INFLUENCE OF SOIL TEXTURE ON POTASSIUM AVAILABILITY, FIXATION AND UPTAKE BY RICE IN LATERITE SOILS

By

JESSYMOL, A S

THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE

Vellanikkara, Thrissur

1991

DECLARATION

I herebv declare that the thesis entitled "Influence of soil texture on potassium availability fixation and uptake by rice in laterite soils" is a bona fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society

Vellanikkara,

1-11-1991

JESSYMOL, A S.

Dr. K. A. Mariam,
Associate Professor,
Department of Soil Science &
Agricultural Chemistry

College of Horticulture,
Vellanikkara,
Dated Ist November, 1991

CERTIFICATE

Certified that this thesis entitled "**Influence of soil texture on potassium availability, fixation and uptake by rice in laterite soils**" is a record of research work done independently by Miss Jessymol A S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her

K. A. Mariam
Chairperson,
Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of Miss Jessymol A S., a candidate for the degree of Master of Science in Agriculture majoring in Soil Science and Agricultural Chemistry, agree that the thesis entitled **"Influence of soil texture on potassium availability, fixation and uptake by rice in laterite soils"** may be submitted by Miss Jessymol A.S., in partial fulfilment of the requirement for the degree

Chairperson

Dr K. A. Mariam
Associate Professor
Department of Soil Science & Agricultural Chemistry
College of Horticulture

Members

Dr. A.I. Jose
Professor and Head
Department of Soil Science & Agricultural Chemistry
College of Horticulture

Dr. K C. Marykutty
Associate Professor
RARS, Pattambi

Sri V K G. Unnithan
Associate Professor
Department of Agricultural Statistics
College of Horticulture.

ACKNOWLEDGEMENT

I feel immense pleasure in extending my unbounded gratitude and sincere thanks to **Dr. (Mrs.) K.A. Mariam**, Associate Professor, Department of Soil Science and Agricultural Chemistry, and Chairperson of my Advisory Committee, for her incessant inspiration, untiring interest, constructive criticisms and manifold help bestowed throughout the course of this investigation.

Grateful acknowledgement is also due to **Dr. A.I. Jose**, Professor and Head, Department of Soil Science and Agricultural Chemistry for his timely help, valuable suggestions and critical comments during the period of this study.

I owe sincere thanks to **Mr V.K.G. Unnithan**, Associate Professor, Agricultural Statistics and **Dr. (Mrs.) K.C. Marykutty**, Associate Professor, RRS, Pattambi, Members of my Advisory Committee, for their valuable suggestions and help

My heart-felt gratitude to all the staff members of the Department of Soil Science and Agricultural Chemistry for their timely assistance Special thanks are also due to **Dr. (Mrs.) Alice Abraham**.

I express my deep respects to Mr. P.M. **Augusthy**, Agricultural Officer, Department of Agriculture for his kind help rendered in collection of soil samples

I shall be failing in my duty if I do not thank **Dr. P.K. Thampi**, Head, Geo Science Division, Centre for Earth Science Studies, for providing all the necessary facilities and. **Miss. T.S. Anitha** and **Mr. V. R. Pravinkumar**, Junior Research Fellows for their help, in the mineralogical studies

Sincere thanks are also due to **Mr. P.V. Prabhakaran**, Professor and Head, Department of Agricultural Statistics, for providing the necessary facilities in the computer analysis of the data.

I earnestly express my heartfelt thanks to **Dr. R S.Aiyer**, Former Head, Department of Soil Science and Agricultural Chemistry, College of Agriculture and **Dr. P.S John**, Associate Professor, Department of Agronomy, College of Horticulture, for helping me with their personal collections of literature

I also take this opportunity to thank all my friends for their help and inspiration

Diction is not enough to express my indebtedness to my beloved mother, brother, sisters, brothers in law and sister in-law for their unfailing support and constant encouragement throughout the course of my study

I wish to acknowledge the ICAR for awarding the Junior Research Fellowship

Last but not the least, I thank God Almighty for enabling me to complete this venture successfully

JESSYMOL, A. S.

To

my

beloved

Mother

CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF PLATES

LIST OF APPENDICES

Introduction

INTRODUCTION

Potassium is one of the major nutrients required for crop production and is taken up in large amounts by plants. It acts as a chemical carrier, regulating the movement of other nutrients, in the plant system. Potassium helps to control or reduce the severity of plant diseases and increases the plant's resistance to drought and other stress situations. Adequate potassium supply helps to improve the quality of fruits and vegetables. It enhances the synthesis and translocation of carbohydrates, thereby encouraging cell wall thickness and stalk strength in cereals.

It is a major component of the earth's crust and its concentration in soil normally varies from 0.5 to 2.5 per cent. In soil it occurs in the form of primary and secondary minerals. Its availability to plants however differs according to the soil environment.

Soil potassium exists in four forms namely the mineral potassium, nonexchangeable potassium, exchangeable potassium and soil solution potassium. All these are in a dynamic equilibrium with each other. It is also present in traces in the organic component of the soil.

