8	78.0	77.8		
Kvr	83.0	82.5	86.3	87.3		
Mdk	47.0	46.0	50.5	51.3		
Pkt	53.3	56.3	57.0	58.3		
Klt	96.0	96.3	98.0	93.8		
Adn	78.8	78.5	80.8	81.8		

4.2.2.9.2. Residual Crop (Table 79)

Application of N increased the 0.01N HNO_3-K, the N_{100} level recorded the highest value followed by N_{150}, N_{50} and N_0 the latter two were on a par. Almost the same trend was observed at all levels of K and in most of the soils except Kondal and Kalathur soils where in N_{150} was superior over the rest of the levels. The 0.01N HNO_3-K increased with increasing levels of K and this effect was also observed at all levels of N and in all soils except Adanur wherein the change was not marked. The soils followed the same trend as in the first crop at all levels of N and K.

4.2.2.10. 6N H_2SO_4-K

4.2.2.10.1. First Crop (Table 80)

The K extracted by 6N H_2SO_4 increased with N application, the levels N_{150} and N_{100} being on a par registered the highest value followed by N_{50} and N_0 . Almost the same trend was observed in most of the soils except Madukkur soil, where in N_{50} was superior over the rest and in Kondal and Valuthalakudi soils, N application did not result in marked changes. The results of K application and soils followed the same trend as observed in 0.01N HNO_3-K.

Table 80. Results of the statistical analysis of the 6N H_2SO_4 extractable K of soil in first crop (ppm)

1. <u>Nitrogen levels</u>

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
220	226	228	229	0.9	2

2. <u>Potassium levels</u>

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
218	228	229	232	0.9	2

3. <u>Soil series</u>

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
216	258	161	234	229	1.45	3
Kvr	Mdk	Pkt	Klt	Adn		
264	173	192	278	251		

4. <u>Nitrogen x Soils interaction</u>

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	216	218	215	213	2.9	6
Pdg	242	247	260	282		
Vld	159	162	163	160		
Skr	229	234	235	239		
Ndb	229	225	234	229		
Kvr	250	269	271	264		
Mdk	171	179	170	169		
Pkt	185	191	193	198		
Klt	270	279	282	280		
Adn	244	250	256	254		

Table 81. Results of the statistical analysis of the 6N H_2SO_4 extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
152	153	155	156	0.85	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
151	154	154	155	0.85	2

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
160	173	95	177	156	1.35	3
Kvr	Mdk	Pkt	Klt	Adn		
186	98	115	199	178		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	165	159	159	158	2.70	5
Pdg	169	167	175	180		
Vld	95	99	92	94		
Skr	168	181	179	180		
Ndb	157	155	156	155		
Kvr	187	185	187	184		
Mdk	98	95	98	102		
Pkt	157	155	156	155		
Klt	193	196	200	208		
Adn	174	180	182	177		

4.2.2.10.2. Residual Crop (Table 81)

The effects of N, K and soils followed almost the same trend as in the first crop excepting that in Kivalur and Nedumbalam soils, the effect of N was not well pronounced.

4.2.2.11. 0.5N EDTA-K

4.2.2.11.1. First Crop (Table 82)

Application of 50 kg. N ha^{-1} level recorded the highest 0.5N EDTA-K followed by N_0, N_{100}, N_{150} levels. Almost the same trend was observed at all levels of K irrespective of the soils. Increasing levels of K increased the 0.5N EDTA-K and this trend was also seen at lower levels of N. At higher levels of N, the effect of K was not well pronounced. Kivalur series registered the highest 0.5N EDTA-K and the lowest value was observed in Valuthalakudi soil. This was true also at all levels of N.

4.2.2.11.2. Residual Crop (Table 83)

Increase in 0.5N EDTA-K was recorded with N application and in most of the soils except Nedumbalam, Pattukkottai and Adanur series where in its effect was not pronounced. The soils and K behaved similar to their effect as observed in the first crop.

Table 82. Results of the statistical analysis of the 0.5N EDTA extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
66.8	69.1	63.3	61.6	0.52	1.0

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
63.4	65.0	65.3	67.0	0.50	1.0

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
63.9	73.1	45.7	73.6	72.1	0.58	1.2
Kvr	Mdk	Pkt	Klt	Adn		
82.7	49.2	54.2	74.9	62.6		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	63.7	66.7	67.0	69.9	0.7	1.5
N_{50}	64.9	67.5	70.4	73.5		
N_{100}	62.6	64.5	63.2	63.1		
N_{150}	62.4	61.5	60.8	61.7		

(Contd.,)

Table 82. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	64.7	70.2	62.0	58.5	1.2	2.3
Pdg	75.5	74.7	71.0	71.0		
Vld	44.2	49.7	45.5	43.5		
Skr	76.2	75.5	70.5	72.2		
Ndb	69.5	74.2	72.2	72.2		
Kvr	88.5	89.2	81.5	76.7		
Mdk	53.2	53.0	46.5	44.0		
Pkt	57.0	56.2	52.2	51.5		
Klt	79.7	79.0	72.7	68.2		
Adn	64.5	68.7	59.2	58.0		

Table 83. Results of the statistical analysis of the 0.5N EDT extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
43.4	44.8	46.6	46.4	0.49	1.0

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
43.9	45.2	45.5	46.7	0.49	1.0

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
44.6	52.3	34.5	52.8	43.6	0.78	1.6

Kvr	Mdk	Pkt	Klt	Adn
61.6	34.6	35.6	54.0	39.5

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	42.8	45.0	44.3	46.3	1.56	3.1
Pdg	50.3	51.8	54.0	53.0		
Vld	33.5	34.0	34.8	38.3		
Skr	48.3	53.5	56.3	53.8		
Ndb	45.0	42.8	43.5	43.0		
Kvr	58.5	60.5	64.0	64.0		
Mdk	30.8	33.5	37.0	37.0		
Pkt	34.5	35.8	36.3	36.0		
Klt	54.0	53.5	56.0	52.5		
Adn	39.5	37.8	40.3	40.5		

4.2.2.12. 0.01M $CaCl_2$-K

4.2.2.12.1. First Crop (Table 84)

The effect of N and K application and soils were similar to that observed with 0.5N EDTA-K and the effect of N application was also true irrespective of the levels of K and soils.

4.2.2.12.2. Residual Crop (Table 85)

The individual effects of N and K and their interactions followed the same trend as observed in 0.5N EDTA-K. Among the soils, Kalathur and Valuthalakudi soils registered the highest and the lowest values of 0.01M $CaCl_2$-K respectively and at all levels of N except at N_{150} where in Adanur series was superior to the rest of the soils. In the absence of K, Adanur and Kondal soil series being comparable recorded higher 0.01M $CaCl_2$-K, the latter was also on a par with Kalathur soil series. In the presence of K, Kalathur soil was superior over the rest of the soils and the lowest value was observed in Valuthalakudi soils at all levels of K. Application of K increased the 0.01M $CaCl_2$-K irrespective of the soils.

4.2.2.13. Bray's - K

4.2.2.13.1. First Crop (Table 86)

Application of N in increasing levels increased the Bray's-K. At lower levels of K, higher levels of N were

Table 84. Results of the statistical analysis of the 0.01M $CaCl_2$ extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
41.1	43.7	41.0	38.4	0.3	0.6

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
38.2	40.3	41.8	43.9	0.3	0.6

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
38.6	46.1	22.4	50.5	42.7	0.47	0.9
Kvr	Mdk	Pkt	Klt	Adn		
54.4	30.8	33.8	47.9	43.6		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	37.4	40.4	42.0	44.8	0.59	1.2
N_{50}	40.2	42.0	45.0	47.6		
N_{100}	38.5	40.7	41.7	43.0		
N_{150}	36.9	38.1	38.7	40.1		

(Contd.,)

Table 84. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	38.5	40.0	40.0	35.7	0.9	1.9
Pdg	46.2	50.2	44.5	43.2		
Vld	25.0	25.3	20.8	18.7		
Skr	49.7	53.7	49.7	48.7		
Ndb	43.7	45.7	42.0	39.2		
Kvr	52.7	58.5	55.0	51.2		
Mdk	32.2	31.5	31.2	28.2		
Pkt	33.0	36.2	34.0	32.0		
Klt	48.5	49.0	48.5	45.5		
Adn	41.7	46.7	44.0	41.7		

Table 85. Results of the statistical analysis of the 0.01M CaC: extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
21.85	23.15	20.15	18.80	0.04	0.09

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
19.45	20.52	21.62	22.35	0.04	0.09

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
22.62	21.81	13.31	22.19	20.87	0.07	0.13
Kvr	Mdk	Pkt	Klt	Adn		
22.37	16.37	19.31	26.00	25.00		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	20.20	20.90	22.80	23.50	0.09	0.17
N_{50}	20.50	22.90	23.90	25.30		
N_{100}	19.00	19.70	20.50	21.40		
N_{150}	18.20	18.60	19.30	19.20		

(Contd.,)

Table 85. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	23.25	22.00	23.50	21.75	0.14	0.27
Pdg	22.75	24.25	20.25	20.00		
Vld	11.75	17.00	12.25	12.25		
Skr	23.75	24.00	21.00	20.00		
Ndb	21.50	23.00	20.00	19.00		
Kvr	23.75	26.25	21.00	18.50		
Mdk	16.25	18.00	17.00	14.25		
Pkt	20.25	21.00	18.00	18.00		
Klt	29.00	29.50	24.50	23.25		
Adn	26.25	26.50	24.00	23.25		

6. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	22.75	23.50	22.50	21.75	0.14	0.27
Pdg	22.00	20.50	21.50	23.25		
Vld	13.50	14.00	14.50	11.25		
Skr	20.50	21.50	22.75	24.00		
Ndb	18.50	20.00	22.00	23.00		
Kvr	20.25	21.75	28.25	24.25		
Mdk	14.00	16.50	18.00	17.00		
Pkt	17.50	17.75	20.00	22.00		
Klt	22.50	25.00	26.75	29.75		
Adn	23.00	24.75	25.00	27.25		

comparable than the lower levels of N in increasing Bray's-K whereas almost all the levels of N were comparable but superior to control at higher levels of K. In all the soils except Valuthalakudi, N application increased the Bray's-K. Increased Bray's K was observed with every increase in K levels irrespective of the levels of N. The highest Bray's-K was observed in Kivalur soil series and the lowest in Valuthalakudi soil which was also true at all levels of N.

4.2.2.13.2. Residual Crop (Table 87)

Increasing levels of N application increased the Bray's-K and this was observed in all soils except Kondal, Padugai, Valuthalakudi, Nedumbalam, Kalathur and Adanur soils, where in its effect was not marked. The soils and K behaved similar to their effect in the first crop.

4.2.2.14. Morgan's-K

4.2.2.14.1. First Crop (Table 88)

Increasing levels of N and K correspondingly increased the Morgan's-K. This was also observed in their interactions. Kivalur and Valuthalakudi soils recorded the highest and the lowest values of Morgan's-K respectively at all levels of N. The effect of N application in increasing Morgan's-K was also observed in all soils.

Table 86. Results of the statistical analysis of Bray's reagent extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
41.6	45.3	46.6	46.8	0.4	0.8

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
41.2	44.0	46.3	48.7	0.4	0.8

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
40.5	45.6	26.6	50.7	52.6	0.6	1.3
Kvr	Mdk	Pkt	Klt	Adn		
61.5	33.4	38.4	54.9	46.6		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	38.9	40.1	42.1	45.2	0.8	1.6
N_{50}	40.2	43.6	47.2	50.2		
N_{100}	41.6	45.6	48.5	50.6		
N_{150}	44.1	46.9	47.4	48.9		

(Contd.,)

Table 86. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	38.7	40.5	43.0	39.7	1.3	2.6
Pdg	40.0	48.7	46.5	47.0		
Vld	25.7	26.5	26.2	27.7		
Skr	48.7	51.2	52.7	50.2		
Ndb	49.7	53.2	53.0	54.5		
Kvr	57.5	61.0	63.5	64.0		
Mdk	30.5	34.2	33.0	35.7		
Pkt	35.0	37.0	40.0	41.5		
Klt	45.5	54.5	59.8	59.8		
Adn	44.2	46.0	48.0	48.0		

Table 87. Results of the statistical analysis of Bray's reagent extractable K of soil in residual crop (ppm

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
23.02	24.15	24.72	25.92	0.55	1.10

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
23.25	24.52	24.82	25.22	0.55	1.10

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
22.56	32.87	13.25	25.19	24.87	0.87	1.70
Kvr	Mdk	Pkt	Klt	Adn		
34.56	20.25	19.75	26.50	24.75		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	22.75	22.00	21.50	24.00	1.74	3.50
Pdg	31.25	32.75	32.75	34.75		
Vld	14.00	13.00	13.00	13.00		
Skr	24.25	27.25	25.75	23.50		
Ndb	25.50	24.50	24.00	25.50		
Kvr	32.00	34.75	33.75	35.75		
Mdk	13.75	17.75	23.00	26.50		
Pkt	17.50	18.50	19.50	23.50		
Klt	25.50	26.25	26.75	27.50		
Adn	23.75	24.75	25.25	25.25		

Table 88. Results of the statistical analysis of Morgan's reagent extractable K of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
37.57	39.92	41.97	42.97	0.38	0.75

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
36.65	39.70	41.60	44.50	0.38	0.75

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
40.94	42.50	23.69	51.50	43.94	0.60	1.20
Kvr	Mdk	Pkt	Klt	Adn		
54.19	25.56	33.87	45.62	44.31		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	33.90	38.00	37.30	41.10	0.75	1.50
N_{50}	35.80	38.50	41.40	44.00		
N_{100}	37.60	40.40	43.30	46.60		
N_{150}	39.30	41.90	44.40	46.30		

(Contd.,)

Table 88. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	35.25	40.50	43.50	44.50	1.19	2.40
Pdg	40.00	41.50	44.50	44.00		
Vld	20.50	23.25	25.50	25.50		
Skr	45.25	50.50	54.25	56.00		
Ndb	41.00	42.50	46.00	46.25		
Kvr	30.50	31.75	33.75	37.50		
Mdk	26.25	26.50	24.00	25.50		
Pkt	30.50	31.75	35.75	37.50		
Klt	44.25	44.50	47.00	46.75		
Adn	41.25	44.25	43.50	48.25		

Table 89. Results of the statistical analysis of Morgan's reagent extractable K of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
19.12	20.35	20.55	21.17	0.456	0.91

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
19.10	20.30	20.37	21.45	0.456	0.91

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
23.87	23.62	11.87	24.05	19.44	0.72	1.43
Kvr	Mdk	Pkt	Klt	Adn		
26.06	12.44	13.81	23.94	23.44		

4.2.2.14.2. Residual Crop (Table 89)

Application of N increased the Morgan's-K, the levels being comparable were superior to control. There was increase in the value of Morgan's K with every increase in the levels of K application. Kivalur soil series registered the highest Morgan's-K and the Valuthalakudi soil which was comparable to Madukkur soil recorded lower values than the rest of the soils.

4.2.3. Quantity/Intensity Parameters of K

The Q/I curve of the initial soils are presented in Fig.6, 7 and 8.

4.2.3.1. Equilibrium Activity Ratio of K (AR_e^K)

The AR_e^k values of different soils as affected by cropping are presented in Table 90.

The results indicated that the AR_e^K values ranged from $3.25 \times 10^{-3} (m.1^{-1})^{\frac{1}{2}}$ (Kondal soil series) to 6.50×10^{-3} (Kivalur soil series) before cropping and from 2.90×10^{-3} (Adanur soil series) to 7.00×10^{-3} (Pattukkottai soil series) after the first crop and from 2.70×10^{-3} (Adanur soil series) to 7.50×10^{-3} (Pattukkottai soil series) after the residual crop. The mean values indicated that among the soils, the highest AR_e^K values were registered by Pattukkottai soil followed by Kivalur and Nedumbalam

FIG. 6 Q/I CURVE OF THE INITIAL SOILS

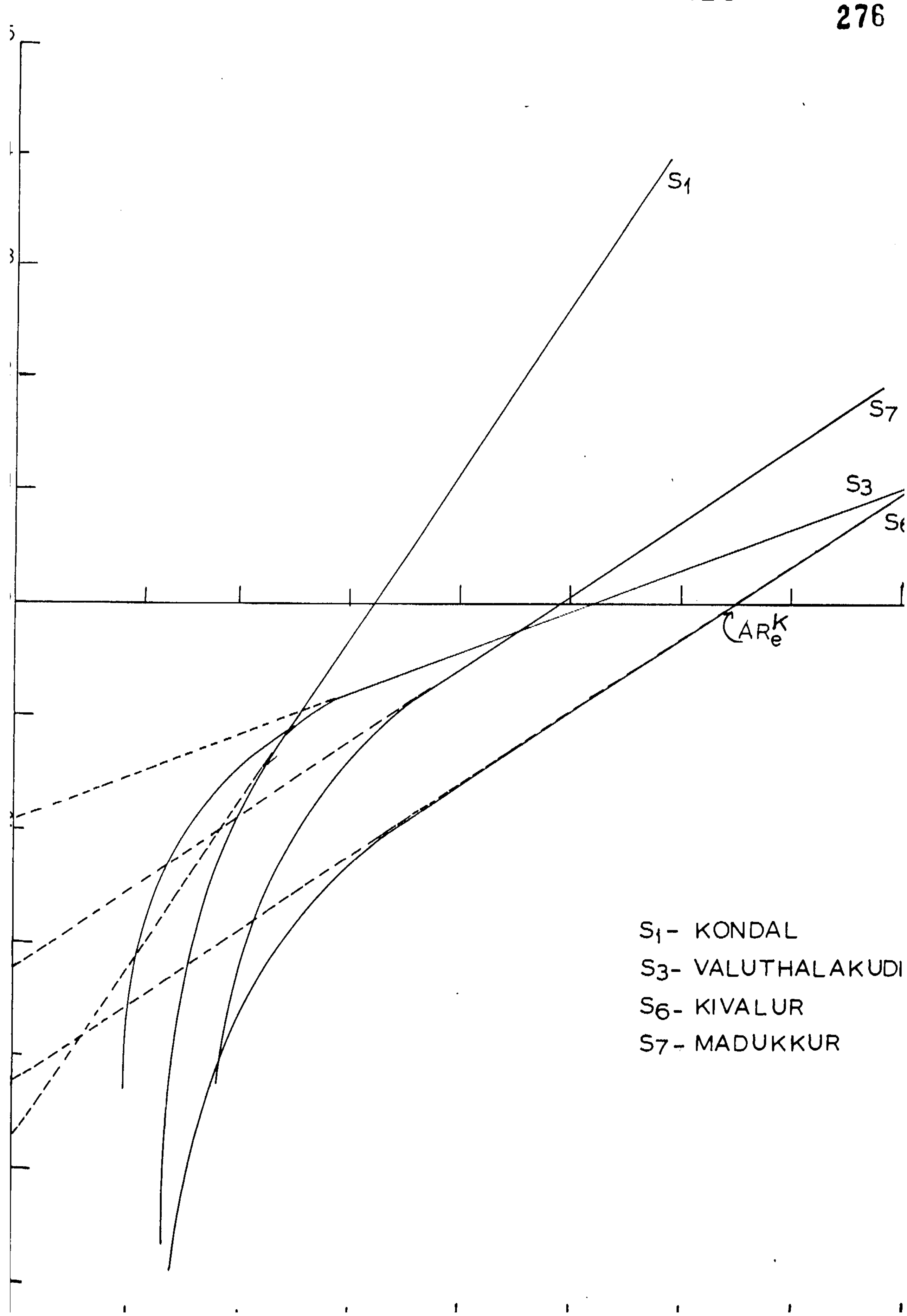
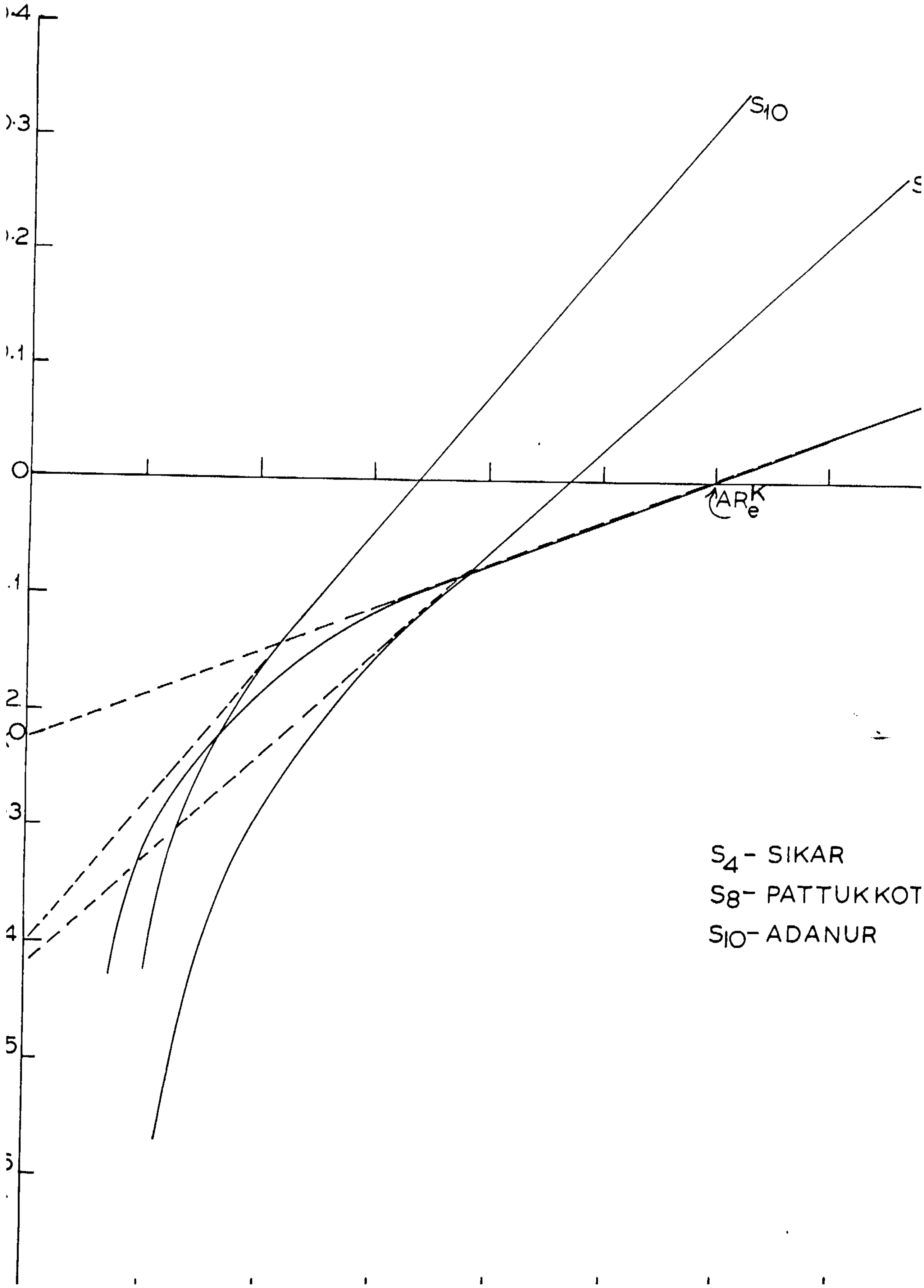


FIG. 7 Q/I CURVE OF THE INITIAL SOILS



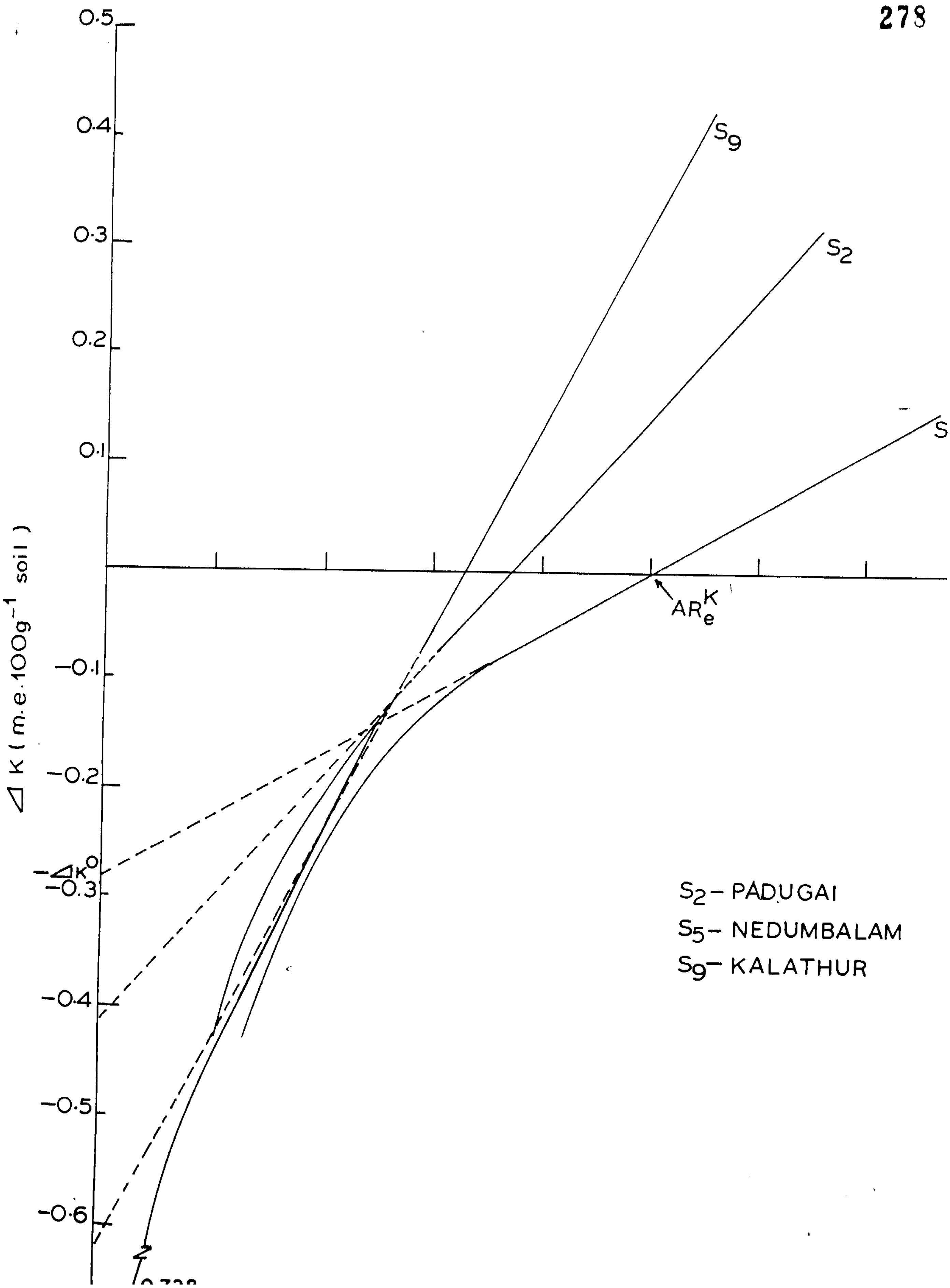

0.5
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
$-\Delta K^0$
ΔK (m.e.100g^{-1} soil)
S_9
S_2
S
AR_e^K
S_2 – PADUGAI
S_5 – NEDUMBALAM
S_9 – KALATHUR

Table 90. Results of the statistical analysis of the Equilibri
Activity Ratio of Potassium in soil $(m \cdot l^{-1})^{1/2} \times 10^{-3}$

Soil series	Before cropping	After Kuruvai crop	After Residual crop	Mean
Knd	3.25	3.25	3.00	3.17
Pdg	3.70	3.25	3.05	3.33
Vld	5.20	3.35	4.50	4.35
Skr	4.75	4.65	4.05	4.48
Ndb	5.00	4.85	5.40	5.08
Kvr	6.50	5.45	5.15	5.70
Mdk	4.90	4.80	3.80	4.50
Pkt	6.00	7.00	7.50	6.83
Klt	3.30	3.35	3.75	3.47
Adn	3.40	2.90	2.70	3.00
Mean	4.60	4.28	4.29	

	SE_D	CD
Soil series	0.43	0.91
Cropping	NS	--

soils which were comparable. Adanur soil series which was on par with Kondal, Padugai and Kalathur recorded the lowest AR_e^K value. There was no marked reduction in the AR_e^K values with cropping.

4.2.3.2. Labile K ($-\Delta K^o$) (Table 91)

The results indicated that the labile K values ranged from 0.190 (Valuthalakudi soil series) to 0.625 (Kalathur soil series) m.e.100 g^{-1} before cropping and from 0.145 (Pattukkottai soil series) to 0.625 (Kalathur soil series) after the first crop and from 0.145 (Pattukkottai soil series) to 0.525 (Kalathur soil series) after the residual crop. The mean values of labile K indicated that Kalathur soil series recorded the highest labile K value followed by Sikar, Adanur, Kondal, Kivalur and Padugai soils which were comparable. The Pattukkottai and Valuthalakudi soils being on a par registered the lowest $-\Delta K^o$ values. The Madukkur and Nedumbalam soil series were comparable and superior to Pattukkottai and Valuthalakudi soils. The $-\Delta K^o$ values showed a decreasing trend with cropping.

4.2.3.3. Potential Buffering Capacity of K (PBC^K) (Table 92)

The values of PBC^K ranged from 37 to 189 before cropping and from 21 to 187 after the first crop and from 19 to 140 after the residual crop. Kalathur soil series recorded the highest value of PBC^K followed by Adanur, Kondal and

Table 91. Results of the statistical analysis of the labile K content ($-\Delta K_o$) of the soil ($m.e \cdot 100g^{-1}$)

Soil series	Before cropping	After Kuruvai crop	After Residual crop	Mean
Knd	0.470	0.345	0.335	0.383
Pdg	0.415	0.375	0.355	0.382
Vld	0.190	0.170	0.200	0.187
Skr	0.420	0.395	0.425	0.413
Ndb	0.285	0.335	0.325	0.315
Kvr	0.425	0.380	0.345	0.383
Mdk	0.325	0.355	0.250	0.310
Pkt	0.225	0.145	0.145	0.172
Klt	0.625	0.625	0.525	0.592
Adn	0.405	0.405	0.375	0.395
Mean	0.378	0.353	0.328	

	SE_D	CD
Soil series	0.029	0.062
Cropping	0.016	0.034

Padugai which were on a par and the least were in Pattukkottai and Valuthalakudi series which were also on a par. There was no reduction in the PBC^K values due to cropping.

4.2.3.4. Free Energy (ΔG) (Table 93)

The values of ΔG ranged from -3032 (Kivalur soil series) to -3427 (Kondal soil series) before cropping and from -3036 (Kalathur soil series) to -3495 (Adanur soil series) after the first crop and from -2927 (Pattukkottai soil series) to -3538 (Adanur soil series) after the residual crop. The cropping did not change the ΔG values markedly. Among the soils, higher values of ΔG were recorded by Adanur, Kondal and Padugai soils which were comparable. The Kivalur, Pattukkottai, Nedumbalam and Madukkur soils which were on a par recorded the lowest ΔG values.

4.2.4. Results of the Correlation Studies made between Q/I Parameters and Soil Parameters (Table 94)

The results of simple correlations made indicated that the AR_e^K values were related to per cent fine sand only and negatively to per cent clay. The $-\Delta K^o$ values were related to per cent clay, total K, organic carbon and CEC whereas it was negatively related to per cent fine sand and

Table 93. Results of the statistical analysis of the free energy (ΔG) (-calories$\cdot$mole^{-1})

Soil series	Before cropping	After Kuruvai crop	After Residual crop	Mean
Knd	3427	3427	3475	3443
Pdg	3350	3427	3465	3414
Vld	3145	3409	3232	3262
Skr	3200	3215	3295	3237
Ndb	3169	3188	3123	3160
Kvr	3032	3118	3152	3101
Mdk	3182	3194	3334	3237
Pkt	3060	3383	2927	3123
Klt	3418	3036	3342	3265
Adn	3400	3495	3538	3478
Mean	3238	3289	3288	

	SE_D	CD
Soil series	98	206
Cropping	NS	--

Table 94. Results of the correlation studies made between Q/I Parameters and soil properties (n = 10)

S.No.	X	Y	'r'	Regression equation
1.	% clay	AR_e^K	-0.580^{*}	Y=0.00664-0.00065x
2.	% clay	$-\Delta K^o$	0.810^{**}	Y=0.0486+0.00886x
3.	% clay	PBC^K	0.775^{**}	Y=-19.0+3.17x
4.	% clay	ΔG	0.324^{NS}	---
5.	% Silt	AR_e^K	-0.456^{NS}	---
6.	% Silt	$-\Delta K^o$	0.440^{NS}	---
7.	% Silt	PBC^K	0.452^{NS}	---
8.	% Silt	ΔG	0.406^{NS}	---
9.	% Fine sand	AR_e^K	0.7006^{**}	Y=0.00205+0.00011x
10.	% Fine sand	$-\Delta K^o$	-0.668^{*}	Y=0.572 - 0.01 x
11.	% Fine sand	PBC^K	-0.824^{**}	Y = 191 - 4.6 x
12.	% Fine sand	ΔG	-0.630^{*}	Y = 3502 - 10.5x
13.	% Coarse sand	AR_e^K	0.480^{NS}	---
14.	% Coarse sand	$-\Delta K^o$	-0.779^{**}	Y = 0.572-0.011x
15.	% Coarse sand	PBC^K	-0.614^{*}	Y = 144 - 3.33x
16.	% Coarse sand	ΔG	-0.180^{NS}	---
17.	% Total K	AR_e^K	-0.170^{NS}	---

(Contd.,)

Table 94. (Contd.,)

18.	Total K	$-\Delta K^{o}$	0.752^{**}	Y = 0.055+0.204x
19.	Total K	PBC^{K}	0.665^{*}	Y = -8.68+67.6x
20.	Total K	ΔG	0.01^{NS}	---
21.	Organic carbon	AR_{e}^{K}	-0.15^{NS}	---
22.	Organic carbon	$-\Delta K^{o}$	0.717^{*}	Y = 0.174+0.33x
23.	Organic carbon	PBC^{K}	0.565^{*}	Y = 37.25+98.2x
24.	Organic carbon	ΔG	0.09^{NS}	---
25.	Cation exchange capacity	AR_{e}^{K}	-0.418^{NS}	---
26.	Cation exchage capacity	$-\Delta K^{o}$	0.815^{**}	Y = 0.095+0.012x
27.	Cation exchange capacity	PBC^{K}	0.745^{**}	Y = 1.73+4.23x
28.	Cation exchange capacity	ΔG	0.25^{NS}	---

coarse sand. The PBC^K values were related to per cent clay, total K, organic carbon and CEC. It was negatively correlated to per cent fine sand and coarse sand.

4.2.5. Fractions of K

4.2.5.1. Water Soluble K

4.2.5.1.1. First Crop (Table 95)

Application of N at lower levels increased the water soluble K whereas at higher levels of N, this fraction decreased. Almost the same trend was observed irrespective of the soils and K levels. This fraction consistently increased with every increase in K level irrespective of the levels of N and soils. At all legels of N and K, the Kivalur soil series recorded the highest water soluble K and the lowest value was in Valuthalakudi soil.

4.2.5.1.2. Residual Crop (Table 96)

Application of N_{50} recorded higher water soluble K than higher levels of N which were also comparable with N_0. Application of K increased the water soluble K, though the levels were comparable. Kivalur series recorded the highest water soluble K fraction, and the least was in Kalathur, Adanur, Madukkur and Valuthalakudi soils which were comparable. Almost the same trend could be seen irrespective of the levels of N. The influence of N was not pronounced in six out of ten soils. In Pattukkottai, Kondal, Kivalur and Sikar soils, N application increased water soluble K fraction.

Table 95. Results of the statistical analysis of the water soluble K fraction of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
14.77	16.00	14.35	13.67	0.17	0.34

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
12.47	14.30	15.47	16.55	0.17	0.34

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
14.50	17.19	9.37	15.87	14.81	0.27	0.54
Kvr	Mdk	Pkt	Klt	Adn		
21.06	12.37	12.56	15.44	13.81		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	12.70	14.00	15.40	17.00	0.35	0.69
N_{50}	13.20	15.80	16.60	18.40		
N_{100}	12.20	13.90	15.20	16.10		
N_{150}	11.80	13.50	14.70	14.70		

(Contd.,)

Table 95. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	15.00	15.25	15.00	12.75	0.55	1.10
Pdg	17.50	18.75	16.25	16.25		
Vld	9.50	10.00	9.00	9.00		
Skr	17.50	17.00	14.25	14.75		
Ndb	13.50	17.00	14.75	14.00		
Kvr	20.00	22.00	22.25	20.00		
Mdk	11.25	13.75	12.75	11.75		
Pkt	12.50	13.75	12.00	12.00		
Klt	16.50	17.00	14.25	14.00		
Adn	14.50	15.50	13.00	12.25		

6. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	11.75	14.50	15.75	16.00	0.55	1.10
Pdg	14.50	17.25	17.75	19.25		
Vld	8.25	9.25	9.75	10.25		
Skr	13.50	16.50	16.00	17.50		
Ndb	13.00	15.00	15.00	16.25		
Kvr	19.00	19.75	22.00	23.50		
Mdk	10.50	11.50	13.75	13.75		
Pkt	10.00	12.25	13.50	14.50		
Klt	12.00	14.25	16.50	19.00		
Adn	12.25	12.75	14.50	15.75		

Table 96. Results of the statistical analysis of the water soluble K fraction in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
9.92	10.45	9.85	9.65	0.27	0.54

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
9.20	9.80	10.22	10.65	0.27	0.54

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
10.60	12.31	8.06	11.50	10.06	0.43	0.85
Kvr	Mdk	Pkt	Klt	Adn		
15.44	7.75	9.25	7.50	7.73		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	10.75	11.25	9.25	9.00	0.86	1.70
Pdg	11.75	12.75	12.75	12.00		
Vld	8.25	8.25	7.75	8.00		
Skr	12.00	12.50	10.75	10.75		
Ndb	9.50	10.75	10.25	9.75		
Kvr	16.75	16.25	15.00	13.75		
Mdk	7.25	8.50	7.75	7.50		
Pkt	7.50	8.50	9.50	11.50		
Klt	7.75	8.25	7.25	6.75		
Adn	7.75	7.50	8.25	7.50		

4.2.5.2. Exchangeable K

4.2.5.2.1. First Crop (Table 97)

The exchangeable K fraction increased with every increase in the levels of N. This was almost true irrespective of the levels of K and soils excepting Madukkur and Adanur soils where in the trend was not pronounced. The exchangeable K increased with the application K at all levels of N. Kivalur series recorded the highest exchangeable K and the lowest was in Valuthalakudi soil. This was true at all levels of N.

4.2.5.2.2. Residual Crop (Table 98)

Application of K enhanced the exchangeable K content of the soil, the levels being on a par, were superior to control. This trend was true only in the absence of N. In the presence of N, the effect of K was not pronounced. Kivalur and Kalathur soils being comparable recorded the highest value and least was in Valuthalakudi soil. At all levels of N, this could be seen. The effect of N in increasing the exchangeable K was seen in Kivalur and Pattukkottai soils alone.

4.2.5.3. Non-exchangeable K

4.2.5.3.1. First Crop (Table 99)

Application of K increased the non-exchangeable K, the levels being comparable were superior to control. Kalathur series possessed the highest non-exchangeable K,

Table 97. Results of the statistical analysis of the exchangeable K fraction of the soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
219	221	224	226	0.77	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
215	219	226	230	0.77	2

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
200	229	134	260	238	1.2	2
Kvr	Mdk	Pkt	Klt	Adn		
281	173	188	270	251		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	210	213	223	229	1.54	3
N_{50}	213	219	225	227		
N_{100}	218	222	227	230		
N_{150}	220	223	228	233		

(Contd.,)

Table 97. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	198	196	202	203	2.4	5
Pdg	227	228	229	233		
Vld	131	132	136	138		
Skr	250	256	267	269		
Ndb	229	239	241	242		
Kvr	274	273	286	291		
Mdk	171	172	175	175		
Pkt	183	189	188	191		
Klt	271	275	266	266		
Adn	254	250	250	251		

Table 98. Results of the statistical analysis of the exchangeable K fraction of soil in residual crop (ppm)

1. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
176	179	180	181	0.89	2

2. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
149	172	92	216	190	1.4	3
Kvr	Mdk	Pkt	Klt	Adn		
238	126	157	236	213		

3. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	172	180	181	182	1.8	4
N_{50}	175	178	179	182		
N_{100}	177	179	179	181		
N_{150}	179	178	180	181		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	147	149	149	151	2.8	6
Pdg	174	169	172	173		
Vld	94	92	91	90		
Skr	215	216	217	215		
Ndb	192	190	188	187		
Kvr	232	238	240	242		
Mdk	131	123	124	127		
Pkt	151	158	159	160		
Klt	239	237	236	234		
Adn	212	212	215	214		

and the lowest was in Valuthalakudi soil. This trend was also observed at all levels of N. The effect of N was not well pronounced in any of the soils.

4.2.5.3.2. Residual Crop (Table 100)

Almost the same trend of results were obtained in the residual crop with the application of K and among the soils as the first crop. Application of N tended to increase this fraction, the levels being comparable were superior to control.

4.2.6. Fractions of N

4.2.6.1. NH_4-N

4.2.6.1.1. First Crop (Table 101)

Application of N consistently increased the NH_4-N content of the soil irrespective of the soils and K levels. Application of K at K_{50} registered the highest NH_4-N followed by the rest which were almost comparable. This trend was almost true at all levels of N. Highest NH_4-N was registered in Kondal soil and the lowest was in Nedumbalam and Sikar soils which were comparable at all levels of N.

4.2.6.1.2. Residual Crop (Table 102)

The results of the NH_4-N content of the residual crop followed almost the same trend as that of the first crop.

able 99. Results of the statistical analysis of the Non-exchangeable K fraction of soil in first crop (ppm)

. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
719	749	752	753	6.5	13

. Soil series

nd	Pdg	Vld	Skr	Ndb	SE_D	CD
45	701	413	779	762	10	21
vr	Mdk	Pkt	Klt	Adn		
63	623	645	1131	869		

. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
nd	637	653	647	643	21	41
dg	721	681	682	719		
ld	413	423	406	410		
kr	823	750	776	768		
db	743	763	743	797		
vr	891	873	852	835		
dk	604	618	646	624		
kt	646	654	654	627		
lt	1134	1144	1136	1108		
dn	872	871	854	881		

ible 100. Results of the statistical analysis of the non-exchangeable K fraction of soil in residual crop (ppm)

Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
677	687	688	688	3.64	7

Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
673	685	687	693	3.64	7

Soil series

d	Pdg	Vld	Skr	Ndb	SE_D	CD
8	673	347	748	671	5.75	11
r	Mdk	Pkt	Klt	Adn		
8	555	593	1065	800		

Table 101. Results of the statistical analysis of the NH_4-N content of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
10.03	11.55	13.67	15.74	0.18	0.36

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
12.55	13.37	12.84	12.24	0.18	0.36

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
18.87	14.11	13.04	9.81	9.77	0.29	0.57
Kvr	Mdk	Pkt	Klt	Adn		
12.29	12.88	11.53	14.19	11.11		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	9.20	10.40	10.66	9.87	0.36	0.73
N_{50}	11.32	11.95	11.89	11.02		
N_{100}	13.54	14.20	13.50	13.45		
N_{150}	16.13	16.92	15.30	14.62		

(Contd.,)

Table 101. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	15.57	17.68	20.44	21.78	0.58	1.15
Pdg	11.04	12.90	15.59	16.90		
Vld	9.96	11.92	13.57	16.70		
Skr	7.85	8.42	11.06	11.88		
Ndb	7.66	8.62	10.53	11.85		
Kvr	10.33	11.50	12.33	15.00		
Mdk	9.84	11.48	13.97	16.22		
Pkt	9.02	10.76	12.70	13.65		
Klt	10.77	12.99	14.18	18.80		
Adn	8.27	9.18	12.34	14.64		

Table 102. Results of the statistical analysis of the NH_4-N content of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
7.61	8.03	8.61	9.28	0.09	0.18

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
8.10	8.51	8.43	8.50	0.09	0.18

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
12.53	8.54	8.00	7.12	6.45	0.14	0.28
Kvr	Mdk	Pkt	Klt	Adn		
8.19	8.70	8.30	8.58	7.43		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	11.31	12.19	12.61	13.99	0.28	0.56
Pdg	7.50	7.81	9.20	9.63		
Vld	7.29	7.52	8.17	9.02		
Skr	6.33	7.06	7.46	7.62		
Ndb	5.84	5.91	6.76	7.31		
Kvr	7.15	7.65	8.28	9.68		
Mdk	7.99	8.51	8.74	9.54		
Pkt	7.67	8.10	8.53	8.90		
Klt	8.65	8.92	8.44	8.29		
Adn	6.37	6.60	7.78	8.86		

4.2.6.2. NO_3-N

4.2.6.2.1. First Crop (Table 103)

The NO_3-N content consistently increased with N application irrespective of the soils. Application of K_{50} recorded higher value than K_{150} and control, the latter two were also comparable with K_{100}. Padugai series recorded the highest NO_3-N fraction. The lowest was in Kivalur series.

4.2.6.2.2. Residual Crop (Table 104)

The effect of N or K application on NO_3-N content followed the same trend as observed in the first crop irrespective of the soils. Among the soils, Padugai soil series recorded the highest NO_3-N content where as the lower values was recorded by Adanur soil series which was comparable with Kivalur and Nedumbalam soil series.

4.2.7. Available Nutrient Status of the Soils

4.2.7.1. Available N

4.2.7.1.1. First Crop (Table 105)

The available K content of the soil increased with every increase in the levels of N. Almost the same trend was observed in all the soils. Application of K increased the available K, the levels being comparable but superior over the control. Among the soils, the Madukkur and Kivalur soils recorded the highest and lowest available N respectively and this was also seen at all levels of N.

Table 103. Results of the statistical analysis of the NO_3-N content of soil in first crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
7.99	9.90	12.55	14.13	0.027	0.41

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
10.99	11.54	11.18	10.85	0.207	0.41

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
12.46	13.56	10.52	10.53	10.19	0.33	0.65
Kvr	Mdk	Pkt	Klt	Adn		
9.28	12.65	10.54	11.29	10.39		

4. Nitrogen x Soil interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	8.87	10.79	14.42	15.76	0.65	1.30
Pdg	10.04	12.80	14.28	17.17		
Vld	7.48	9.38	12.20	13.04		
Skr	6.45	8.78	12.86	14.01		
Ndb	6.77	9.01	11.60	13.37		
Kvr	6.13	8.19	10.44	12.37		
Mdk	9.80	10.32	14.06	16.44		
Pkt	8.62	9.49	11.67	12.37		
Klt	8.75	10.39	11.57	14.45		
Adn	6.95	9.82	12.37	12.41		

Table 104. Results of the statistical analysis of the NO_3-N content of soil in residual crop (ppm)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
5.73	6.99	8.56	10.27	0.11	0.21

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
7.72	8.33	7.96	7.55	0.11	0.21

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
9.64	10.30	7.19	7.16	6.91	0.17	0.33
Kvr	Mdk	Pkt	Klt	Adn		
6.62	8.48	8.54	8.03	6.62		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	7.18	7.77	10.11	11.11	0.34	0.67
Pdg	7.55	9.11	11.31	13.22		
Vld	5.61	6.51	8.15	8.47		
Skr	4.75	6.73	7.74	9.43		
Ndb	4.53	5.50	8.20	9.42		
Kvr	5.00	5.62	6.87	8.98		
Mdk	6.53	7.54	8.67	11.16		
Pkt	5.69	7.67	9.11	11.67		
Klt	5.87	7.47	8.18	10.64		
Adn	4.62	5.98	7.24	8.64		

(Contd.,)

Table 104. (Contd.,)

5. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	9.00	9.55	9.38	8.24	0.34	0.67
Pdg	10.10	11.01	10.53	9.57		
Vld	7.30	7.78	6.95	6.72		
Skr	6.92	6.94	7.67	7.12		
Ndb	7.10	7.31	6.67	6.57		
Kvr	6.65	6.54	6.64	6.65		
Mdk	8.06	9.07	8.51	8.26		
Pkt	8.22	8.98	8.46	8.49		
Klt	7.71	7.89	8.83	7.71		
Adn	6.15	7.27	6.90	6.16		

4.2.7.1.2. Residual Crop (Table 106)

Application of N increased the available N in all the soils. The available K was not altered with N application. The Madukkur soil series recorded the highest available N, and the lowest was in Valuthalakudi soils. In the absence of N, Padugai soil, which was comparable with Kalathur recorded the highest available N and the lowest was in Kivalur soils. In the presence of N, Madukkur soil series was superior over the rest of the soils and the Valuthalakudi soil series registered numerically low available N.

4.2.7.2. Available P

4.2.7.2.1. First Crop (Table 107)

Application of N increased the available P content, the levels being almost comparable were superior to control. Application of K did not influence available P content of the soils. Among the soils, Pattukkottai soil series being on a par with Madukkur soil recorded the highest available P. The lowest values were registered by Valuthalakudi and Kivalur soils which were comparable.

4.2.7.2.2. Residual Crop (Table 108)

Increase in available P status with N application was observed, the levels were comparable but superior to N_0. In Kondal and Kalathur soils alone, this trend was observed,

Table 105. Results of the statistical analysis of the availabl N content of soil in first crop ($kg \cdot ha^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
118	129	137	144	0.74	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
130	133	133	134	0.77	2

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
124	147	114	121	120	1.22	2
Kvr	Mdk	Pkt	Klt	Adn		
103	163	134	152	144		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	108	114	132	143	2.40	5
Pdg	131	143	152	161		
Vld	100	112	121	124		
Skr	109	113	127	137		
Ndb	108	118	123	130		
Kvr	92	99	106	113		
Mdk	149	159	168	174		
Pkt	112	137	141	144		
Klt	145	150	155	157		
Adn	120	142	147	159		

Table 106. Results of the statistical analysis of the available N of soil in residual crop ($kg \cdot ha^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
78	108	119	129	1.01	2

2. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
109	128	90	100	94	1.6	3
Kvr	Mdk	Pkt	Klt	Adn		
95	135	98	127	108		

3. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	86	105	115	131	3.2	6
Pdg	97	129	141	144		
Vld	68	88	99	105		
Skr	64	99	105	127		
Ndb	66	90	110	111		
Kvr	62	97	107	115		
Mdk	97	139	150	161		
Pkt	78	99	104	110		
Klt	92	120	141	154		
Adn	74	109	115	134		

Table 107. Results of the statistical analysis of the avilable P content of soil in first crop ($kg.ha^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
33.05	34.22	35.08	35.04	0.43	0.85

2. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
33.08	36.78	17.62	28.26	34.59	0.68	1.35
Kvr	Mdk	Pkt	Klt	Adn		
18.82	46.40	47.05	42.74	38.10		

Table 108. Results of the statistical analysis of the available P content of soil in residual crop ($kg \cdot ha^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
27.27	28.41	28.69	29.00	0.26	0.53

2. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
31.36	32.51	16.44	25.86	24.72	0.42	0.83

Kvr	Mdk	Pkt	Klt	Adn
16.61	30.51	31.67	39.65	34.11

3. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	25.35	33.45	32.70	32.95	0.84	1.67
Pdg	32.27	32.32	32.47	32.95		
Vld	15.50	16.10	17.10	17.07		
Skr	25.30	25.35	25.90	26.90		
Ndb	24.62	24.72	24.42	25.12		
Kvr	16.20	16.42	16.72	17.10		
Mdk	30.47	30.40	30.60	30.57		
Pkt	31.92	31.57	31.50	31.57		
Klt	36.45	40.27	40.62	51.82		
Adn	34.65	33.47	34.35	33.97		

whereas the rest of the soils behaved alike. Kalathur soil series registered the highest available P. The Valuthalakudi and Kivalur soils were comparable and contained the lowest available P. Similar results were obtained also at all levels of N.

4.2.7.3. Available K

4.2.7.3.1. First Crop (Table 109)

The available K content increased with the application of N. This trend was also seen in Kondal, Padugai, Valuthalakudi, Nedumbalam and Adanur soils. In all other soils the available K content was not altered with N application. The available K consistently increased with every increase in the levels of K. Kivalur and Adanur soils being on a par recorded the highest available K and Valuthalakudi soil recorded the lowest value. This trend was also seen at all levels of N.

4.2.7.3.2. Residual Crop (Table 110)

The available K status of the soil increased with N application, the levels being on a par were superior to control. This trend could be seen also at all levels of K except K_{150}, Where in N_{50} was superior over the rest of the treatments which were on a par. Similar trend of increase in available K with N application was also noted in most of the soils except Pattukkottai soil where in the effect was not pronounced.

Table 109. Results of the statistical analysis of the available K content of soil in first crop ($kg \cdot ha^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
373	382	384	389	2.2	4

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
369	378	387	393	2.2	4

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
356	380	255	442	424	3.5	7
Kvr	Mdk	Pkt	Klt	Adn		
468	285	312	430	467		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	347	344	361	367	7.0	14
Pdg	369	371	382	397		
Vld	233	243	246	247		
Skr	400	442	445	440		
Ndb	415	423	425	431		
Kvr	461	473	470	469		
Mdk	280	289	284	289		
Pkt	304	316	316	313		
Klt	426	430	433	429		
Adn	456	472	473	465		

Table 110. Results of the statistical analysis of the avaialble K of soil in residual crop (kg ha^{-1})

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
290	298	297	296	1.1	2

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
286	294	297	302	1.1	2

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
288	303	169	379	244	1.7	3
Kvr	Mdk	Pkt	Klt	Adn		
394	221	240	345	366		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	281	287	290	300	2.2	4
N_{50}	283	296	302	309		
N_{100}	291	297	299	302		
N_{150}	291	298	297	298		

(Contd.,)

Table 110. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	282	289	290	289	3.40	7
Pdg	297	310	304	302		
Vld	160	174	172	169		
Skr	374	382	376	384		
Ndb	240	243	244	248		
Kvr	389	403	392	391		
Mdk	213	223	226	222		
Pkt	239	243	240	239		
Klt	343	351	350	344		
Adn	358	358	376	372		

4.2.8. Drymatter Production and Yield of Rice

4.2.8.1. Drymatter Production

4.2.8.1.1. First Crop (Table 111)

The drymatter yield of rice increased with increasing levels of N. This trend was seen irrespective of the soils. The drymatter yield was the highest at K_{150} followed by K_{100} and K_{50} which were comparable and K_0. In the interaction of K x soils, application of K did not show beneficial effect in five out of ten soils. Only in Kondal, Padugai, Valuthalakudi, Pattukkottai and Madukkur soils, application of K increased the drymatter yield. Among the soils, Pattukkottai soils registered the highest yield and the least was in Kivalur soil. This was also observed at all levels of K.

4.2.8.1.2. Residual Crop (Table 112)

Increasing levels of N proportionately increased the drymatter and this was observed irrespective of the soils. Application of K increased the drymatter production over control, though the levels were comparable but showed a trend of increase with increasing levels. Kalathur series recorded the highest drymatter production the lowest was in Kivalur soil, which was comparable with Valuthalakudi and Nedumbalam. At lower levels of N, almost the same trend could be seen, whereas at N_{100}, the Kalthur soil series being on a par with Pattukkottai soil recorded the highest drymatter production. At N_{150}, the Pattukkottai soil series

Table 111. Results of the statistical analysis of the dry-matter production of rice in first crop ($g.pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
46.1	53.7	62.9	72.0	0.71	1.4

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
55.5	58.6	59.6	61.1	0.71	1.4

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
47.5	51.8	44.2	42.5	39.1	1.1	2.1
Kvr	Mdk	Pkt	Klt	Adn		
37.6	49.6	57.9	49.8	41.4		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	47.5	54.2	64.4	77.4	2.3	4.3
Pdg	57.8	62.9	72.0	82.3		
Vld	44.2	53.2	64.1	71.3		
Skr	42.5	51.6	61.5	78.4		
Ndb	39.1	46.7	54.9	58.3		
Kvr	37.6	42.8	50.0	53.2		
Mdk	49.6	57.5	66.8	73.8		
Pkt	57.9	70.1	84.7	99.8		
Klt	49.8	50.9	59.8	68.9		
Adn	41.4	47.4	51.1	57.0		

(Contd.,)

Table 111. (Contd.,)

5. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	55.2	60.9	62.7	64.6	2.27	4.3
Pdg	63.7	66.7	69.0	69.5		
Vld	51.5	57.3	61.1	62.9		
Skr	57.0	58.7	58.2	60.1		
Ndb	48,0	50.8	50.1	50.1		
Kvr	46.2	45.9	45.1	46.3		
Mdk	56.4	60.8	64.3	66.1		
Pkt	72.4	78.2	79.4	82.6		
Klt	55.8	58.1	57.0	58.2		
Adn	49.0	48.8	48.8	50.3		

Table 112. Results of the statistical analysis of the dry matter production of rice in residual crop ($g.pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
37.3	40.8	46.9	56.3	0.67	1.5

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
43.1	44.8	46.3	47.1	0.76	1.5

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
46.2	42.7	40.0	45.2	41.0	1.2	2.3
Kvr	Mdk	Pkt	Klt	Adn		
39.0	47.5	51.7	55.0	44.8		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	36.4	40.7	49.5	58.4	2.4	4.6
Pdg	35.5	39.0	44.6	51.6		
Vld	31.3	33.7	41.8	51.4		
Skr	40.0	41.4	46.6	52.8		
Ndb	34.0	39.3	43.3	47.2		
Kvr	34.0	38.3	40.8	43.2		
Mdk	37.2	41.2	46.3	65.1		
Pkt	40.8	43.5	53.0	69.6		
Klt	48.0	49.1	55.1	68.0		
Adn	35.7	39.5	48.0	56.1		

which was comparable with Kalathur and Madukkur soil registered the highest production.

4.2.8.2. Yield Data

4.2.8.2.1. Grain Yield

4.2.8.2.1.1. First Crop (Table 113; Fig.9)

The grain yield of rice increased with every increase in the levels of N. Application of K increased the grain yield, the levels being almost comparable and superior to control. This was true in Kondal, Pattukkottai, Padugai and Madukkur soils, whereas in Valuthalakudi soil, the levels K_{150} and K_{100} were comparable and superior to K_{50}. The control recorded the lowest yield. Pattukkottai soil recorded the highest grain yield and the least was in Kivalur and Nedumbalam soils which were comparable. This trend was seen at all levels of K.

4.2.8.2.1.2. Residual Crop (Table 114)

The grain yield increased with every increase in N application. This trend was true in Kondal, Valuthalakudi, Pattukkottai, Madukkur, Kalathur and Adanur soils, whereas in the other soils, higher levels of N were comparable and superior to lower levels which were on a par. Application of K at higher levels (K_{150} and K_{100}) increased the grain yield over control whereas K_{50} was also comparable with K_{100} and

Table 113. Results of the statistical analysis of the grain yield of rice in first crop ($g.pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
13.80	15.65	18.03	20.51	0.16	0.31

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
16.21	17.04	17.26	17.48	0.16	0.31

3. Soils series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
17.46	18.98	16.83	16.95	14.32	0.26	0.5[illegible]
Kvr	Mdk	Pkt	Klt	Adn		
14.11	17.66	21.60	16.60	15.45		

4. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	15.87	17.42	18.12	18.44	0.52	0.9[illegible]
Pdg	18.08	18.78	19.46	19.60		
Vld	14.99	16.63	17.72	17.99		
Skr	16.58	16.75	17.16	17.29		
Ndb	14.07	14.63	14.50	14.07		
Kvr	13.89	14.72	13.84	13.97		
Mdk	16.23	17.48	18.24	18.70		
Pkt	20.26	21.65	22.01	22.47		
Klt	16.27	16.58	16.60	16.96		
Adn	15.69	15.32	15.37	15.44		

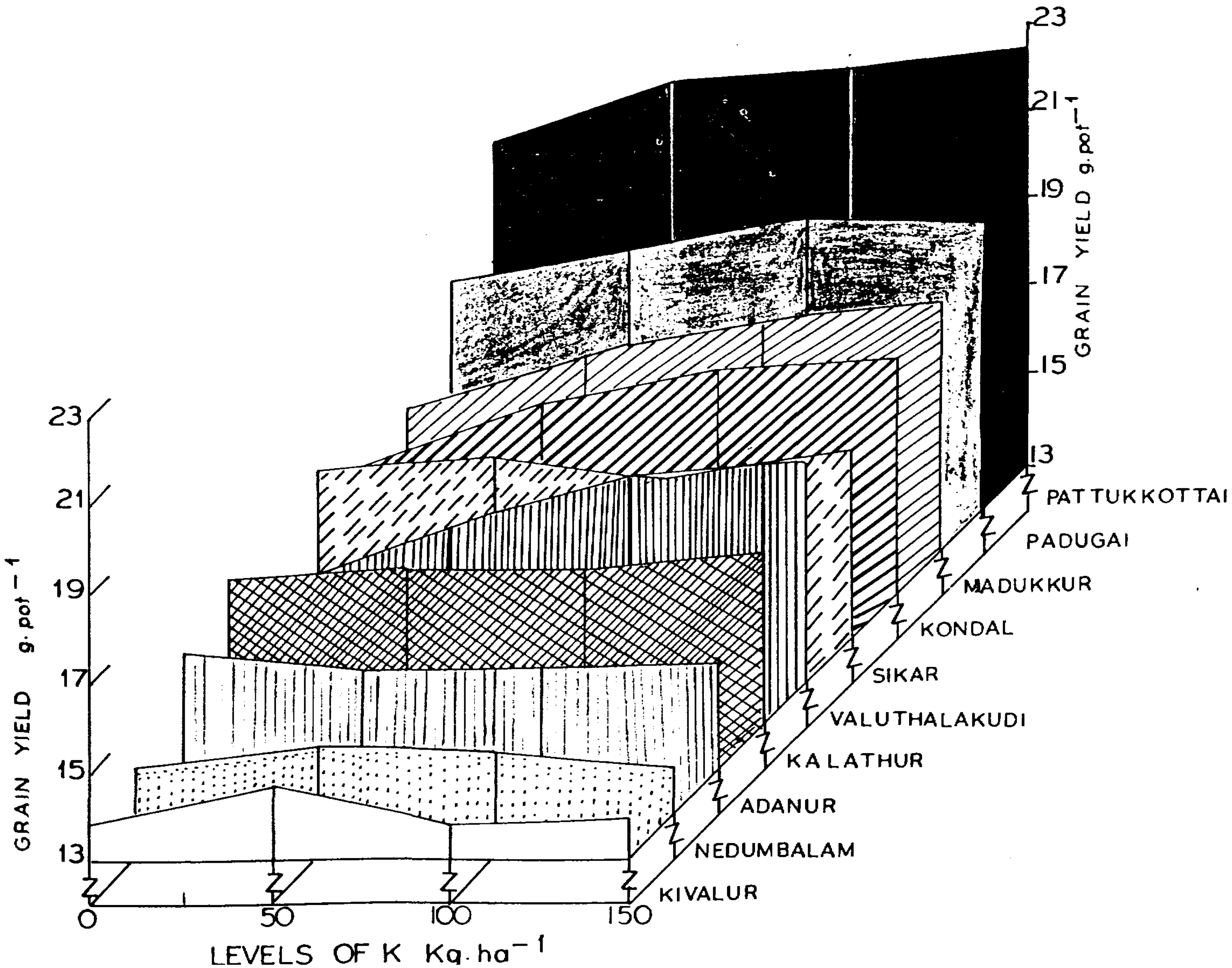

23
21
19
17
15
13
GRAIN YIELD g.pot⁻¹
0
50
100
150
LEVELS OF K Kg.ha⁻¹
PATTUKKOTTAI
PADUGAI
MADUKKUR
KONDAL
SIKAR
VALUTHALAKUDI
KALATHUR
ADANUR
NEDUMBALAM
KIVALUR

Table 114. Results of the statistical analysis of the grain yield of rice in residual crop (g.pot^{-1})

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
10.54	11.34	12.71	14.66	0.20	0.38

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
11.89	12.18	12.50	12.68	0.20	0.38

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
13.22	12.46	11.15	12.36	11.48	0.32	0.60
Kvr	Mdk	Pkt	Klt	Adn		
10.86	12.43	13.12	14.19	11.85		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	10.86	12.66	13.99	15.39	0.63	1.20
Pdg	10.61	11.51	13.30	14.42		
Vld	8.68	10.07	11.90	13.93		
Skr	11.23	11.47	12.77	13.97		
Ndb	10.07	10.92	12.07	12.88		
Kvr	9.83	10.79	11.18	11.65		
Mdk	10.18	10.84	12.03	16.65		
Pkt	11.06	11.10	13.34	16.98		
Klt	12.77	13.16	14.31	16.52		
Adn	10.13	10.89	12.17	14.23		

control. Kalathur series recorded the highest grain yield whereas the Kivalur and Valuthalakudi soils were comparable but inferior to the rest of the soils. Almost the same trend of results could be seen at all levels of N.

4.2.8.2.2. Straw Yield

4.2.8.2.2.1. First Crop (Table 115)

Increasing levels of N increased the straw yield and this was seen irrespective of the soils. The straw yield increased by K application, the K_{150} registering the highest value followed by K_{100} and K_{50} which were on a par and superior to control. Pattukkottai soil series recorded the highest straw yield and the Kivalur soil series being on a par with Adanur soil registered lower grain yield than the rest of the soils.

4.2.8.2.2.2. Residual Crop (Table 116)

The effects of N, K and soil series and the N x soil series interaction on straw yield followed almost the same trend as observed in the grain yield of the residual crop.

4.2.9. Response Functions of N and K with Grain Yield

4.2.9.1. Response Functions of N with Grain Yield (Table 117 and 118)

The response functions of N between its levels and grain yield in the first crop and residual crop are

Table 115. Results of the statistical analysis of the straw yield of rice in first crop ($g \cdot pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
32.34	38.07	44.87	51.74	0.57	1.10

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
39.26	41.85	42.31	43.60	0.57	1.10

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
43.40	48.26	41.24	41.59	35.44	0.91	1.70
Kvr	Mdk	Pkt	Klt	Adn		
32.42	44.23	56.56	40.68	33.77		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	33.60	38.62	46.27	55.09	1.80	3.45
Pdg	36.41	44.92	52.21	59.59		
Vld	31.08	38.01	45.61	50.25		
Skr	29.96	36.27	43.47	56.65		
Ndb	27.52	33.38	39.39	41.48		
Kvr	25.89	29.55	35.17	39.06		
Mdk	35.08	40.52	47.91	53.40		
Pkt	40.54	50.17	61.33	74.18		
Klt	34.64	36.08	42.80	49.18		
Adn	28.68	33.20	34.56	38.62		

Table 116. Results of the statistical analysis of the straw yield of rice in residual crop (g·pot^{-1})

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
26.75	29.43	34.20	41.67	0.67	1.30

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
31.21	32.67	33.78	34.40	0.67	1.30

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
33.03	30.23	28.89	32.86	29.47	1.05	2.00
Kvr	Mdk	Pkt	Klt	Adn		
28.17	35.03	38.58	40.86	32.98		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	25.52	28.08	35.56	42.96	2.11	4.01
Pdg	24.92	27.51	31.30	37.20		
Vld	22.55	25.65	29.92	37.45		
Skr	28.76	29.97	33.85	38.87		
Ndb	23.90	28.40	31.26	34.34		
Kvr	24.13	27.46	29.58	31.51		
Mdk	27.06	30.36	34.28	48.41		
Pkt	29.70	32.37	39.65	52.62		
Klt	35.26	35.93	40.75	51.52		
Adn	25.64	28.59	35.85	41.84		

presented in Table 117 and 118 respectively. The results of the first crop indicated that out of the ten soils studied, except Nedumbalam and Madukkur soils, the response was observed to be linear. In these two soils, it was quadratic. In the residual crop, quadratic relationship was obtained between grain yield and levels of N in Kondal and Kivalur soils. In the rest of the soils it was linear.

4.2.9.2. Response Functions of K with Grain Yield
(Tables 119 and 120; Figs. 10, 11 and 12)

The response functions of K levels with grain yield of the first ctop and residual crop are presented in Table 119 and 120 respectively. In five out of ten soils, viz., Kondal, Padugai, Valuthalakudi, Pattukkottai and Madukkur, response to K application was obtained which was quadratic in the first crop and linear in the residual crop excepting Kondal soil where in it was quadratic again.

4.2.10. Nutrient Content of the Grain and Straw

4.2.10.1. Nutrient Content of the Grain

4.2.10.1.1. Nitrogen Content of the Grain

4.2.10.1.1.1. First Crop (Table 121)

Application of N consistently increased the N content of the grain. This trend was almost the same at all the levels of K and in all the soils except Pudugai and

FIG. 10 RESPONSE CURVES FOR DIFFERENT SOIL SERIES (POT CULTURE)

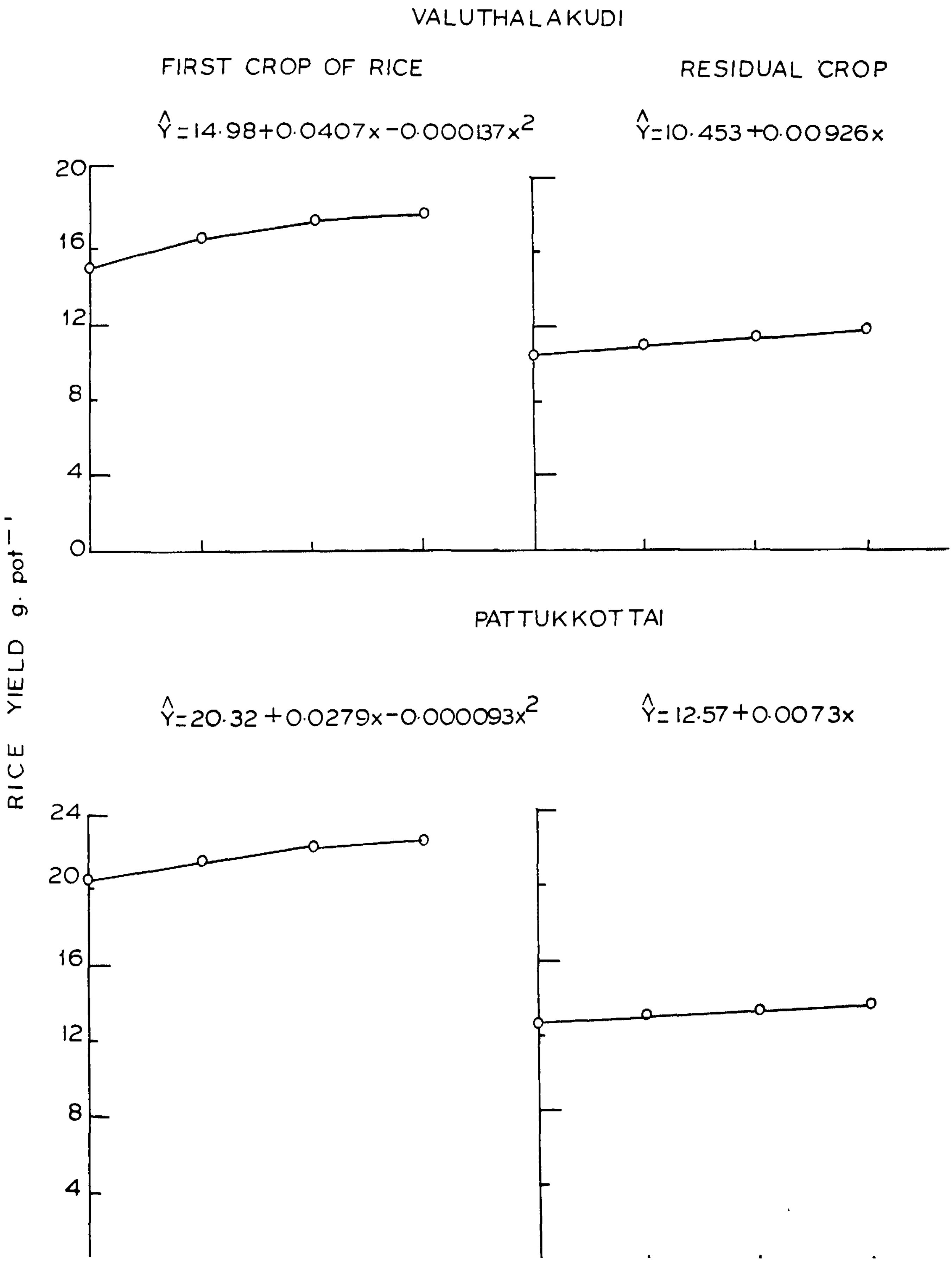


FIG. 11 RESPONSE CURVES FOR DIFFERENT SOIL SERIES (POT CULTURE)

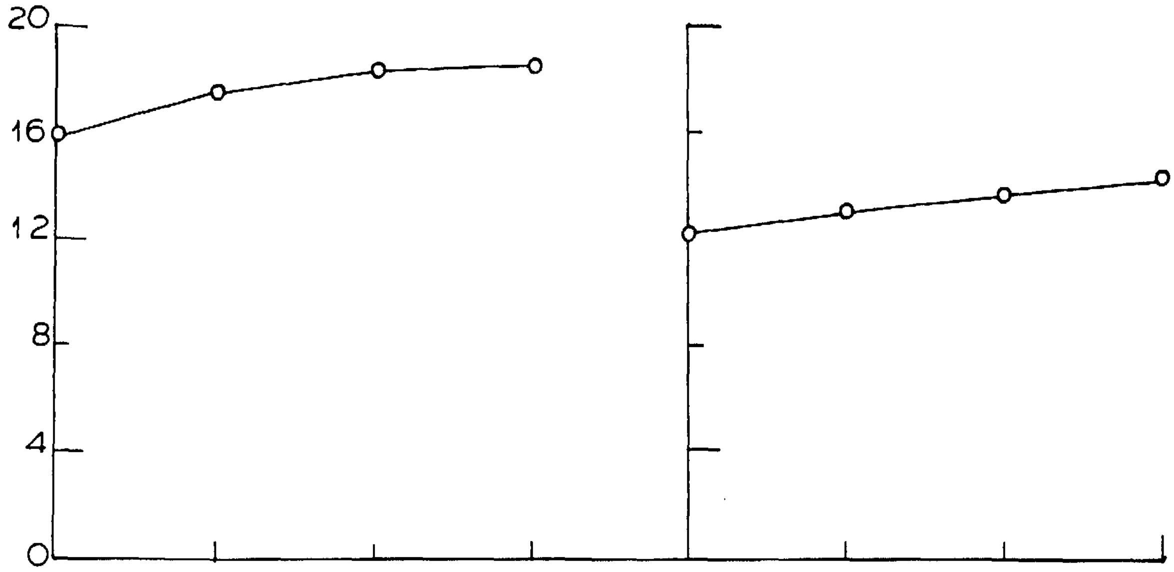
KONDAL

FIRST CROP OF RICE

$\hat{Y} = 15.89 + 0.035x - 0.00012x^2$

RESIDUAL CROP

$\hat{Y} = 12.13 + 0.0195x - 0.000042x^2$



PADUGAI

$\hat{Y} = 18.054 + 0.0189x - 0.000056x^2$

$\hat{Y} = 11.77 + 0.0092x$

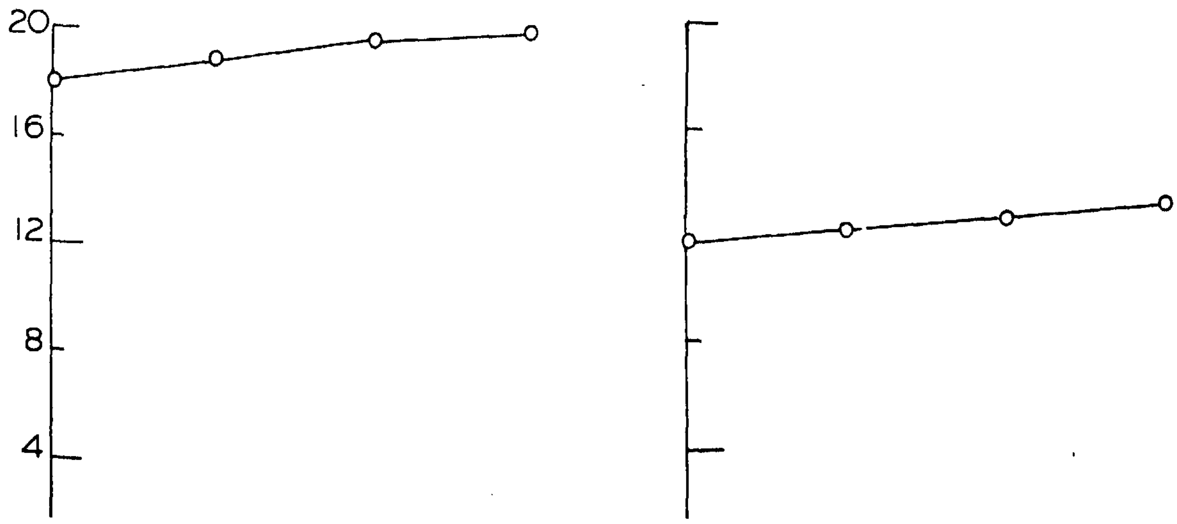


FIG. 12 RESPONSE CURVES OF DIFFERENT SOIL SERIES (POT CULTURE)

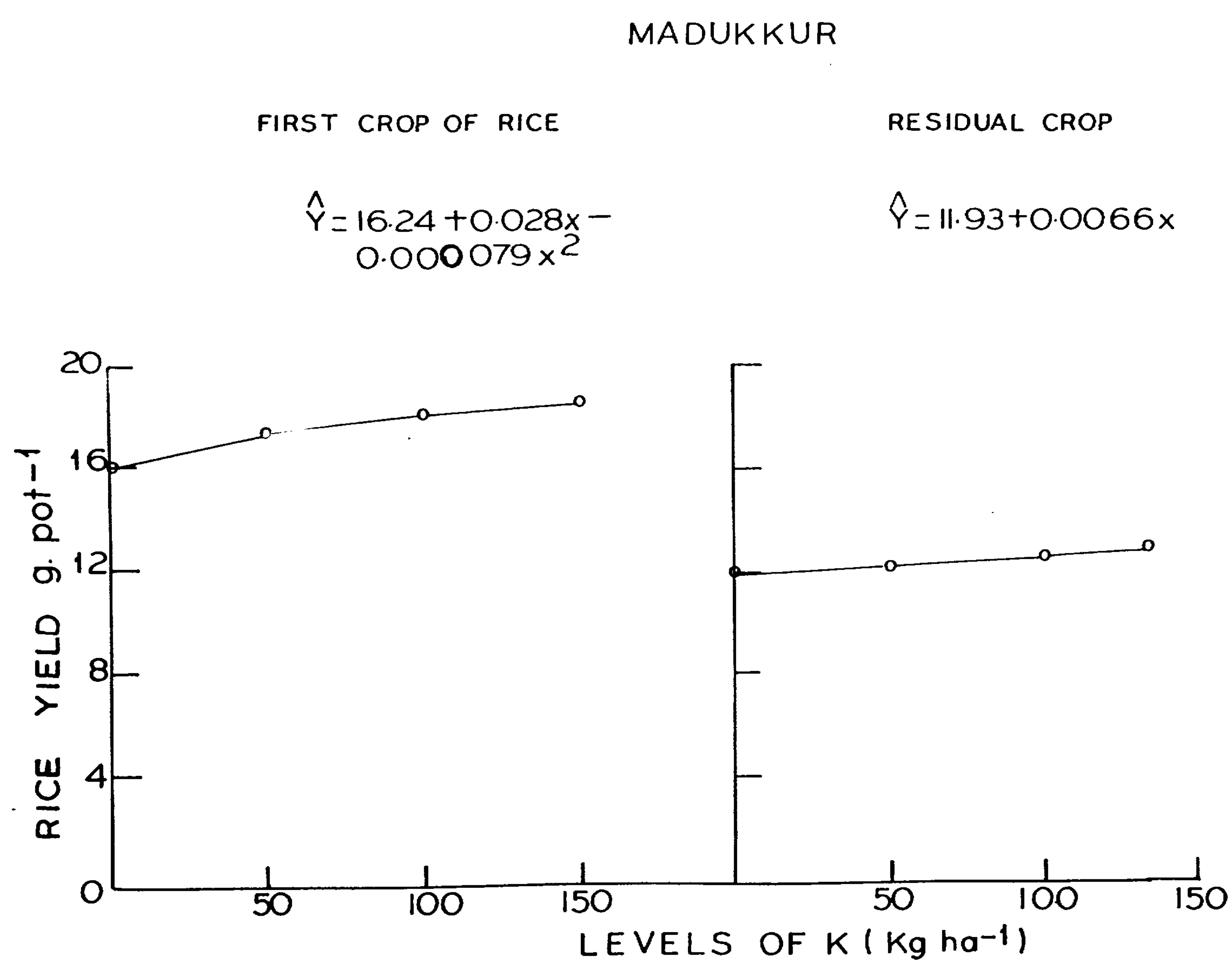


Table 117. Results of the response function equations between grain yield (g.pot^{-1}) and levels of N (kg.ha^{-1}) in first crop

S.No.	Soil series	Best fit	Response equation	Physical optimum	Economic optimum		Actual yield	Predicted yield
1.	Kondal	Linear	$\hat{Y} = 13.27+0.056x$	--	--	N_0	13.86	13.27
						N_{50}	15.54	16.07
						N_{100}	18.15	18.86
						N_{150}	22.31	21.66
2.	Padugai	Linear	$\hat{Y} = 15.36+0.048x$	--	--	N_0	15.35	15.36
						N_{50}	17.98	17.77
						N_{100}	19.80	20.19
						N_{150}	22.79	22.60
3.	Valuthalakudi	Linear	$\hat{Y} = 12.99+0.051x$	--	--	N_0	13.13	12.99
						N_{50}	15.15	15.55
						N_{100}	18.50	18.11
						N_{150}	20.55	20.67

(Contd.,)

Table 117. (Contd.,)

4.	Kivalur	Linear	$\hat{Y} = 11.67+0.0325x$	--	--	N_0	11.72	11.67
						N_{50}	13.24	13.29
						N_{100}	14.86	14.92
						N_{150}	16.80	16.54
5.	Sikar	Linear	$\hat{Y} = 12.37+0.061x$	--	--	N_0	12.56	12.37
						N_{50}	15.37	15.42
						N_{100}	18.01	18.47
						N_{150}	21.84	21.52
6.	Nedumbalam	Quadratic	$\hat{Y} = 11.54+0.0416x - 0.000039x^2$	380	307	N_0	11.60	11.54
						N_{50}	13.33	13.52
						N_{100}	15.50	15.31
						N_{150}	16.84	16.90
7.	Pattukkottai	Linear	$\hat{Y} = 17.38 + 0.0563x$	--	--	N_0	17.40	17.38
						N_{50}	19.98	20.19
						N_{100}	23.36	23.00
						N_{150}	25.65	25.82

(Contd.,)

able 117. (Contd.,)

.	Madukkur	Quadratic	$\hat{Y} = 16.24+0.0282x - 0.000079x^2$	179	124	N_0	16.23	16.24
						N_{50}	17.48	17.25
						N_{100}	18.24	18.27
						N_{150}	18.70	18.70
.	Kalathur	Linear	$\hat{Y} = 14.71+0.029x$	--	--	N_0	15.12	14.71
						N_{50}	16.02	16.18
						N_{100}	16.74	17.65
						N_{150}	19.77	19.11
0.	Adanur	Linear	$\hat{Y} = 12.57+0.038x$	--	--	N_0	12.74	12.57
						N_{50}	14.18	14.49
						N_{100}	16.53	16.42
						N_{150}	18.31	18.34

Table 118. Results of the response function between grain yield ($g.pot^{-1}$) and levels of N ($kg.ha^{-1}$) in residual crop

l.No.	Soil series	Best fit	Response equation	Physical optimum	Economic optimum		Actual yield	Predicted yield
.	Kondal	Quadratic	$\hat{Y} = 10.89+0.036x - 0.00004x^2$	449	341	N_0	10.86	10.89
						N_{50}	12.66	12.58
						N_{100}	13.99	14.07
						N_{150}	15.39	15.36
2.	Padugai	Linear	$\hat{Y} = 10.48+0.026x$	--	--	N_0	10.61	10.48
						N_{50}	11.51	11.80
						N_{100}	13.30	13.12
						N_{150}	14.42	14.44
3.	Valuthalakudi	Linear	$\hat{Y} = 8.51+0.0351\ x$	--	--	N_0	8.68	8.51
						N_{50}	10.07	10.27
						N_{100}	11.90	12.02
						N_{150}	12.93	13.78

(Contd.,)

Table 118. (Contd.,)

4.	Kivalur	Quadratic	$\hat{Y} = 9.89+0.019x - 0.000049x^2$	195	107	N_0	9.83	9.89
						N_{50}	10.79	10.72
						N_{100}	11.18	11.30
						N_{150}	11.65	11.64
5.	Sikar	Linear	$\hat{Y} = 10.93+0.019x$	--	--	N_0	11.23	10.93
						N_{50}	11.47	11.88
						N_{100}	12.77	12.84
						N_{150}	13.97	13.79
6.	Nedumbalam	Linear	$\hat{Y} = 10.05+0.019x$	--	--	N_0	10.07	10.05
						N_{50}	10.92	11.01
						N_{100}	12.07	11.96
						N_{150}	12.88	12.92
7.	Pattukkottai	Linear	$\hat{Y} = 10.12+0.04x$	--	--	N_0	11.06	10.12
						N_{50}	11.10	12.12
						N_{100}	13.34	14.12
						N_{150}	16.98	16.12

(Contd.,)

Table 118. (Contd.,)

8.	Madukkur	Linear	$\hat{Y} = 9.335 + 0.0412x$	--	--	N_0	10.18	9.33
						N_{50}	10.84	11.40
						N_{100}	12.03	13.45
						N_{150}	16.65	15.51
9.	Kalathur	Linear	$\hat{Y} = 12.33 + 0.0248x$	--	--	N_0	12.77	12.33
						N_{50}	13.16	13.57
						N_{100}	14.31	14.81
						N_{150}	16.52	16.05
10.	Adanur	Linear	$\hat{Y} = 9.818 + 0.0272x$	--	--	N_0	10.13	9.82
						N_{50}	10.89	11.18
						N_{100}	12.17	12.53
						N_{150}	14.23	13.89

ble 119. Results of the response function between grain yield ($g.pot^{-1}$) and levels of K ($kg.ha^{-1}$) in first crop

.No.	Soil series	Best fit	Response equation	Physical optimum	Economic optimum		Actual yield	Predicted yield
	Kondal	Quadratic	$\hat{Y} = 15.89+0.035x-0.00012x^2$	144	109	K_0	15.87	15.89
						K_{50}	17.42	17.35
						K_{100}	18.12	18.19
						K_{150}	18.44	18.41
.	Padugai	Quadratic	$\hat{Y} = 18.05+0.0189x--0.000056x^2$	169	92	K_0	18.08	18.05
						K_{50}	18.78	18.86
						K_{100}	19.46	19.38
						K_{150}	19.60	19.63
.	Valuthalakudi	Quadratic	$\hat{Y} =14.98+0.041x - 0.00014x^2$	149	118	K_0	14.99	14.98
						K_{50}	16.63	16.67
						K_{100}	17.72	17.68
						K_{150}	17.99	18.00

(Contd.,)

Table 119. (Contd.,)

4.	Pattukkottai	Quadratic	$\hat{Y}=20.32+0.028x-0.000093x^2$	150	104	K_0	20.26	20.32
						K_{50}	21.65	21.48
						K_{100}	22.01	22.18
						K_{150}	22.47	22.41
5.	Madukkur	Quadratic	$\hat{Y} = 16.24 + 0.028x- 0.000079x^2$	179	124	K_0	16.23	16.24
						K_{50}	17.48	17.44
						K_{100}	18.24	18.25
						K_{150}	18.70	18.66

Table 120. Results of the response function between grain yield (g. pot^{-1}) and levels of K (kg. ha^{-1}) in residual crop

S.No.	Soil series	Best fit	Response equation	Physical optimum	Economic optimum		Actual yield	Predicted yield
1.	Kondal	Quadratic	$\hat{Y} = 12.13+0.0195x-0.000042x^2$	233	130	K_0	12.18	12.13
						K_{50}	12.85	13.00
						K_{100}	13.81	13.66
						K_{150}	14.06	14.11
2.	Padugai	Linear	$\hat{Y} = 11.77+0.0092x$	--	--	K_0	11.83	11.77
						K_{50}	12.18	12.23
						K_{100}	12.61	12.69
						K_{150}	13.22	13.15
3.	Valuthalakudi	Linear	$\hat{Y} = 10.45+0.00926x$	--	--	K_0	10.29	10.45
						K_{50}	11.29	10.92
						K_{100}	11.27	11.38
						K_{150}	11.79	11.84

(Contd.,)

le 120. (Contd.,)

Pattukkottai	Linear	$\hat{Y} = 12.57+0.0073\ x$	--	--	K_0	12.70	12.57
					K_{50}	12.88	12.94
					K_{100}	13.05	13.30
					K_{150}	13.86	13.67
Madukkur	Linear	$\hat{Y} = 11.93+0.0066x$	--	--	K_0	11.91	11.93
					K_{50}	12.31	12.26
					K_{100}	12.55	12.59
					K_{150}	12.93	12.92

Kivalur where in the levels of N were not markedly different. The N content of the grain increased with increasing levels of K. This was seen only in the presence of N, whereas at N_0 level, the levels of K were almost comparable. Among the soils, Padugai soil recorded the highest N content and the Valuthalakudi soil which was comparable to Madukkur soil registered the lowest value.

4.2.10.1.1.2. Residual Crop (Table 122)

Increasing levels of N and K application, correspondingly increased the N content of the grain. The effect of N in increasing the N content of the grain was also observed in all soils. Adanur and Sikar soils which were on a par registered the highest grain N content than the Kondal and Kalathur soils which were comparable among themselves and also with Sikar. The lowest N content was observed in Valuthalakudi soil.

4.2.10.1.2. Phosphorus Content of the Grain

4.2.10.1.2.1. First Crop (Table 123)

The grain P content increased with N application, the level N_{150} being on a par with N_{100} registered higher value than N_{50} and N_0 . In Kondal and Kivalur soils, this trend was observed, whereas in the rest of the soils, excepting Padugai and Nedumbalam, N application tended to increase the P content. In Padugai and Nedumbalam soils, N

Table 121. Results of the statistical analysis of the N content of grain in first crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
1.86	2.06	2.18	2.29	0.015	0.03

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
1.96	2.07	2.14	2.21	0.015	0.03

3. Soils series

Knd	pdg	Vld	Skr	Ndb	SE_D	CD
2.18	2.27	1.98	2.16	2.11	0.02	0.05
Kvr	Mdk	Pkt	Klt	Adn		
2.02	1.99	2.11	2.10	2.10		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	1.78	1.83	1.88	1.94	0.03	0.06
N_{50}	1.90	2.05	2.10	2.17		
N_{100}	2.01	2.15	2.25	2.31		
N_{150}	2.16	2.25	2.33	2.41		

(Contd.,)

Table 121. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	1.96	2.19	2.29	2.36	0.048	0.10
Pdg	1.96	2.22	2.29	2.36		
Vld	1.75	2.01	1.99	2.15		
Skr	1.85	2.13	2.19	2.46		
Ndb	1.89	.204	2.22	2.27		
Kvr	1.89	2.03	2.10	2.08		
Mdk	1.75	1.91	2.12	2.19		
Pkt	1.87	2.07	2.15	2.33		
Klt	1.87	1.92	2.13	2.22		
Adn	1.85	2.01	2.19	2.33		

Table 122. Results of the statistical analysis of the N content of grain in residual crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
1.770	1.897	2.010	2.120	0.013	0.025

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
1.880	1.940	1.970	1.990	0.013	0.025

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
2.040	1.980	1.740	2.060	1.870	0.02	0.040
Kvr	Mdk	Pkt	Klt	Adn		
1.810	1.900	1.960	2.030	2.100		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	1.867	1.995	2.100	2.187	0.04	0.08
Pdg	1.820	1.960	2.030	2.100		
Vld	1.645	1.697	1.785	1.855		
Skr	1.802	1.977	2.152	2.310		
Ndb	1.697	1.785	1.925	2.065		
Kvr	1.715	1.767	1.820	1.925		
Mdk	1.715	1.837	1.942	2.000		
Pkt	1.750	1.872	1.995	2.205		
Klt	1.855	2.065	2.117	2.100		
Adn	1.847	2.065	2.205	2.327		

Table 123. Results of the statistical analysis of the P content of grain in first crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.240	0.268	0.282	0.294	0.008	0.016

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.251	0.275	0.277	0.280	0.008	0.016

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
0.277	0.273	0.241	0.284	0.298	0.013	0.025
Kvr	Mdk	Pkt	Klt	Adn		
0.262	0.272	0.264	0.268	0.271		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	0.200	0.287	0.285	0.335	0.025	0.050
Pdg	0.250	0.260	0.282	0.300		
Vld	0.235	0.200	0.267	0.262		
Skr	0.242	0.285	0.300	0.310		
Ndb	0.307	0.285	0.290	0.310		
Kvr	0.217	0.282	0.275	0.275		
Mdk	0.275	0.285	0.290	0.237		
Pkt	0.230	0.280	0.265	0.282		
Klt	0.225	0.260	0.270	0.317		
Adn	0.220	0.252	0.300	0.310		

Table 124. Results of the statistical analysis of the P content of the grain in the residual crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.245	0.274	0.310	0.334	0.005	0.01

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.270	0.290	0.300	0.310	0.005	0.01

3. Soils series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
0.302	0.309	0.274	0.283	0.279	0.009	0.02
Kvr	Mdk	Pkt	Klt	Adn		
0.291	0.276	0.307	0.285	0.296		

Table 125. Results of the statistical analysis of the K content of grain in first crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.336	0.354	0.365	0.382	0.003	0.007

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.327	0.350	0.367	0.390	0.003	0.007

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
0.359	0.390	0.298	0.361	0.334	0.005	0.011
Kvr	Mdk	Pkt	Klt	Adn		
0.387	0.357	0.379	0.375	0.358		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	0.345	0.347	0.377	0.367	0.010	0.020
Pdg	0.377	0.390	0.395	0.397		
Vld	0.277	0.292	0.310	0.312		
Skr	0.332	0.342	0.387	0.380		
Ndb	0.332	0.327	0.332	0.345		
Kvr	0.345	0.375	0.402	0.427		
Mdk	0.300	0.340	0.347	0.387		
Pkt	0.322	0.382	0.405	0.407		
Klt	0.355	0.380	0.355	0.410		
Adn	0.345	0.360	0.337	0.390		

Table 126. Results of the statistical analysis of the K content of grain in residual crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.276	0.295	0.309	0.332	0.004	0.007

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.291	0.298	0.308	0.316	0.004	0.007

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
0.292	0.334	0.269	0.292	0.291	0.006	0.011
Kvr	Mdk	Pkt	Klt	Adn		
0.307	0.309	0.289	0.337	0.344		

series, which was comparable with Kivalur and Pattukkottai soils than the rest of the soils. Valuthalakudi soil registerd the lowest value.

4.2.10.1.3.2. Residual Crop (Table 126)

The K content of the grain progressively increased with increasing levels of N application. Application of K increased the grain K, K_{150} registered the highest value followed by K_{100}, K_{50} and K_0, the latter two being comparable. Adanur and Kalathur soils registered the highest grain K, whereas the Valuthalakudi soil recorded the lowest value.

4.2.10.2. Nutrient Content of the Straw

4.2.10.2.1. Nitrogen Content of the Straw

4.2.10.2.1.1. First Crop (Table 127)

The N content of the straw increased with increasing levels of N application and also irrespective of the soils. Application of K in increasing levels increased the N content of the straw. The Kalathur and Valuthalakudi soils registered the highest and lowest straw N content respectively. Almost the same trend could be seen at all levels of N.

Table 127. Results of the statistical analysis of the N content of straw in first crop (%)

1. Nitrogen levels

N_0	N50	N_{100}	N_{150}	SE_D	CD
1.110	1.225	1.310	1.410	0.012	0.023

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
1.150	1.250	1.297	1.360	0.012	0.023

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
1.210	1.300	1.150	1.280	1.250	0.02	0.040
Kvr	Mdk	Pkt	Klt	Adn		
1.190	1.280	1.250	1.400	1.300		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	0.997	1.242	1.265	1.330	0.04	0.074
Pdg	1.137	1.277	1.365	1.422		
Vld	0.945	1.085	1.260	1.312		
Skr	1.085	1.295	1.365	1.382		
Ndb	1.102	1.72	1.200	1.452		
Kvr	1.067	1.137	1.207	1.352		
Mdk	1.137	1.190	1.330	1.452		
Pkt	1.120	1.242	1.277	1.365		
Klt	1.285	1.277	1.470	1.557		
Adn	1.225	1.242	1.365	1.487		

Table 128. Results of the statistical analysis of the N content of straw in residual crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
1.12	1.24	1.33	1.39	0.014	0.03

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
1.22	1.28	1.28	1.32	0.014	0.03

3. Soils series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
1.27	1.35	0.98	1.18	1.40	0.022	0.04
Kvr	Mdk	Pkt	Klt	Adn		
1.29	1.37	1.19	1.31	1.38		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	1.07	1.26	1.36	1.40	0.044	0.09
Pdg	1.19	1.35	1.36	1.50		
Vld	0.87	1.00	1.08	0.98		
Skr	1.00	1.12	1.22	1.36		
Ndb	1.24	1.38	1.49	1.50		
Kvr	1.21	1.24	1.33	1.36		
Mdk	1.24	1.35	1.40	1.50		
Pkt	0.96	1.14	1.28	1.36		
Klt	1.19	1.26	1.36	1.43		
Adn	1.21	1.35	1.45	1.50		

4.2.10.2.1.2. Residual Crop (Table 128)

Application of N and K correspondingly increased the N content of the straw. Nedumbalam, Adanur, and Madukkur soils were comparable in their straw N content and superior to the rest. The lowest value was observed in Valuthalakudi soils. At all the levels of N, this trend was observed. The increase in straw N content with N application was seen also in all the soils.

4.2.10.2.2. Phosphorus Content

4.2.10.2.2.1. First Crop (Table 129)

Application of N in increasing levels increased the P content of the straw. In Kondal, Sikar, Kalathur and Adanur soils almost the same trend was noticed whereas in all other soils except Pattukkottai and Madukkur, it tended to increase. In these two soils, N application did not show marked changes. Application of K at K_{150} and K_{100} being on a par recorded the highest P content of the straw followed by K_{50} and K_0. In Padugai, Valuthalakudi and Adanur soils, the P content of the straw increased with K application, the levels being comparable were superior to control. In Pattukkottai and Kalathur soils, the differences were not conspicuous and in the rest of the soils, P content tended to increase with K application.

Table 129. Results of the statistical analysis of the P content of straw in first crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.128	0.148	0.160	0.177	0.005	0.010

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.138	0.149	0.163	0.163	0.005	0.010

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
0.145	0.150	0.132	0.159	0.163	0.007	0.014
Kvr	Mdk	Pkt	Klt	Adn		
0.184	0.169	0.160	0.156	0.136		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	0.100	0.142	0.167	0.170	0.015	0.029
Pdg	0.132	0.142	0.157	0.167		
Vld	0.107	0.122	0.150	0.150		
Skr	0.117	0.167	0.160	0.185		
Ndb	0.150	0.135	0.175	0.192		
Kvr	0.142	0.160	0.167	0.185		
Mdk	0.167	0.167	0.157	0.182		
Pkt	0.150	0.170	0.150	0.170		
Klt	0.122	0.150	0.160	0.192		
[illegible]	[illegible]	[illegible]	0.160	0.167		

Table 129. (Contd.,)

5. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	0.142	0.125	0.160	0.152	0.015	0.029
Pdg	0.150	0.115	0.167	0.167		
Vld	0.107	0.142	0.140	0.140		
Skr	0.132	0.152	0.177	0.175		
Ndb	0.150	0.160	0.157	0.185		
Kvr	0.142	0.167	0.160	0.185		
Mdk	0.140	0.175	0.192	0.167		
Pkt	0.160	0.160	0.150	0.170		
Klt	0.150	0.140	0.167	0.167		
Adn	0.107	0.150	0.142	0.142		

Table 130. Results of the statistical analysis of the P content of straw in residual crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.117	0.137	0.158	0.175	0.005	0.009

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.132	0.143	0.151	0.161	0.005	0.009

3. Soils series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
0.135	0.150	0.114	0.171	0.166	0.007	0.014

Kvr	Mdk	Pkt	Klt	Adn
0.137	0.131	0.176	0.137	0.149

4.2.10.2.2.2. Residual Crop (Table 130)

Application of N in increasing levels promoted the P content of the straw. The level K_{150} registered the highest P content followed by K_{100} and K_{50} which were on a par and superior to control. Pattukkottai soil being on a par with Sikar and Nedumbalam soils registered higher P content than the rest of the soils. The lowest value was observed in Valuthalakudi soil.

4.2.10.2.3. Potassium Content

4.2.10.2.3.1. First Crop (Table 131)

The K content of the straw consistently increased with the application of N and also at all levels of K. In almost all soils, N application increased the K content of the straw. The K content of the straw increased with each increment in the levels of K. This was true at all levels of N. The highest K content was recorded in Kivalur soil series, whereas Valuthalakudi soil recorded comparable values with that of the Kondal and Madukkur soils and recorded the lowest value.

4.2.10.2.3.2. Residual Crop (Table 132)

The straw K content of the residual crop followed almost the same trend as observed in the first crop with the application of N and K, the effect being true in all soils.

Table 131. Results of the statistical analysis of the K content of straw in first crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.631	0.685	0.735	0.766	0.008	0.016

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.591	0.675	0.746	0.804	0.008	0.016

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
0.632	0.691	0.626	0.716	0.715	0.013	0.026
Kvr	Mdk	Pkt	Klt	Adn		
0.860	0. 645	0.672	0.763	0.720		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	0.550	0.600	0.660	0.710	0.016	0.033
N_{50}	0.580	0.650	0.720	0.790		
N_{100}	0.590	0.730	0.770	0.850		
N_{150}	0.640	0.720	0.830	0.880		

Table 131. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	0.560	0.605	0.637	0.727	0.03	0.051
Pdg	0.672	0.652	0.702	0.737		
Vld	0.512	0.595	0.677	0.717		
Skr	0.647	0.710	0.720	0.787		
Ndb	0.595	0.737	0.780	0.747		
Kvr	0.812	0.845	0.855	0.927		
Mdk	0.570	0.605	0.695	0.710		
Pkt	0.540	0.662	0.735	0.752		
Klt	0.712	0.777	0.795	0.772		
Adn	0.687	0.662	0.752	0.777		

Table 132. Results of the statistical analysis of the K content of straw in residual crop (%)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
0.528	0.583	0.638	0.675	0.009	0.017

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
0.563	0.607	0.614	0.640	0.009	0.017

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
0.577	0.634	0.517	0.656	0.621	0.014	0.027
Kvr	Mdk	Pkt	Klt	Adn		
0.646	0.572	0.544	0.636	0.653		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	0.512	0.537	0.605	0.655	0.028	0.055
Pdg	0.535	0.645	0.557	0.720		
Vld	0.430	0.495	0.535	0.610		
Skr	0.597	0.595	0.702	0.730		
Ndb	0.545	0.615	0.647	0.677		
Kvr	0.530	0.622	0.702	0.727		
Mdk	0.465	0.560	0.615	0.630		
Pkt	0.537	0.495	0.560	0.585		
Klt	0.545	0.652	0.660	0.685		
Adn	0.560	0.612	0.712	0.727		

The K content of the straw did not vary much due to soils, although Sikar and Valuthalakudi soils recorded numerically higher and lower value respectively.

4.2.11. Uptake of Nutrients by the Grain and Straw

4.2.11.1. Uptake of Nutrients by Grain

4.2.11.1.1. Uptake of N by the Grain

4.2.11.1.1.1. First Crop (Table 133)

Application of N correspondingly increased the N uptake of the grain and this was seen in all the soils. Increasing levels of K increased the N uptake of the grain. This was true in Kondal, Padugai and Madukkur soils. In Valuthalakudi, Pattukkottai and Kalathur soils, the levels were on a par but superior to K_0, where as in Kivalur, Sikar and Nedumbalam soils, the levels were almost comparable to K_0. In Adanur soils, K application did not show marked changes. Pattukkottai and Kivalur soils registered the highest and lowest uptake values respectively. This was almost true at all levels of N and K.

4.2.11.1.1.2. Residual Crop (Table 134)

Application of increasing levels of N and K increased the N uptake of the grain. This was true in all the soils and at all levels of K. At lower levels of N, K application tended to increase the uptake whereas at higher levels, the levels were superior to control. Kalathur soil

Table 133. Results of the statistical analysis of the N uptake of grain in first crop ($mg \cdot pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
255	316	387	468	4.3	9

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
320	353	369	385	4.3	9

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
389	427	339	368	317	7.0	14
Kvr	Mdk	Pkt	Klt	Adn		
293	343	444	332	310		

4. Nitrogen x soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	251	349	414	540	13.7	27
Pdg	314	374	458	562		
Vld	226	311	369	451		
Skr	240	330	392	510		
Ndb	224	272	363	409		
Kvr	224	273	322	353		
Mdk	243	299	393	437		
Pkt	321	405	486	565		
Klt	289	272	339	430		
Adn	221	267	329	422		

(Contd.,)

Table 133. (Contd.,)

5. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	334	370	410	440	13.7	27
Pdg	386	418	446	458		
Vld	281	337	360	379		
Skr	343	373	361	393		
Ndb	294	311	326	338		
Kvr	268	306	292	306		
Mdk	295	333	366	379		
Pkt	386	446	469	478		
Klt	303	333	339	354		
Adn	300	297	314	321		

Table 134. Results of the statistical analysis of the N uptake by grain in residual crop (mg.pot^{-1})

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
185	213	255	320	3.3	7

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
226	241	249	257	3.3	7

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
293	249	192	263	208	5.2	10
Kvr	Mdk	Pkt	Klt	Adn		
191	230	259	308	239		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	171	183	191	195	6.6	13
N_{50}	203	210	220	219		
N_{100}	241	255	256	267		
N_{150}	287	317	328	346		

(Contd.,)

Table 134. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	205	252	320	394	10.4	21
Pdg	194	227	268	305		
Vld	129	167	215	259		
Skr	206	242	263	341		
Ndb	174	180	221	256		
Kvr	162	191	186	224		
Mdk	167	192	219	342		
Pkt	187	203	275	372		
Klt	248	270	328	386		
Adn	181	205	254	317		

recorded the highest uptake of N and the Kivalur and Valuthalakudi soils being on a par recorded the lowest values. This was seen also at all levels of N.

4.2.11.1.2. Phosphorus Uptake of the Grain

4.2.11.1.2.1. First Crop (Table 135)

The uptake of P by the grain increased with every increase in the levels of N. This was almost true in all the soils. Application of K increased the P uptake, the levels being on a par and superior to K_0. The highest P uptake was recorded in the Pattukkottai soil and the least was in Kivalur, Adanur and Valuthalakudi soils which were on a par. At different levels of N, the soils did not follow a definite trend.

4.2.11.1.2.2. Residual Crop (Table 136)

The individual effects of N and K and their interaction on the P uptake of the grain in the residual crop followed almost the same trend as seen in the first crop. The Kondal and Kalathur soil series being on a par registered the highest P uptake. The Valuthalakudi and Nedumbalam soils being on a par recorded the lowest value.

4.2.11.1.3. Uptake of K by the Grain

4.2.11.1.3.1. First Crop (Table 137)

Increasing levels of N correspondingly increased the grain K uptake. This was true in all soils. The grain K

Table 135. Results of the statistical analysis of the P uptake by in first crop ($mg.pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
32.77	41.30	49.84	60.03	1.28	2.50

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
41.43	46.36	47.98	48.18	1.28	2.50

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
50.24	51.49	42.09	48.38	43.85	2.03	4.00
Kvr	Mdk	Pkt	Klt	Adn		
38.38	45.67	55.59	43.89	40.37		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	26.78	45.90	51.50	76.76	4.06	8.10
Pdg	40.44	43.76	53.93	67.81		
Vld	30.34	33.33	49.62	55.09		
Skr	31.44	44.01	53.82	64.24		
Ndb	33.96	38.14	41.45	55.86		
Kvr	21.11	38.02	42.32	46.76		
Mdk	38.15	45.00	51.78	47.73		
Pkt	39.54	54.72	59.58	68.53		
Klt	34.76	36.59	42.93	61.27		
Adn	26.22	33.56	45.47	56.22		

Table 136. Results of the statistical analysis of the P uptake by grain in residual crop ($mg.pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
25.69	30.54	39.01	50.44	0.76	1.50

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
31.78	36.25	37.59	40.05	0.76	1.50

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
43.79	39.18	30.91	35.33	31.20	1.20	2.40
Kvr	Mdk	Pkt	Klt	Adn		
31.42	33.47	41.28	43.70	33.95		

4. Nitrogen x potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	22.07	25.86	26.69	28.13	1.51	3.00
N_{50}	28.60	29.37	31.20	32.99		
N_{100}	33.86	39.54	39.70	42.96		
N_{150}	42.61	50.23	52.76	56.14		

Table 136. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	29.13	35.56	49.35	61.13	2.4	4.70
Pdg	28.02	34.45	43.67	50.39		
Vld	15.63	26.29	35.34	46.36		
Skr	27.98	33.08	35.62	44.65		
Ndb	23.68	25.76	34.45	40.91		
Kvr	22.33	30.99	33.92	38.45		
Mdk	24.01	28.18	32.75	48.93		
Pkt	27.21	29.21	44.82	63.86		
Klt	32.87	34.71	44.86	62.36		
Adn	26.02	27.12	35.35	47.31		

Table 137. Results of the statistical analysis of the K uptake by grain in first crop ($mg \cdot pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
45.67	54.56	65.18	78.07	0.916	1.80

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
53.11	59.47	62.90	68.00	0.916	1.80

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
63.52	73.24	50.65	61.34	50.32	1.45	2.90
Kvr	Mdk	Pkt	Klt	Adn		
56.45	60.45	80.18	59.86	52.70		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	39.39	43.25	47.97	52.08	1.83	3.60
N_{50}	47.20	53.34	56.32	61.87		
K_{100}	56.83	64.01	67.49	72.41		
K_{150}	69.01	77.29	79.82	86.15		

(Contd.,)

Table 137. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	46.35	55.40	68.30	84.02	2.9	5.80
Pdg	60.70	66.90	75.40	89.95		
Vld	34.12	45.47	57.35	65.65		
Skr	43.05	52.09	69.50	79.90		
Ndb	39.35	44.40	55.20	62.15		
Kvr	40.85	50.50	61.87	72.57		
Mdk	45.80	53.45	64.92	77.62		
Pkt	60.70	74.85	91.62	98.87		
Klt	49.95	53.82	56.50	79.15		
Adn	40.97	47.87	51.17	70.77		

6. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	54.07	60.77	65.77	73.45	2.9	5.80
Pdg	62.30	73.12	75.15	82.45		
Vld	39.17	50.95	54.27	58.20		
Skr	52.40	61.85	61.22	69.87		
Ndb	44.70	50.27	53.22	53.10		
Kvr	53.95	57.75	56.25	57.85		
Mdk	49.30	58.07	63.80	70.82		
Pkt	68.95	78.67	84.57	88.52		
Klt	56.05	53.92	60.47	68.97		
Adn	50.17	49.40	54.25	56.97		

Table 138. Results of the statistical analysis of the K uptake by grain in residual crop ($mg.pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
29.01	33.01	39.40	50.20	0.63	1.25

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
34.89	36.99	39.04	40.71	0.63	1.25

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
42.32	38.60	29.51	37.19	32.77	1.00	1.93
Kvr	Mdk	Pkt	Klt	Adn		
32.44	37.36	31.89	51.76	39.24		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	28.92	35.40	43.70	61.25	2.0	3.97
Pdg	27.45	34.47	41.87	50.60		
Vld	19.25	25.40	32.85	40.55		
Skr	30.87	35.15	36.65	46.10		
Ndb	27.52	28.37	36.12	39.05		
Kvr	25.92	30.87	33.15	39.80		
Mdk	27.65	32.10	35.30	54.37		
Pkt	28.80	31.65	39.97	51.12		
Klt	41.82	43.17	54.60	67.42		
[illegible]	[illegible]	[illegible]	39.77	51.77		

uptake progressively increased with every increase in K levels. This could be seen at all levels of N and in most of the soils, except Valuthalakudi, Nedumbalam and Adanur soils where in the levels were almost comparable to control and in Kivalur soil, where in the influence of N application was not marked. Pattukkottai soil series recorded the highest uptake value and the least was in Nedumbalam, Valuthalakudi and Adanur soils. Irrespective of the levels of N and K, similar trends were observed.

4.2.11.1.3.2. Residual Crop (Table 138)

Application of N consistently increased the K uptake in all the soils. Increasing levels of K correspondingly increased the grain K uptake. Kalathur and Valuthalakudi soils respectively registered the highest and lowest uptake values. This was true at all levels of N.

4.2.11.2. Uptake of Nutrients by the Straw

4.2.11.2.1. Nitrogen Uptake by the Straw

4.2.11.2.1.1. First Crop (Table 139)

With every increase in the levels of N, the uptake of N increased. Irrespective of the soils and K levels this trend was seen. The N uptake of the straw increased with increasing levels of K. This was true only at higher levels of N, whereas at lower levels of N, the levels of K were comparable and superior to K_0. Increased N uptake with K

Table 139. Results of the statistical analysis of the N uptake by straw in first crop ($mg.pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
357	468	583	727	8.6	17

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
462	525	549	598	8.6	17

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
553	619	486	515	481	13.4	27
Kvr	Mdk	Pkt	Klt	Adn		
402	551	680	580	469		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	311	359	364	393	17.0	34
N_{50}	403	467	485	518		
N_{100}	503	567	602	660		
N_{150}	632	708	746	820		

(Contd.,)

Table 139. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	330	497	609	776	27	54
Pdg	443	593	623	817		
Vld	292	426	568	656		
Skr	317	462	565	714		
Ndb	305	401	530	688		
Kvr	276	353	437	543		
Mdk	376	443	633	754		
Pkt	427	587	753	953		
Klt	464	484	626	734		
Adn	340	435	484	617		

6. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	448	525	573	667	27	54
Pdg	537	591	631	716		
Vld	392	472	520	559		
Skr	476	535	503	545		
Ndb	422	465	494	543		
Kvr	380	425	494	543		
Mdk	454	530	598	623		
Pkt	563	675	714	769		
Klt	504	584	603	631		
Adn	448	456	467	510		

Table 140. Results of the statistical analysis of the N uptake by straw in residual crop (mg.pot^{-1})

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
294	351	424	573	16	32

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
372	403	242	443	16	32

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
455	379	279	409	377	26	51
Kvr	Mdk	Pkt	Klt	Adn		
355	471	457	518	404		

application was observed in Kondal, Padugai, Valuthalakudi, Madukkur, Pattukkottai and Kalathur soils. In Sikar, Nedumbalam and Adanur soils, it tended to increase and in Kivalur soil, K application did not result in marked changes. The highest and lowest values of N uptake were registered by Pattukkottai and Kivalur soils respectively. At all levels of N and K this trend was observed.

4.2.11.2.1.2. Residual Crop (Table 140)

The uptake of N by the straw progressively increased with the application of N. Application of K only tended to increase the K uptake. Kalathur and Madukkur soils recorded higher N uptake than the rest of the soils whereas Valuthalakudi soils registered the lowest value.

4.2.11.2.2. Phosphorus Uptake of the Straw

4.2.11.2.2.1. First Crop (Table 141)

Application of N in increasing levels promoted the uptake of P in straw. The levels K_{150} and K_{100} being on a par registered the highest P uptake followed by K_{50} and K_0. Application of K promoted the P uptake in Padugai, Valuthalakudi and Madukkur soils. In Kondal, Sikar, Nedumbalam, Pattukkottai and Adanur soils, P uptake tended to increase whereas in Kivalur and Kalathur soils, K application did not show marked difference. Pattukkottai and Adanur soils registered the highest and lowest values of P uptake respectively. This was almost true at all levels of K.

Table 141. Results of the statistical analysis of the P uptake by straw in first crop (mg. pot^{-1})

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
41.86	56.89	71.32	91.08	2.10	4.20

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
56.35	63.44	69.56	71.29	2.10	4.20

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
67.39	71.80	56.22	64.98	63.90	3.30	6.60
Kvr	Mdk	Pkt	Klt	Adn		
55.50	71.96	85.96	65.23	48.64		

4. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	62.01	59.09	74.33	74.12	6.60	13.20
Pdg	68.87	54.57	79.53	84.22		
Vld	41.28	60.03	60.66	62.90		
Skr	53.01	65.81	68.82	72.01		
Ndb	56.47	64.29	61.84	73.01		
Kvr	50.14	58.63	51.37	61.88		
Mdk	52.92	74.12	85.76	75.03		
Pkt	78.86	85.87	93.37	85.76		
Klt	61.23	58.70	69.62	71.37		
Adn	38.67	53.25	50.29	52.33		

Table 142. Results of the statistical analysis of the P uptake by straw in residual crop ($mg.pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
30.85	39.44	50.36	72.02	1.71	3.39

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
40.65	45.95	50.69	55.39	1.71	3.39

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
49.15	42.87	33.20	59.65	44.69	2.70	5.36
Kvr	Mdk	Pkt	Klt	Adn		
38.09	47.01	68.19	54.51	44.32		

4. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	28.67	34.57	56.57	76.81	5.40	10.70
Pdg	24.23	33.96	45.86	67.85		
Vld	19.89	24.31	35.39	53.21		
Skr	34.56	58.03	59.91	86.11		
Ndb	34.42	40.52	45.58	58.36		
Kvr	26.18	37.60	38.27	50.32		
Mdk	27.47	25.84	47.89	86.84		
Pkt	37.83	56.45	71.28	106.63		
Klt	43.70	52.06	52.84	69.43		
Adn	31.67	31.52	49.61	65.08		

4.2.11.2.2.2. **Residual Crop** (Table 142)

The uptake of P consistently increased with the increase in the levels of N and K. The effect of N in increasing the uptake of P could also be seen in all the soils. The highest and lowest values of P uptake were recorded by Pattukkottai and Valuthalakudi soils respectively.

4.2.11.2.3. Potassium Uptake of the Straw

4.2.11.2.3.1. First Crop (Table 143)

Increasing levels of N application progressively increased the straw K uptake. Similar results were also seen irrespective of the soils and levels of K. Application of K in increasing levels promoted the straw K uptake consistently. This was seen also at all levels of N and in all soils. The highest K uptake was observed in Pattukkottai soil whereas the least was in Adanur and Valuthalakudi soils. This was true almost at all levels of N and K.

4.2.11.2.3.2. Residual Crop (Table 144)

The individual effects of N and K application on the straw K uptake followed similar trend as observed in the first crop. The effect of N in increasing straw K uptake was seen irrespective of the levels of N and soils. At lower levels of N, K application tended to increase the straw K uptake whereas at higher levels, the levels were on a par

Table 143. Results of the statistical analysis of the K uptake of straw in first crop ($mg \cdot pot^{-1}$)

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
201	260	327	393	4.8	10

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
236	282	314	350	4.8	10

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
290	329	267	287	275	7.6	15
Kvr	Mdk	Pkt	Klt	Adn		
289	279	370	315	253		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	166	196	211	231	9.7	19
N_{50}	206	248	274	311		
N_{100}	256	320	341	391		
N_{150}	314	364	427	468		

(Contd.,)

Table 143. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	186	242	308	425	15.3	30
Pdg	262	284	343	426		
Vld	160	235	314	359		
Skr	189	254	297	406		
Ndb	164	253	328	354		
Kvr	208	262	311	373		
Mdk	189	226	332	369		
Pkt	204	316	431	529		
Klt	255	294	338	371		
Adn	190	232	267	323		

6. Potassium x Soils interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
Knd	226	281	305	349	15.3	30
Pdg	255	306	358	395		
Vld	202	254	287	324		
Skr	230	271	301	344		
Ndb	233	269	276	321		
Kvr	252	285	300	318		
Mdk	210	258	310	337		
Pkt	270	342	411	458		
Klt	261	306	330	362		
Adn	216	232	271	292		

Table 144. Results of the statistical analysis of the K uptake by straw in residual crop (mg.pot^{-1})

1. Nitrogen levels

N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
142	165	202	278	4.5	9.0

2. Potassium levels

K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
171	193	206	215	4.5	9.0

3. Soil series

Knd	Pdg	Vld	Skr	Ndb	SE_D	CD
267	178	150	226	173	7.2	14.0
Kvr	Mdk	Pkt	Klt	Adn		
179	197	206	256	193		

4. Nitrogen x Potassium interaction

	K_0	K_{50}	K_{100}	K_{150}	SE_D	CD
N_0	121	135	160	150	9.1	18.0
N_{50}	152	167	169	172		
N_{100}	179	198	209	220		
N_{150}	234	274	287	318		

(Contd.,)

Table 144. (Contd.,)

5. Nitrogen x Soils interaction

	N_0	N_{50}	N_{100}	N_{150}	SE_D	CD
Knd	138	151	227	313	14.4	29
Pdg	120	155	173	264		
Vld	92	120	154	232		
Skr	178	194	218	315		
Ndb	155	156	175	206		
Kvr	129	177	190	220		
Mdk	124	156	194	314		
Pkt	153	187	210	305		
Klt	195	239	252	340		
Adn	132	146	220	272		

Table 145. Results of the correlation studies made between the K availability indices of pre planting soils and total K uptake in the residual crop

Sl.	K indices	Knd	Pdg	Vld	Skr	Ndb	Kur	Mdk	Pkt	Klt	Adn
1.	H_2O-K	--	--	0.711**	--	--	--	0.492*	0.615*	--	--
2.	NH_4OAc-K	0.714**	0.740**	0.625**	--	0.544**	--	--	0.564**	0.740**	0.585**
3.	0.1N HCl-K	0.426*	0.501**	0.656**	--	0.505**	--	--	0.485*2	--	--
4.	0.5N HCl-K	--	--	0.726**	--	--	--	--	--	--	0.482*
5.	0.01N HCl-K	--	0.452*	0.811**	--	0.465*	--	--	0.552**	--	0.580**
6.	0.1N HNO_3-K	0.612**	--	0.751**	--	--	--	0.612**	0.565**	0.512**	--
7.	0.5N HNO_3-K	0.642**	--	--	0.465*	--	--	--	0.468*	--	--
8.	1N HNO_3-K	0.826**	0.756**	0.521**	--	0.70**	0.869**	--	0.856**	0.812**	0.789**
9.	0.01N HNO_3-K	--	--	0.465*	--	--	--	0.715**	0.582**	--	--
10.	6N H_2SO_4-K	--	0.521**	--	0.564**	--	--	0.582**	--	--	0.572**
11.	0.5N EDTA-K	--	--	--	--	--	--	--	--	--	--
12.	0.01M $CaCl_2$-K	--	--	--	--	--	--	--	--	--	--
13.	Brays-K	--	--	--	--	--	--	0.610**	0.488*	--	--
14.	Morgan's-K	0.801**	--	0.761**	0.705**	0.596**	0.662**	--	0.744**	--	--
15.	Watersoluble - K	--	--	--	--	--	--	--	0.575**	--	--
16.	Exch - K	0.705**	0.560**	0.541**	0.801**	0.754**	0.812**	0.786**	0.744**	0.652**	0.742**
17.	Non-exch-K	0.612**	0.502**	--	--	0.531**	0.606**	--	--	0.681**	0.686**
18.	AR_e^K	0.652**	--	0.560*	--	--	--	0.656**	0.742**	--	--
19.	$-\Delta K^o$	0.615**	0.701**	0.672**	0.710**	0.686*	0.562*	--	0.70**	0.812**	0.705**
20.	PBC^K	--	--	--	-0.62**	--	--	--	--	0.65	--
21.	ΔG	--	--	--	--	--	--	--	--	--	--

58

Table 146. Results of the correlation studies made between the K availability indices of pre-planting soils and grain yield and total K uptake of the residual crop

S.No.	K indices	Grain yield	Total K uptake
1.	H_2O - K	0.456*	--
2.	NH_4OAc-K	0.489*	0.639**
3.	0.1N HCl-K	--	0.515*
4.	0.5N HCl-K	--	--
5.	0.01N HCl-K	0.542**	0.565**
6.	0.1N HNO_3-K	0.582**	0.502*
7.	0.5N HNO_3-K	--	--
8.	1N HNO_3-K	0.820**	0.766**
9.	0.01N HNO_3-K	0.652**	0.712**
10.	6N H_2SO_4-K	--	--
11.	0.5N EDTA-K	--	--
12.	0.01M $CaCl_2$-K	--	--
13.	Brays - K	--	--
14.	Morgan's-K	0.54**	0.565**
15.	Water soluble K	--	--
16.	Exchangeable K	0.721**	0.70**
17.	Non-exchangeable K	--	0.461*
18.	AR^K_e	--	--
19.	$-\Delta K^o$	0.656**	0.621**
20.	PBC^K	--	--
21.	ΔG	--	--

and superior to control. Kalathur and Valuthalakudi soils recorded the highest and lowest uptake values respectively. At all levels of N, this trend was observed.

4.2.12. Results of the Simple Correlation Studies made among the Grain Yield and Total K Uptake of The Residual Crop and K Availability Indices at Preplanting Stage (Tables 145 and 146)

The results indicated that in seven out of ten soils, the K extracted by 1N HNO_3 showed the highest 'r' values. In Valuthalakudi, Sikar and Madukkur soils highest 'r' values were obtained between total K uptake and the K extracted by 0.01N HCl-K, Morgan's-K and 0.01N HNO_3-K respectively. The correlations made between the K availability indices and grain yield and total K uptake values of all the soils pooled together indicated that the highest 'r' values of 0.820^{**} and 0.766^{**} was obtained between 1N HNO_3-K and the grain yield and total K uptake respectively. Among the Q/I parameters, almost in all soils $-\Delta K^{o}$ was closely related to total K uptake whereas PBC^{K} and ΔG were not related.

DISCUSSION

CHAPTER 5

DISCUSSION

Thanjavur District, the rice bowl' of Tamil Nadu, comprising twenty two soil series of cretaceous, tertiary, and alluvial deposits, provide an ample opportunity and scope for several aspects of soil research. The lateritic soils of cretaceous and tertiary formations and the alluvial deposits of river Cauvery, resulted in soils of varying physico-chemical characteristics and formed a base for diversified rice soil research. Although considerable research on various soil fertility aspects has been done on these soils, investigations on soil K in general and dynamics of K and Q/I parameters as affected by N and K interactions in particular are very much less and sporadic. The response of rice to K fertilisation is often reported to be little or limited in this tract and a definite recommendation is yet to be made. For making such recommendations, the knowledge about the extent and nature of different soil series and of soil types within a series provide better information (Sekhon et al., 1988). Owing to the occurrence of heterogenity of soils with diversified characteristics and the existence of dynamic equilibrium of K in soils, the response of K in a high K soil and poor response in a low K soil are often met with. Hence the prediction of soil K by a suitable method which will take into consideration these variations is an immediate necessity.

The interaction of N and K in soil is an interesting phenomenon of great practical significance in determining their availability . Both NH_4^+ and K^+ being lattice fixable cations of similar ionic radii, they compete for the same exchange site. Therefore, the effect of one over the other in influencing their availability is affected by the concentration of the respective ions, moisture status of soil, amount and nature of clay minerals in the soil etc. Though their interaction is well established under gardenland conditions, in rice soils under continuous submergence, the interaction of N and K needs detailed investigations as it is very much influenced by the moisture status. More over, work on the effect of N x K interaction on the Q/I parameters is little which needs to be studied. By keeping all these in mind, the present investigation was taken up to study the dynamics of K in the alluvial soils of Thanjavur delta as influenced by the interaction of K with N. Possibility of fixing a most suitable method to predict the K availability in soil as reflected from the yield of rice and uptake of K by rice was also attempted. The results so obtained from the field and pot experiments as detailed in Chapter 4 are discussed here under.

5.1. Field Experiment

5.1.1. General Properties of the Soils

The soils of the experimental fields belonged to Adanur series (Entic Chromustert) and were silty clay loam

(Samba crop field-K_3C) and clayloam (Kuruvai and Thaladi crop field - D_2a) in their texture. The fertility status of these soils was similar revealing that they were not different among themselves. The soils contained predominatly montmorillonitic clay as reported by Ramanathan (1974). The soils possessed moderately high CEC ranging from 15.8 c eq$\cdot$kg to 25.2 c eq$\cdot$kg^{-1} in K_3C and D_2a fields respectively. The soils had higher levels of NH_4OAc extractable K and did not respond to K fertilisation.

5.1.2. Availability Indices of K in Soils as Affected by Application of N and K

Literature on the K availability indices of soils are replete and quite a number of methods have been advocated for different situations of soil and crop. Since there exists a dynamic equilibrium of K in soil, the replenishment of soil solution K from exchangeable and non-exchangeable K is a continuous process and hence any method which could closely extract that proportion of exchangeable and non-exchangeable K that might be released into soil solution could be a better index of K availability. The reproducibility and accuracy of the method depends on the soil characteristics which vary in their quality and quantity of secondary clay minerals and primary minerals which are important contributing factors for predicting the K supplying power of soils (Van Diest, 1978). Durairaj

Muthiah (1986) made an attempt to evaluate the relative performance of nine extractants for predicting the K availability in Thanajavur soils and inferred that NH_4OAc was the best extractant. In the present study, dynamics of K in the Thanjavur soils was investigated as influenced by interactions of N and K and employing 15 extractants including Q/I parameters.

The effect of N application in increasing the quantity of K extracted by different extractants was evident during different seasons of experimentation. Increased release of K from the specific and non-specific sites of clay minerals by NH_4^+ resulting from the hydrolysis of applied urea as N source could have contributed for the phenomenon. This effect was observed at all the stages of sampling viz., tillering, panicle initiation and post-harvest stages which revealed that the hydrolysis of urea and formation of NH_4^+ continued from the basal and top dressing stages and persisted from tillering to advanced stages of crop growth. This finding is in accordance with the work of Kar et al. (1975) and Sato et al. (1980).

During Samba season alone, the K extracted by most of the extractants excepting H_2O and NH_4OAc was more at lower levels than at higher levels of N, revealing that at higher levels of N, there was reduced extraction of K by these extractants. This effect could be explained in the following manner. The K^+ ions are held in planar, edge, wedge and inter lattice positions, which have different selectivity for K. The inter lattice sites have very high K selectivity, the edge and wedge positions having high selectivity, whereas the planar positions have the lowest K selectivity (Grimme, 1976). As a consequence, the soils with high K content as in the present study, might have all the K selective sites occupied by K^+ ions and the application of higher levels of N and consequential increase in the concentration of NH_4^+ ions of similar ionic radii could have occupied the edge and wedge positions and blocked the release of K from the inter lattice positions. The blocking effect of N application over K release was also reported by Singh and Sinha (1975). This effect was not observed when water was used as an extractant and when NH_4OAc was used, the extractable K increased with increasing levels of N. This might be due to the increased ionic activity and higher polarisability of NH_4^+ ion (Sparks, 1987) in soil solution when NH_4OAc was used, which could have resulted in the penetration of NH_4^+ ions into the inter lattice positions of the clay minerals. As the Samba crop was preceeded by a long spell of summer fallow drought which resulted in deep cracks of the alluvial soils, there might have been a shrinkage of clay minerals. As a consequence, the clay minerals could have expanded at a much slower rate which resulted in the blocking effect of NH_4^+ ions at the edge positions of the clay minerals. This might be the possible reason for this effect to occur during Samba season alone but not during Kuruvai and Thaladi seasons, where the fields were continuously submerged and cultivated.

Increase in the K content of the solutions with the application of K is quite expected since the applied K initially increased the concentration of labile or exchangeable pool of soil K in a soil particularly rich in K content. This finding is in close agreement with the works of Ramanathan (1977) and Durairaj Muthiah (1986). The gradual decrease of K from the available pool of the soil is attributed to the depletion of K from soil due to absorption by the plant. Similar findings were also reported by Ekambaram and Kothandaraman (1983).

The amount of K extracted by different extractants was interrelated in all the seasons of the present study. This indicated that though the magnitude of extraction of K from soil depends on the nature of the extractant and particularly of its concentration, they derive K from a common pool but in varying proportions from the different forms of K. The strong acids extracted relatively greater amount of K, possibly from the non-exchangeable fraction also, than the solutions of neutral salts and weak acids. Close relationships between the values of K extracted by different extractants were also reported by Ramanathan (1977), Andrade et al. (1978), Nagarajan et al. (1982) and Durairaj Muthiah (1986).

5.1.3. Changes in the Q/I Parameters with the Application of N and K and Cropping

According to Schroeder (1974), the supply of K to the plants can be adequately described by three parameters viz., a) the intensity parameter, that is the activity or the concentration of K in the soil solution, b) the quantity parameter, that is the amount of K present in the soil in an available form made up of the amount of exchangeable and part of the non-exchangeable K, c) the mobility parameter or the rate factor, that is the rate at which a certain amount of K is transported per unit of time to given root area.

In the conventional method of K estimations, acids of different concentrations and neutral solutions of salts are used, and hence they extract K from the exchangeable pool and from a part of the non-exchangeable K depending upon their strength. Since this could account for only intensity and/or a part of the three parameters of K supply to plants, these methods at times or in several cases failed to predict the yield and uptake of K and the reproducibility was also low. Beckett (1964a) proposed a method wherein quantity/intensity (Q/I) parameters and rate factors were estimated to describe the K supplying power of the soils. In the present study, the Q/I parameters as described by Beckett (1964a) was investigated as an index of K availability. Further, the changes in Q/I parameters by the interaction of K with N were not studied so far and hence it was also attempted in the present study.

5.1.3.1. AR_e^K

The AR_e^K value is a measures of instantaneously available K or status of immediately exchangeable K. This value is arrived at from the Q/I graph when the changes in labile K ($-\Delta K^o$) is zero, in a system of complete equilibrium of K with the complementary ions like Ca^{+2} and Mg^{+2}.

Increase in the values of AR_e^K with the application of N at lower levels observed in the present study could be attributed to the release of K from the planar and edge sites of the clay minerals by the NH_4^+ ions resulting from the urea hydrolysis. This trend was already discussed in section 5.1.2, highlighting the effect of applied N in increasing the K extraction by different extractants. The lowest value of AR_e^K obtained at the highest levels of N might be due to the release of Ca_{2+} and Mg2+ ions from the non-specific sites which could have reduced the AR^K_e values. Decrease in the AR^K_e values with lime application was reported by Islam and Bolton (1971) and with the increase in the Ca content was reported by Beckett (1971). In the absence of K, the effect of N was not pronounced which could be attributed to the less marked changes that occur in the K values of the soil solution when K was not applied.

The AR^K_e values increased consistently with the application of K which could be attributed to the increase in the concentration of solution K with the K fertilisation as observed by Beckett (1971). The increase in the AR^K_e values with K application was observed only at lower levels of N whereas at higher levels of N, the levels of K were not significantly changing this value which might possibly due to the release of Ca_{2+} and Mg2+ ions at higher levels of N. The decrease in AR^K_e values with the advancement of sampling might be due to the depletion of solution and exchangeable K by the crop uptake, as also observed by Beckett (1971) and Durairaj Muthiah (1986).

5.1.3.2. Labile K ($-\Delta K^o$)

While the AR^K values are related to the activity of K in soil solution, the $-\Delta K^o$ values represent the amount of K held in the soil on sites or surfaces of which the exchange equilibria is describeed by the linear part of the Q/I relation (Beckett, 1971). This value is obtained by extrapolating the linear part of the Q/I curve, which represents the K held in non-specific sites in the exchange complex viz., planar (Beckett and Nafady, 1968), which is easily accessible for exchange reactions. Though this value can not be taken as an absolute value of availability, it can be taken as an index of K availability.

In the present study, $-\Delta K^{o}$ showed a decreasing trend with the application of N fertilizers. This trend could be explained in the following manner. In soils with montmorillonite as the dominant clay mineral, the extent of negative charges in the planar sites could be comparitively less than the inter lattice space. The planar sites are non-specific and less selective for K, whereas the inter lattice space is highly selective and specific for K ions (Grimme, 1976). Hence in these soils, K would be much prevalent in the specific sites than in planar sites. Therefore, the applied N could have replaced the K in non-specific sites i..e planar positions, at lower levels and might have blocked the edges of the interlattice space at higher levels. This might possibly result in a situation where in the planar sites being occupied by NH_4^+ ions thereby reducing the easily exchangeable form of K viz., $-\Delta K^{o}$.

Thus, the present study indicated reduced $-\Delta K^{o}$ values with increased application of N fertilizer. The increase in $-\Delta K^{o}$ due to K application was evident in the present study due to the increase in the exchangeable K content. This finding corraborates with the results of Beckett (1971) and Durairaj Muthiah (1986). The release of labile K from the planar sites into the soil solution resulting from the depletion of K might have decreased the $-\Delta K^{o}$ values due to cropping. This finding is in close association with the findings of Durairaj Muthiah (1986) and Sparks and Liebhardt (1981).

5.1.3.3. Potential Buffering Capacity of K (PBC^{K})

The PBC^{K} values of a soil represents the amount of K that must be added or removed to cause a given change in AR_{e}^{K}. Beckett (1971) reported that the PBC^{K} was not affected by short term changes in AR_{e}^{K}. In the present study, during Kuruvai and Thaladi seasons, the PBC^{K} values were not changed due to cropping. The soils of Samba season being low in pH, clay content and organic matter could have shown decreased PBC^{K} values at higher levels of K application. Beckett and Nafady (1968) reported that the variation in the PBC^{K} could be due to the pH and adsorbed organic matter content, because of which the PBC^{K} was reduced due to K fertilization. At lower levels of K application, higher values of PBC^{K} was observed, which could be attributed to the low saturation of exchange compelx with K at lower levels of K application. Close negative correlation between AR_e^K and PBC^K ($r = -0.615^{**}$) furthur supports this finding. Ie Roux and Sumner (1968) reported increased PBC^K values due to increased preference for K at lower levels of K application.

5.1.3.4. Woodruff's Free Energy (ΔG)

The ΔG value, which is computed from the Q/I parameters, describes the ease with which the K^+ ions got desorbed from the clay complex. The low values of ΔG denotes the low tenacity of the ions held in the clay complex and hence they can be easily desorbed. The higher values of ΔG with the higher levels of N observed, indicated that K^+ ions are held more tenaciously in the presence of increased amounts of NH_4^+ ions. This could be attributed to the role of NH_4^+ ions in blocking the release of K^+ ions from the specific K exchange sites as elucidated earlier in the present study. The increase in the levels of K application caused reduction in the ΔG values was established in the present study irrespective of the seasons and levels of N application possibly due to increased concentration of K in the non-specific sites which was released with much ease. Ganeshmoorthy and Biswas (1984) and Durairaj Muthiah (1986) were also of the same view. Cropping increased the ΔG values in the present study. Depletion of K due to cropping would have caused increased ΔG values, as also observed by Mahendra Singh et al. (1982) and Durairaj Muthiah (1986).

5.1.4. Relationship Studies among the K Extracted by Different Extractants and Q/I Parameters

Since K is in a dyanamic equilibrium in the soil with its different forms, no single method presisely predicts the K availability in soils under all situations. Depending upon the strength aand composition of the extractants used, the amount of K extracted varied. Even though there were wide variations in the actual amounts of K extracted by different extractants, the relative proportions of K from different forms of it could be seen. As the extractants derived the K from a common pool, there existed a close relationship among the K extracted by different extractants. This finding is in close association with the observations of Ramanthan (1977), Durairaj Muthiah (1986), Singh et al. (1986) and Prezotti and Defelipo (1987).

The AR_e^K values and the K extracted by different extractants are closely related. The $-\Delta K^o$ was not related to the K extracted by most of the extractants because in the methods of K estimation, K was computed in the solution which contained the K desorbed from the exchange complex whereas the $-\Delta K^{o}$ denotes the K held in the low perferential, non-specific planar sites in a system of complete equilibrium. Hence relationship was not exhibited. Close negative relationships were obtained between the PBC^{K} and the K extracted by different extractants. A well buffered soil could release least amount of K in the soil solution as reported by Grimme (1976). Similarly, negative relationships between the ΔG values and K extracted by different methods could be attributed to the high tenacity of the adsorbed K^{+} ions resulting in the low extraction by the extractants.

The interdependance of AR_{e}^{K} and $-\Delta K^{o}$ values was clearly evident from the existance of close relationship between these two parameters. Similarly negative relationship between $-\Delta K^{o}$ and ΔG values was evidently clear indicating that higher ΔG values would mean a low value of labile K. The AR_{e}^{K} was negatively related to PBC and ΔG values whereas, PBC^{K} was positively related to ΔG values as could be expected.

5.1.5. Effect of N and K Levels on the Forms of K

The low clay content and low CEC of the soil of Samba crop resulted in the increased water soluble K fraction with increasing levels of N compared to the soils of Kuruvai and Thaladi which contained high clay content and CEC. This could be the reason for the low values of water soluble K fraction at higher levels of N. Grimme (1976) reported that soils of low clay content had higher K in soil solution and the reverse was true in the case of heavy clay soils. The soils of Samba crop contained lesser clay content and low buffering capacity and hence resulted in increased soil solution K when N was applied. The water soluble K also increased with the increase in the levels of K as could be expected. This finding is an accordance with the results of Ekambaram and Kothandaraman (1983) and Chakravorti et al. (1988). This increase was observed only during tillering and panicle initiation stages but not during post-harvest stage which might be due to the increased uptake of K at maturity as also observed by Ramanathan and Krishnamoorthy (1973) who reported increased K uptake with the increase in the K fertilization. There was depletion in the water soluble K with the advancement of sampling due to crop removal which is in accordance with the results of Ekambram and Kothandaraman (1983).

The exchangable K fraction of the soil increased with the increase in the levels of N, due to the release of K by the NH_4^+ ions. Similarly, increased levels of K application also increased the exchangeable K fraction due to increased ionic activity of K in soil solution by K application. Advancement of sampling decreased the exchangeable K due to the increase uptake of K with the crop growth. The results of Kar et al. (1975), Ekambaram and Kothandaraman (1983) *and Chakravorti et al. (1988) lend* support to the present findings.

The non-exchangeable K fraction increased with the increasing levels of N and K possibly due to the dyanamic equilibrium of this form with the water soluble and exchangeable K which were increased by the application of N and K. The non-exchangeable K fraction decreased with the advancement of crop growth due to the uptake of K from the solution and exchangeable K which could have resulted in the release of K from the non-exchangeable fraction. This result is in accordance with the results of Ramanathan (1977) and Durairaj Muthiah (1986).

5.1.6. Forms of N as Influenced by N and K Application

The ability of a soil to supply nutrients depends on the presence in the soil, of adequae nutrients in forms the plant can absorb; the soils ability to deliver nutrients by mass flow and diffusion to the root surface, which according to Parish (1971) is high in soils with a high water content; the presence of favourable ionic composition and the absence of substances in the solution that interfere with movement of nutrients into the root. In submerged paddy soils, the physico-chemical properties that control fertility are the pH, Eh, specific conductance, ionic strength, ion exchange, sorption and desorption, chemical kinetics and mineral equilibria (Ponnamperuma, 1977). Among the different forms of N, the NH_4-N is the most dominating ion in the rice soil and its existance or further mineralization into NO_3-N is governed mainly by the redox potential of the soil. As could be expected, the NH_4-N extent increased with the application of N in all the seasons of the present study as also observed by Nitant (1974), Sattar (1975), Shankhyan and Shukla (1978) and Velu et al. (1986). This trend was observed at earlier phases but at latter stages, the effect of N was not well pronounced due to the increased uptake of N when the crop was attaining maturity, corresponding to its application. The increase in NH_4-N content with K application could be attributed to the exchange of NH_4^+ ions by the K^+ ions in both the specific and non-specific sites. This is in conformity with the results of Sato et al. (1980). The depletion of soil solution NH_4-N content by crop uptake might be the reason for the marked decrease in the NH_4-N content of the soil which is in line with the works of Bhoiya et al. (1974), Sattar (1975), Shankhyan and Shukla (1978) and Velu et al. (1986). The NO_3-N content almost followed the same trend as that of the NH_4 -N excepting that the highest NO_3-N content was observed in the post harvest stage of the crop growth during Samba and Thaladi seasons due to the draining of the water prior to harvest which resulted in the oxidation of NH_4-N to

NO_3-N. But during Kuruvai season, the harvest of the crop coincided with heavy rainfall resulting in the continuous submergence of the field and hence the reduced conditions was prevalent till the harvest of the crop and as a consequence the NO_3-N content was the least.

5.1.7. Effect of N and K Application on the Available Nutrient Status of the Soil

Increasing levels of N and K application enhanced the available N and K contents due to the reasons brought out in the earlier part of the discussion. The available P content increased due to the favourable interaction of N and K on increasing the P availability. The plants derive their nutrients from soil for their growth and development leading to the depletion of soil available nutrients. Similar observations were also made by Durairaj Muthiah (1986).

5.1.7. Influence of N and K on Rice Yield

Increase in the drymatter production and grain and straw yields of the crop was obtained in the present study with the addition of N fertilizer in all the three seasons of experimentation. The soils were low in available N status and hence responded positively to N application. The soils contained high amount of NH_4OAc extractable K and hence its application did not result in any increase in the drymatter and yield of rice. Sparks (1980) opined that lack of crop response to K application on soils of high K content was due to the high indigenous level of mineral and non-exchangeable K, which became available to crop during its growth. Ramanathan and Palaniappan (1987) concluded that in Adanur soil series where the present study was also conducted, significant response for K application was obtained only from the fifth crop.

Response functions between the yield and the N levels indicated linear relationship during Samba season and quadratic relationships during Kuruvai and Thaladi seasons. The physical and economic optimum levels of N were computed as 244 and 222 kg $N \cdot ha^{-1}$ during Kuruvai season and 169 and 159 kg $N \cdot ha^{-1}$ during Thaladi season respectively. Thaladi season synchronising with winter coupled with low temperature, high humidity and intensive rain due to North East monsoon favoured low soil temperature, reduced mineralization and uptake of nutrients and yield of rice. This has favoured for low value of optimum N during this season and recorded low yield.

The response functions of N at varying levels of K revealed an interesting finding, where in increasing levels of K application increased the response of rice to N application as could be seen from the increasing values of physical and economic optimum of N. This might possibly be due to the increased uptake of N and raised K_2O/N ratio of plant which could have resulted in the increased yield and response (Mandal and Des Mahapatra, 1982). Similarly, the reduced resonse of rice to N at low levels of K might be due to the less utilization of N, decreased photosynthesis and export of photosynthetic products from leaves which could have reduced the yield of the crop (Lips, 1985). The observatiions of Tahir Saleem et al. (1980) Von Peter (1985) and Tandon and Sekhon (1988a) lend support to the present findings.

5.1.9. Effect of N and K Application on the Content of Nutrients in Grain and Straw

With increasing levels of applied N and K, the contents of N, P and K in grain and straw increased which could be due to increased availability, absorption and translocation of these nutrients to the economic parts. Similar observations were also made by Durairaj Muthiah (1986). The increase in the K content of the grain and straw was also observed by Chakravorti et al. (1988). It was also observed that the content of N, P and K in the straw were high at tillering stage. Such increased concentration of nutrients at young stage could be due to the combined effect of increased availability and absorption of the nutrients and relatively low biomass production. With the advancement in the growth of the plants accompanied by the corresponding increase in drymatter production, the concentration of nutrients get reduced due to dilution. Also at maturity stage, the nutrients get translocated into the economic parts of the plant which also resulted in the low concentration at later stages. This result is in accordance with the findings of Durairaj Muthiah (1986).

5.1.10. Uptake of Nutrients by the Grain and Straw as Influenced by N and K Application

The uptake of the nutrients is governed by the availability of the respective nutrients in the soil. In the present study since the availability of the nutrients was markedly influenced by the interaction of N and K, the uptake of the nutrients was also correspondingly influenced by this interaction. The increased uptake of N with increasing levels of N application and accompanying increased N availability was evident in the present study. The interaction effect of N and K in influencing the uptake of these nutrients was clearly seen in the present study. The uptake of N increased with the application of K and vice versa might be due to the enhancement of N availability resulting from the release of NH_4^+ ions from the clay complex. Close correlation ($r=0.759^{**}$) obtained between the available K and available N also confirmed the favourable interaction of N and K. The favourable effect of K application on increasing the N uptake of grain was noteworthy, even though the crops did not respond to K application. Singh and Sinha (1975) Esakkimuthu et al. (1975), Mandal and Das Mahapatra (1982) and Von Peter (1985) also made similar observations. The increased uptake of P with the application of N and K might be due to the higher translocation of P and higher yield of the crop due to their application. This result is in confirmation with the works of Dutta and Barua (1978).

The uptake of K also increased with the application of N which might be due to the favourable and positive interaction of N and K in increasing the K content of the grain. The application of N also increased the yield of the grain which could have resulted in the higher absorption of K by the crop and consequent translocation to the grain. This result is in confirmity with the findings of Singh and Sinha (1975), Raju and Varma (1982), Patel and Khatri (1983) and Tandon and Sekhon (1988a). Increased uptake of K with K addition observed in the present study could be attributed to the increased availability and absorption of K when K was applied as observed by Chakravorti et al. (1988).

Similar to the uptake of nutrients by grain, the straw uptake of nutrients was favourably increased with the application of N and K. The uptake of the nutrients progressively increased with the crop growth and maximum accumulation was observed at harvest stage due to the higher dry matter production and higher absorption of nutrients at this stage.

5.1.11. Relationship Studies for Identifying Suitable Extractant for Predicting the K Availability

The terms 'availability' and 'available amount' of nutrient are not synonymous since the availability of a nutrient is a complex phenomenon controlled by many soil edaphic and pedogenic factors. This is more often true in the case of soil K owing to the fact that not only the exchangeable K which is often denoted to represent K available status of soil but also a part of the non-exchangeable K which is released and utilised for crop use.

The most important factor which contributes for plant growth is the nutrient availability. The nutrient availability is influenced both by the quantity of nutrient present and the rate at which the given quantity is released or supplied for plant absorption. Hence poor relationships obtained more frequently between soil test results and crop responses are often attributed to the failure of the method to describe the K availability.

In the present investigation, an attempt was made to compare the relative performance of 15 extractants with an aim to choose a better index of K availability which could be used to predict not only the yield but also the K uptake. The results of the simple correlation studies indicated that out of the 15 extractants compared for their efficiency and relative performance to predict the yield parameters of rice and K uptake values, the 1N HNO_3-K and 0.01N HNO_3 -K were more closely related to the grain yield and K uptake values respectively. The validity of these findings was also verified by working out multiple regression analysis. The results of both simple correlation and multiple regression analyses indicated that 1N HNO_3-K was found to be best extractant for predicting the grain yield of rice. Elsewhere, 1N HNO_3-K was found to be the best index of K availability by Ghosh and Ghosh (1976), Ramanathan (1978) and Pieri and Oliver (1987). Pieri and Oliver (1987) opined that in soils where K response was absent and where clay mineral was illitic, the K extraction by 1N HNO_3 could be the best index of K availability. The results of the simple correlation and multiple regression analysis indicated that 0.01N HNO_3-K could be a better index of K availability to predict the total uptake of K and uptake of K in grain and straw. Ramanathan(1975) concluded that in reality, the actual amount of available K is truly reflected by plant uptake. Hence any single method of K determination which approaches more closely the actual uptake of nutrients by plant can be considered as a reliable and suitable method. In that context, 0.01N HNO_3 can be recommended as a better method of K determination. Though many workers (Ramanathan, 1977 and Nagarajan et al., 1982) concluded 0.1N HNO_3-K as the best index of K availability, in the present study, 0.01N HNO_3-K was found to be a better index of K availability compared to 0.1N HNO_3-K.

The most popularly and widely used N NH_4OAc-K as a measure of K availability index has certain limitations. This was evident from the present study since the values of 1N HNO_3-K and 0.01N HNO_3-K were found to be better related to predict grain yield and K uptake values respectively than the N NH_4OAc-K. The possible reasons for such conclusions could be explained as follows: The similar ionic radius and charge of the NH_4^+ as that of K^+ may result in the replacement of K^+ in the inter layer positions and may also cause the layers to collapse at the edges, entrapping K in the inter layer positions (Van Diest, 1978). Although this phenomenon is dependent on the type of dominant clay minerals and moisture content, it may reduce the suitability of NH_4OAc-K for all type of soils. Hence the 1N HNO_3-K and 0.01N HNO_3-K were ragarded as better indices of K availability in the present study for predicting rice yield and K uptake values respectively.

5.2. Pot Culture Experiments

Thanjavur district occupying a major area of Cauvery delta is endowed with fairly large number of soil series. Twenty two soil series, covering an area of 7,66,888 hectares in the district, has been identified and out of which 10 major soil series covering an area 6,20,955 hectares (81 per cent of the total area) was selected for the present pot culture experiment. The heterogenity of the soils selected and the dynamic nature of the nutrients element K necessiated the study of the K dynamics in these soils with a special reference to the interaction of N and K. The results thus obtained and enumerated in section 4.2 are discussed here under.

5.2.1. General Properties of the Soils Used in the Pot Experiment

All the ten soils used for the study were low in their available N status, medium in their available P status except Valuthalakudi soil which was low in the content. The available K status varied among the soils, the Padugai, Kondal, Valuthalakudi, Madukkur and Pattukkottai soils were medium and the rest of the soils contained high levels of NH_4OAc extractable K. The taxonomic classification of teh soils indicated that all the ten soils can be grouped into three orders viz., Vertisols, Alfisols and Entisols. It is noteworthy to mention that the soils belonging to Alfisols and Entisols contained medium level of available K while the soils of Vertisols possessed high level of available K. This could be attributed to the weathering of the K bearing minerals in Vertisols and to its higher amount of clay content particularly of montmorillonitic type. This could have favoured the Vertisols to retain more K and enriching the soil non-exchangeable K. On the contrary, the Alfisols and Entisols were low in clay content, predominantly of Kaolinitic type having low CEC and hence possessed lesser amount of exchange and fixation sites for K, thus retaining relatively less amount of K in soil. Tandon and Sekhon (1988) opined that the Aridisols contained the highest exchangeable K fraction which decreased progressively in Mollisols, Vertisols, Inceptisols, Oxisols, Alfisols, Entisols and Ultisols.

Investigations on the K potential parameters of these soils revealed that highest AR_e^K values were registered in Kivalur soil series (6.50×10^{-3} $(m.l^{-1})^{1/2}$ followed by Pattukkottai (6.00×10^{-3} $(m.l^{-1})^{1/2}$). This might be due to the high K status and medium texture (clay loam) of the Kivalur soil and light texture and lateritic nature of the Pattukkottai soil which could have increased the activity of K with reference to Ca and Mg in soil solution. The high clay content of Adanur soil could be attributed to the lowest AR_e^K values of this soil.

The Kalathur and Valuthalakudi soils with the highest and lowest clay content respectively also recorded the highest and lowest labile K values ($-\Delta K^{o}$) which could be attributed to the direct relationship of $-\Delta K^{o}$ values with the total negative charges on the clay complex which governs the labile K status of the soils. The close relationship existing between $-\Delta K^{o}$ and clay content ($r = 0.81^{**}$) and CEC ($r = 0.815^{**}$) would furthur support this observation. The PBC^{K} value was the highest in Kalathur soil and decreased correspondingly to the clay content of the soils. The Kalathur soils also had the highest ΔG values revealing that the K^{+} ions in these soils are more tenaciously held. The ΔG values were lower in Pattukkottai, Kivalur and Valuthalakudi soils on account of their light textured nature.

5.2.2. Availability Indices of K in Soils

Though the soils of Thanjavur district are of cretaceous, tertiray and alluvival deposits, the major area is however occupied by the alluvial and tertiary deposits of the river Cauvery. The thickness of river deposits ranges from 30 metres in the inland to 400 meters near the coast (Dhanapalan Mosi et al., 1974). As the soils had been irrigated from river Cauvery for centuries, the soils had progressive pedogenisity and alterations due to frequent floods and alluvial deposits leading to a high heterogenity among them. On account of the heterogenity of these soils, the behaviour of K was also unique and varied markedly among the soils. As a result, there had been certain amount of difficulties in choosing a precise and reproducible method for determining K availability. Hence different extractants were used from time to time for predicting K availability. In the present study the efficiency of different extractants was compared and the extractability as influenced by the application of N and K fertilizers in different soils was investigated.

The K extracted by different extractants varied depending upon the strength of solution used. The highest value of 285 ppm of K was extracted by 1N HNO_3 and water extracted the lowest value of K. In the majority of the soils, increase in K extraction with N application was prominent, whereas in some soils, higher levels of N decreased the amount of K extracted due to the blocking effect of NH_4^+ ions at the edge positions of the clay minerals. The differential behaviour of N could be attributed to the highly heterogenous nature of the soils with respect to its clay mineralogical composition. Kar et al. (1975) and Sato et al. (1980) also observed increased K extraction due to N application in their studies. As also opined by Ramanathan (1977) and Durairaj Mathiah (1986), the K extracted by different extractants increased with K application.

The Kivalur soil being rich in K status and medium textured released more K in solution and hence registered the highest values of K by all the extractants. The Valuthalakudi soils were coarse textured and contained low level of K and hence released less K in solution and recorded the lowest K extraction. This result corraborates with the findings of Grimme (1976).

At varying levels of K, N behaved differently. When the concentration of NH_4^+ ions was higher in solution than the K^+ ions, at low levels of K, NH_4^+ ions released the K^+ ions from the specific and non-specific sites resulting in the increase in the solution K. But at higher levels of K, K fixation was maximum in the presence of higher levels of NH_4^+ (Ramanathan, 1977) resulting in the blocking of K ions in their high preference specific sites. The blocking effect of NH_4^+ was also observed by Singh and Sinha (1975). Further, in the presence of equal amounts of NH_4^+ and K^+ ions, the preferential fixation of NH_4^+ ions could result in the release of K ions from the specific and non-specific sites. But the higher activity of K ions, at higher levels of K application, than the NH_4^+ ions would result in the preferential adsorption and fixation of K ions which would be blocked by the NH_4^+ ions resulting from urea hydrolysis, at the edge positions of clay minerals. In the residual crop, this effect was not observed due to the fact that this crop did not receive K and hence and applied N released more K into solution. The increased activity of NH_4^+ ions in solution, in the absence of K could have resulted in the release of K from the planar and inter lattice positions.

5.2.3. Changes in the Quantity/Intensity parameters

The quantity and intensity parameters tend to differ among the soils of the same series notably due to liming and differences in clay content (Beckett, 1971). The soils chosen for the present study were highly heterogenous of varying clay composition, resulting in wider differences in their quantity and intensity parameters.

As regards the AR_e^K values, the Pattukkottai soils being coarse textured (sandy loam) could have released more K into soil solution contributing to the higher ionic activity of K resulting in higher AR_e^k values as also observed by Sharma and Mishra(1986) who were of the view that the coarse textured soils released mored K in solution.

Further, the soils of Pattukkottai series were lateritic in origin with Kaolinite as the predominant clay mineral which could have also contributed for higher AR_e^K values on account of the fact that the K is held with low tenacity (Durairaj Muthiah, 1986). Similar results of higher activity ratio of K being associated with soils of low clay content were also reported by Ramakrishnayya and Chatterjee (1976) and Maji and Sengupta (1982). The low AR_e^K values observed in the present study in Adanur, Kondal, Padugai and kalathur soils might he due to the high clay content of these soils which could have resulted in the low concentration of K in solution because of the high tenacity of the K^+ ions on the clay complex. Zandstra and Mackenzie (1968), Subba Rao et al. (1984) and Durairaj Muthiah (1986) made similar observations in their studies. Negative correlation existing between the clay content of the soils and the AR_e^K values (-0.58^*) furthur supports this trend. The AR_e^K values did not vary markedly due to crop removal on account of the fact that the depleted K was replenished from the total pool as most of the soils were rich in K.

The labile K values ($-\Delta K^o$) of the Kalathur soil was the highest due to the high clay content of predominantly 2:1 montmorillonitic type. The surface area of the montmorillonitic clay being higher could have resulted in the higher retention of K^+ ions in the non-specific sites. The Pattukkottai and Valuthalakudi soils were coarse textured containing 1:1 Kaolinite clay mineral of less surface area and hence recorded the lowest labile K values. This result is in accordance with the finding of Biddappa and Sarkunan (1981) and Durairaj Muthiah (1986). Close relationships obtained for the labile K values with clay content of the soil ($r = 0.81^{**}$) and CEC ($r=0.815^{**}$) lend support to the above inference. The depletion of K from soil solution by crop uptake might have resulted in the release of K from the non-specific sites initially and hence the $-\Delta K$ values decreased due to cropping as also observed by Durairaj Muthiah (1986) and Sparks and Liebhardt (1981).

The PBC^K value which is a measure of the ability of soil to resist the reduction in the relative activity of K (AR_e^K) was higher in Kalathur, Adanur, Kondal and Padugai soil series due to the high clay content of these soils. The Pattukkottai and Valuthalakudi soils being coarse textured and low in clay content possessed the lowest PBC^K values. Furthur, the presence of 2:1 expanding clay minerals in the former group of soils with high CEC could have accounted for higher category of soils which contained predominantly 1:1 non-expanding clay minerals of low CEC. This result is in accordance with the reports of Zandstra and Mackenzie (1968), Ram and Prasad (1981), Bandyopadhyay et al. (1985) and Durairaj Muthiah (1986). The close correlations among PBC^K and clay content (0.775^{**}), fine sand (-0.824^{**}), coarsee sand (-0.614), total K (0.665), organic carbon (0.565^{*}) and CEC (0.745^{**}) furthur support this finding.

The Woodruff free energy values (ΔG) which are measures of the ease with which the K^+ ions are desorbed, were higher in Adanur, Kondal and Padugai soils and lower in Kivalur, Pattukkottai, Nedumbalam and Madukkur soils. The higher ΔG values of the former category of soils might be due to the high tenacity of K^+ ions on the clay complex owing to the high exchange capacity of these soils. The low clay content and poor exchange capacity of the Madukkur and Pattukkottai soils could be related to the low ΔG values of these soils. This result corraborates with the findings of Balasundaram (1973), Ramanathan (1977), Mahendra Singh et al. (1982), Valliappan (1984) and Durairaj Muthiah (1986). The Kivalur and Nedumbalam soils which were clay loam and sandy clayey in texture respectively registered comparable ΔG values with that of Pattukkottai and Madukkur soils which might possibly be due to the mixed clay minerology of these soils which could have resulted in this differential behaviour.

5.2.5. Dynamics of K in Different Soil Series as Affected by N and K Application

The dynamic equilibrium of K existing between different forms of soil K, has got a significant role to play while making fertilizer recommendations. The proportion of K in different forms varies with the soil and the driving force of this equilibrium is largely a functiion of clay composition, while the magnitude of the process is a function of the clay content of a given soil (McLean, 1978). In the present study, soils varying widely in their clay composition and clay content were investigated resulting in the differential behaviour of this equilibrium among the soils.

The low values of water soluble K at higher levels of N might be due to the possible blocking effect of the NH_4^+ ions at the edge positions of the clay minerals reducing K concentration in soil solution as described in the earlier parts of this Chapter. Singh and Sinha (1975) also made similar observations. Increased exchangeable K fraction with increase in the levels of N observed in the present study might be due to the higher polarisability of K ions over NH_4^+ ions, which could have increased the preference of K^+ ions in the ion exchange reactions as opined by Sparks (1987). This effect was not pronounced in the residual crop, due to the fact that in the absence of K, higher activity of NH_4^+ ions in solution would result in the release of K^+ ions from the clay complex.

The increase in water soluble K fraction with the addition of K was observed in the first crop while the levels were comparable in the residual crop. The depletion of K in the residual crop corresponding to its drymatter production which was proportional to N application might be the reason for this trend. Ramanathan and Krishnamoorthy (1973) reported similar results. The increase in the exchangeable and non-exchangeable K fraction of the soil with the addition of K might be attributed to the dynamic equilibirum of these fractions with the soil solution K. The above trend was clearly manifested during the first season crop due to increase in the concentration of applied K, whereas the residual crop did not show such an increase as it did not receive K application.

The high level of water soluble and exchangeable K fraction in the Kivalur soil series could be attributed to the high K status of these soils coupled with low CEC among the Vertisols. Though the Kivalur soil series belonged to Vertisol, it contained higher water soluble K fraction because of the fact that the soil was of recent origin (Dhanapalan Mosi et al., 1974) containing predominantly Kaolinite and illite as the dominant clay minerals (Ramanathan, 1977, 1979). Soils of recent origin and predominantly kaolinitic are known to possess relatively higher proportion of water soluble K fraction than the rest. A soil predominant with illitic clay minerals might also release considerable amount of K into solution. Besides these, it could be also possible that frequent dressings of K application resulting in saturation of the adsorption sites for K could also lead to increased water soluble and exchangeable K fractions. Hence in the present study, the Kivalur soil series had contributed for higher proportion of water soluble and exchangeable K fractions. The Kalathur soil was clayey in texture, containing predominantly montmorillonite clay of high amount of K specific sites, registered the highest non-exchangeable K fraction. All the forms of K were the lowest in Valuthalakudi soil which could be attributed to the coarse textured nature, preponderance of quartz, reduced occurrence of K minerals and poor K status of this soil. The Kalathur and Adanur soils being fine textured could have exhibited high resistence for K release in the residual crop which resulted in the low amount of water soluble K in the absence of K.

5.2.6. Fractions of N in Soils as Affected by N and K Applications

Increase in the NH_4-N and NO_3-N content with the addition of N was evident in all the soils as could be expected. Velu et al. (1986) made similar observations in their studies. The release of NH_4^+ from the clay complex might be responsible for the increased concentration of NH_4^+ ions at low levels of K application, whereas higher levels of K resulted in the blocking of NH_4^+ ions in the internal sites causing reduced concentration, of NH_4^+ in soil solution. Raju and Mukhopadhyay (1973) concluded that when NH_4^+ and K^+ ions were added simultaneously, because of the smilarly fixable K^+ and NH_4^+ ions, the release of already fixed NH_4^+ ions was prevented. Beauchamp (1982) also indicated that the addition of K slowed the release rate of NH_4^+ ions by blocking the NH_4^+ in the inner layers.

5.2.7. Available Nutrient Status of Soils as Influenced by N and K Applications

The availability of N of all the soils was enhanced with the application of N in both the crops in the present study. The applied K favouring the release of NH_4^+ from the exchange complex had increased the availability of N during the first crop. The residual effect of K applied to the first crop was not evident in influencing the available N content of the soil during the second crop season. The favourable effect of N application in increasing available P content of the soil was also seen in both the seasons. Similarly, availability of K was also promoted with the N and K applications. This result corraborates with the findings of Velu et al. (1986).

5.2.8. Effect of N and K Application on the Drymatter Production and Yield of Rice in Different Soils

The results of the present study indicated that the drymatter yield of rice increased correspondingly with every increase in the level of N applied in all the soils investigated and during both the seasons of experimentation. The effect of growth element N, in contributing for the increased biomass production is an established phenomenon. This was clearly evident in the present study due to the fact that the soils studied were deficient in available N content. As regards the effect of K fertilisation on the drymatter production of rice, five soils out of ten viz., Kondal, Padugai, Valuthalakudi, Pattukkottai and Madukkur soil series responded to K application. These five soils being medium textured, relatively containing medium level of K had positively responded to K application. Although, Kalathur soil series was more fertile and rich in K than Pattukkottai soil series, yet the latter recorded the highest yield in the first crop which could be attributed to the depressive effect of addition of K to Kalathur soil which was rich in K. This is supported by Patel and Khatri (1983) who reported that addition of K to a soil rich in K reduced the crop yield by decreasing N and P absorption. However, in the residual crop, which did not receive K, the Kalathur soil series registered the highest production, possibly due to the crop removal of K in the first season accompanied by the beneficial effect of N application. Hence the possible ill effect of addition of K to the K rich Kalathur soil series during the second crop season was nullifield due to the depletion of K suggesting that withholding the K application to such K rich soil was beneficial.

The favourable effect of N in increasing the yield of rice grain was also spectacular, the increase being linear with corresponding increase in the level of N. But the effect of K was pronounced only in five out of ten soils investigated. In Kondal, Padugai, Madukkur and Pattukkottai soil series, the levels of K being comparable registered higher grain yield than control. Thus it is concluded that in these soil series, application of K at 50 kg $K_2O \cdot ha^{-1}$ level to be adequate for obtaining higher yield of rice. In respect of Valuthalakudi soil series, which was coarse textured and medium in available K, the higher levels of K were comparable and superior to lower levels of K. This indicated that 100 kg $K_2O \cdot ha^{-1}$ would be the desired dose for obtaining higher grain yield of rice in Valuthalakudi soil series. Based on the response obtained to K application in the chosen 10 soil series of Cauvery delta discussed above, it could be concluded that five out of 10 soils did respond to K applicatiion. It is note worthy to mention that these soils which responded to K application were either medium or low in available K status. The soils which did not respond to K application were rich in K status. Therefore, concluding from the foregoing inferences, the validity of the grouping of soils into low, medium and high K soils still holds good under such situations as that of the present study.

Increase in the yield of grain with corresponding increase in the application of N was also evident from the response functions worked out relating the grain yield and levels of N. This trend was clearly indicated during both the crop seasons. The trend of response was linear in almost all the soils during both the seasons. The soils investigated being low in available N had responded positively to N application.

Response of rice to K application observed in Kondal, Padugai, Valuthalakudi, Pattukkottai and Madukkur soil series was discussed earlier. However, the response functions fitted between grain yield and levels of K application in these five soil series were different during first and residual crop seasons. To the applications of different levels of K, the rice yield exhibited quadratic trend of response in the first crop whereas in the residual crop season , the response function became linear in four out of these five soils, excepting Kondal soil series, indicating marked depletion of K from the soil by the first crop. Thus the pattern of response of rice to K application in these five soil series revealed a definite answer in prediciting the K fertilizer application schedule. Existence of quadratic trend of response in these five soils in the first crop season which received K dressing and the response of rice turning to be linear in four soils in the residual crop, which did not receive K fertilisers, clearly indicated the possibility of withholding K application to these four soils only for one season. It is quite obvious that if K is with held for the subsequent crops in these soils it is likely that the nutrient K might become limiting restricting the rice yield. Kondal soil series being fine textured belonging to Vertisol and highly buffered containing greater retentivity to K accompained by gradual release of K into soil solution with advancement of time, could have contributed to the quadratic trend of response in both the crops compared to the other four soils. It is essential to mention here that in this soil, the physical and economic optimum of 144 and 109 kg $K_2O \cdot ha^{-1}$ respectively in the first crop had risen to 233 and 130 kg $K_2O \cdot ha^{-1}$ in the residual crop. This indicated that it is possible that the trend of response might become linear in the succeeding crop even in this soil if K application is withheld. Thus it could be inferred that judicious application of K to soil to replenish the depletion due to crop removal is essential in order to sustain the soil fertility and productivity. Durairaj Muthiah (1986) reported linear response to K fertilisation in Pattukkottai soil series owing to its low initial status, low cumulative K release, low $-\Delta K^{o}$ and PBC^{K} values and open textured nature of the soil. In the present study, five out of ten soils were medium textured with medium K status as revealed from the initial analysis.

Further, it is of interest to note that four out of these five soils belonged to either Entisols or Alfisols which were reported to be low in K status (Tandon and Sekhon, 1988b), compared to the remaining soils which were Vertisols. Linear response of rice to K application in Assam soils with low clay content was also reported by Barthakur et al. (1983). Absence of response of rice to K application in the rest of the soils was attributed to the high status of these soils. As the present study was restricted to two crops viz., the first crop with K application and residual crop as second crop, it was not possible to predict the pattern of response that could be expected in the succeeding crops. This suggests that furthur detailed investigation is necessary to draw definite conclusions of the patterns of response that could be expected and to arrive at the frequency of K application that might be necessary to these five soils.

5.2.9. Effect of N and K Application on the Content of Nutrients in Grain and Straw

Increased concentrations of N, P and K in both grain and straw were clearly evident with the addition of N and K in the present study. The increase in the absorption of N and K could be due to the increased availability of these nutrients in the soil with the application of these nutrients. The Synergistic effect of N and K on P availability and consequential increase in the P absorption might have contributed for higher P content of grain and straw. Similar observations were also made by Simonis and Nemeth (1985), Durairaj Muthiah (1986) and Chakravorti et al. (1988). Irrespective of the nutrients, lowest concentration of N, P and K was observed in the grain and straw in Valuthalakudi soil series which could be attributed to the poor fertility status of the soil.

5.2.10. Uptake of Nutrients as Influenced by N and K Application

The uptake of nutrients is a factor governed by the concentration of the nutrients and the drymatter production. The concentration of the nutrients is influenced by the availability of the respective nutrient in the soil. Increasing levels of N applicatioin increasing the N availability in soil could have contributed for increased absorption and corresponding increase in the drymatter production and uptake of N. Application of K increasing the available N in the soil was elaborately discussed else where in the foregoing pages (5.1.10) bringing out the favourable interaction of N and K. Thus, the uptake of N in grain and straw increased due to the application of K. Similar results were also obtained by Singh and Sinha (1975), Esakkimuthur et al. (1975), Mandal and Des Mahapatra

(1982) and Von Peter (1985). The higher uptake of N by grain and straw by K application was an indication of improved quality of these products which was worth mentioning in the present study despite the fact that five out of ten soils did not respond to K application. Increased uptake of P by grain and straw with the application of N and K might be due to the increased absorption of P resulting in the increased drymatter production. Dutta and Barua (1978) were also of the same view. The uptake of grain and straw increased with the application of N and K in the present study due to increased availability and absorption of K as discussed under field experimentation (5.1.10). The inherant poor fertility and productivity of the open textured Valuthalakudi soil series yielding the lowest drymatter yield registered the lowest absorption and uptake of nutrients.

5.2.11. Relationship Studies between the Grain Yield, Total K Uptake Values and the K Availability Indices

The relative efficiency of different extractants to predict the K availability in relation to grain yield and total K uptake was also worked out. Among the different availability indices of K, 1N HNO_3-K was found to be closely related to the total K uptake with the highest 'r' value in seven out of ten soils. The highest 'r' values of 0.820^{**}

and 0.766** were obtained between 1N HNO_3-K and grain yield and total K uptake respectively, when correlation were worked between pooled values of all the ten soils. This trend had clearly brought out the superiority of 1N HNO_3 as an extractant for K determination to predict the K availability.

SUMMARY AND CONCLUSIONS

CHAPTER 6

SUMMARY AND CONCLUSIONS

Potassium is a major component of the Earths' crust and is present in substantial quantities in most soils ranging form 0.1 to 3.0 per cent. Its availability to plants however, differs and is related in many ways to the physical chemistry and structure of soil minerals, intensity of weathering the primary minerals had undergone, nature and amount of secondary minerals and management practices adopted. Although much work has been done and reported on the dynamics of K in soils and its importance to the nutrition of plant,many aspects still remain to be studied and made clear. The availability of K to the plants is governed by many factors like the intensity, quantity and mobility factors. Hence any single method which could take into account all these parameters could be the best one to predict the crop response and uptake of K. The heterogenity and complexity of the soil in its natural system still add much more problem in identifying a suitable method which could predict the K availability in all the soils. The quantity/intensity parameter as described by Beckett (1964a) was one such method which considered all the three factors of K availability. Attempts were made to study the suitability of this method as an index of K availability in the soils of Thanjavur delta. Furthur, the submergence of the paddy soils results in drastic changes in the physical, chemical and physicochemical characteristics of the soils which would affect the K equilibrium. Because of the reduced conditions prevailing in the submerged soils, N compounds are mineralised to NH_4^+ form and furthur oxidation to NO_3^- form is retarded. The NH_4^+ with similar ionic radius and charge as K^+ is similarly fixable in the exchange sites. Hence in the present study, it was attempted to investigate the dynamics of K in the soils of Thanjavur district as influenced by N and K interaction with the objectives listed under Chapter 1. An attempt was made to compare the relative efficiency of different methods of K determination to predict the K availability in the chosen soils of Thanjavur delta.

To achieve the objectives of the study, three field experiments and two pot culture experiments were conducted at Tamil Nadu Rice Research Institute at Aduthurai. The field experiments were conducted with four levels of N (0, 50, 100, 150 kg $N \cdot ha^{-1}$) and four levels of K (0, 50, 100, 150 kg $K_2O \cdot ha^{-1}$) in three seasons (Samba, Kuruvai and Thaladi) with CR 1009, ADT 36 and IR 20 as test varieties. Ten representative major soil series of Thanjavur delta were also investigated with the above set of N and K treatment structures under pot culture conditions to study the response of rice to K fertilisation in these soils. The salient findings and conclusions drawn from the results of these experiments are presented below.

6.1. Field Experiments

The soils of the experimental fields belonged to Adanur series (Entic Chromustert) with low available N, medium available P and high NH_4OAc extractable K.

The K extracted by different extractants increased with N application during Kuruvai and Thaladi seasons and due to K application in all the three seasons. During Samba season, higher levels of N application reduced the K extracted by most extractants, which was attributed to the prolonged drying of the soil resulting in the blocking effect of NH_4^+ on the edge positions of the clay mineral. This could have resulted in the entrapment of K^+ in the inner positions and preventing K release.

There were positive inter relationships among different methods of K determination in the present study.

Among the Q/I parameters, the AR_c^K value increased at lower levels of N application but decreased at higher levels. It increased consistantly with K application and decreased with the advancement of crop growth due to the depletion of K by crop uptake.

The labile K ($-\Delta K^{o}$) values showed a decreasing trend with N application and increased with K application. The $-\Delta K^{o}$ values decreased with crop growth due to the uptake of K by the crops.

The PBC^{K} values were unaltered with N application in all the seasons and due to cropping during Kuruvai and Thaladi seasons. During Samba season, PBC^{K} values decreased after cropping due to low pH and low content of clay and organic matter of the soils.

Free energy values (ΔG) increased with higher levels of N and decreased with lower levels of N. Application of K decreased ΔG values. Values of ΔG increased due to cropping.

There existed positive relationships for the K extracted by different extractants with AR_{e}^{K} values, negative relation ships with PBC^{K} and ΔG values. The $-\Delta K^{o}$ values were not related to the K extracted by most of the extractants.

The water soluble K fraction increased with N application during Samba season and due to K application in

The response of rice to N application increased with the application of K which could be seen from the increased optimum levels of the N fertiliser at higher levels of K.

The response functions between the yield and levels of N were linear during Samba season and quadratic during Kuruvai and Thaladi seasons.

The physical and economic optimum levels of N for rice worked out to be 244 and 222 kg $N \cdot ha^{-1}$ during Kuruvai season and 169 and 159 kg $N.ha^{-1}$ during Thaladi season respectively.

With the application of N and K fertilizers, the contents of N, P and K in the grain and straw increased.

The uptake of N in both grain and straw increased with K application though there was no response to K application.

The uptake of N, P and K by grain and straw increased with the addition of N and K in all the seasons of experimentation.

Based on the relationship studies, 1N HNO_3 was found to be the best extractant for predicting the grain yield of rice.

The 0.01N HNO_3-K was found to be the best index of K availability for predicting the K uptake in rice.

The labile K $(-\Delta K^o)$ value was found to be a better index of K availability than AR_e^K, PBC^K and ΔG value.

6.2. Pot Culture Experiment

The ten representative soils chosen for the study were highly heterogenous as influenced by varying physico-chemical properties. The soils were derived from the alluvial deposits of river Cauvery belonging to three orders viz., Entisols, Alfisols and Vertisols.

The K extracted by all the extractants increased by K application. Increasing levels of N at lower levels of K, correspondingly increased the K extracted by most of the extractants. At higher levels of K, higher levels of N application decreased the release of K.

The highest and lowest AR_e^K values were obtained in the soils of Pattukkottai and Adanur series respectively which were related to the texture of the soils. The coarse textured Pattukkottai soil released more K into solution resulting in high AR_e^K values compared to fine textured Adanur soils.

Kalathur series contained the highest labile K ($-\Delta K^o$) and the lowest values were observed in Pattukkottai and Valuthalakudi soils. The labile K values decreased with cropping.

The fine textured Kalathur soil possessed the highest PBC^K value. The coarse textured Pattukkottai and Valuthalakudi soils contained the lowest PBC^K values.

Adanur, Kondal and Padugai soils recorded higher ΔG value and Kivalur, Pattukkottai, Nedumbalam and Madukkur soils registered lower values of ΔG.

The water soluble and exchangeable K fractions were higher in Kivalur soil series. Kalathur soil possessed the highest non-exchangeable K fraction. All the fractions of K were the lowest in the Valuthalakudi soil.

The yield and drymatter production of rice increased with the application of N during both the crops and in all the soils of the present study.

Rice responded to K application only in Kondal, Padugai, Valuthalakudi, Pattukkottai and Madukkur soils series.

The response functions were linear in eight soils between grain yield and N levels and quadratic in Nedumbalam and Madukkur soils in the first crop season. In the residual crop, response functions were linear in all the soils except Kondal and Kivalur where in it was quadratic.

The response functions of the five soils which responded to K application, were Quadratic in the first crop and linear in the second crop, except Kondal, which was again quadratic.

The content and uptake of N, P and K increased with increasing levels of N and K in all the soils chosen for the study.

The results of the simple correlation studies made between the values of K extracted by different extractants and the yield of rice and uptake of K indicated that 1N HNO_3-K was a better index of K availability.

The study revealed that the phenomenon of K equilibrium and the selection of any method of K determination are governed by nature and amount of clay minerals present in the soil. Hence a study on the clay minerology of the soils of Cauvery delta in relation to K availability is needed. In the present study response pattern of soil series of Thanjavur delta was investigated only for two seasons which revealed that in five out of ten soils, there was response to K application. Though response to K was not obtained in the remaining five soils, information is not available on the K status of these soils after two crops. Hence continuous cropping experiments in these soils will give more details about the response behaviour of these soils, for which studies are needed.

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* Originals not seen