The native potassium status of soils depends on their parent material, climatic situations and its subsequent stage of weathering For instance, soils formed in humid tropical region, such as laterite soils, contain less potassium than those developed under arid or semiarid situations Moreover, the mineralogical composition of soil imparts a profoundly unique relationship on the existing potassium dynamics A major fraction of the primary and secondary potassium bearing minerals is found to occur in different sized soil particles Hence availability of potassium primarily depends upon the composition and proportion of each of these soil separates

In Kerala, laterite soil covers nearly 60 per cent of the total land mass Rice is the major crop grown in the lowland laterites in many of the districts In these soils, the available potassium status is highly variable At present the fertiliser recommendations are made based on the soil chemical analysis without giving importance to the textural class, eventhough the ability of the soil to retain and release potassium largely depends on the proportion of soil separates and the mineralogical composition Hence the present study was undertaken with the following specific objectives

1 To study the physico-chemical characteristics of soils related to potassium availability in soils of different texture

2 To evaluate the changes in potassium dynamics in soils of varying texture on application of potassium fertiliser

3 To find out the mineralogical composition of the primary fractions of the soils selected for the study, and

4 To determine the effect of applied potassium in soils of different clay content on the yield and uptake of nutrients by rice

Review of Literature

REVIEW OF LITERATURE

Rice cultivation in Kerala is carried out mainly in lowlands under different soil situations Even though different soil types are involved, fertiliser recommendations are made based on soil test only without giving importance to its textural class The information on the textural characteristics of the soils and their influence on the potassium supplying power would be more helpful in assessing the exact requirement of potassium Such studies are meagre in lowland laterites of Kerala Studies related to the above aspects are reviewed as follows

1. Physico-chemical characteristics of laterite soils.

The colour of laterite soils depended on the content and form of iron hydroxides and oxides which imparted the yellow, pink, brown and red colours to the ground matrix and earthy clay (Sathyanarayana and Thomas, 1961)

Sivarajasingham et al (1962) observed that the laterite could be formed over a variety of parent rocks ranging from basic rocks like basalt and diorite on one side to acid rocks like granite and gneiss on the other

In the cultivated soils of Kerala the absolute specific gravity and apparent specific gravity appeared to be a function of *coarser particles of soil while water holding capacity, pore space, volume expansion and organic carbon were related to the finer particles of the soil both in quantity and quality (Nair, et al (1966) Venugopal (1980) studied the laterite catena in Kerala and reported a decrease in the chroma from crest to the valley in the case of Varkala and Poruvazhy toposequences The bulk density of the red soil profiles in Varkala ranges from 0 58 to 2 00gcm^{-3} Varghese (1981) in a study of laterites showed the bulk density values to vary from 0 76 to 1 45 grm^{-3} from different regions of Kerala*

Manickam (1977) reported a negative correlation between clay and silt contents of different laterite soils of Tamil Nadu Mallikarjuna et al (1979) studied the composition of laterite and parent rock from different regions of Kerala and observed that the residual profiles over crystalline rock were much more mature than those from sediments

In the laterite soils of Kerala, calcium formed the predominant exchangeable base followed by magnesium (Venugopal and Koshy 1976) However, Hussan (1977) observed that the calcium and magnesium status of laterite soils of Kerala was very poor both in the surface and subsurface layers of the soil profile Total calcium increased with depth while magnesium showed a reverse trend

Raguraj (1981) reported that the laterite soils of Madurai showed pH values ranging from 3 4 to 6 3 Jacob (1987)and Valsaji (1989) reported that laterite soils from upland regions of Kerala showed a very low cation exchange capacity and electrical conductivity and the soils were generally acidic

2 Mineralogy of fine sand

Sarkar and Raj (1973) carried out mineralogical studies on the fine sand fractions of some soils of South India and observed that the minerals were generally in conformity to the parent rock. Iron bearing minerals were appreciably high in laterites with limonite being characteristic of low level laterites. Zircon was invariably present in all soil groups

Manickam (1977) observed that laterite soils of Tamil Nadu was dominated by quartz in the light mineral suite Haematite was predominant in the heavy fraction followed by limonite and zircon

Venugopal (1980) reported predominance of quartz in the light mineral fraction of the laterite soils of Kerala The heavy mineral suite consisted of ilmenite, leucoxene, haematite, zircon, rutile and sillimanite

Jacob (1987) reported that the fine sand fraction of the laterite soils of Kerala showed a predominance of quartz and only very little weatherable minerals The heavy fraction consisted of mainly opaques, zircon, sillimanite mica rutile and sphene

3.1 Different forms of potassium in soils

Praseedom (1970) found that in Kerala soils the total K_2O content ranged from 0 04 to 0 54 per cent

Different forms of potassium present in the laterite soils of Tamil Nadu and Kerala were estimated by Nambiar (1972) According to him the total potassium content of these soils varied from 0 04 to 0 27 per cent Values of water soluble potassium, available potassium and nitric acid soluble potassium ranged from 0 028 to 0 248, 0 166 to 0 969 and 0 44 to 2 041 me $100g^{-1}$ respectively

Prabhakumari (1981) reported that total potassium content in red and lateritic soils of Thiruvananthapuram district varied from 1200 to 1290 ppm

Singh et al (1983) noticed that in eastern Haryana soils, the available K ranged from 0 0625 to 0 8367 me $100g^{-1}$ and constituted only 0 32 per cent of the total K Singh and Datta (1986) noted that in Mizoram soils, the available K ranged from 0 2381 to 2 044 me $100g^{-1}$ and constituted only 0 69 per cent of the total K

Ramanathan and Krishnamoorthy (1982) reported that in rice soils of Tamil Nadu, the nitric acid soluble potassium ranged from 0 391 to 7 6245 me $100g^{-1}$ In alluvial soils of Agra region, Prakash and Singh (1986) noted that the content of nitric acid soluble K ranged from 3 097 to 8 086 me $100g^{-1}$

Rao <u>et al</u> (1988) reported that water soluble potassium ranged from 0 018 to 0 032 me $100g^{-1}$ in Nedumangad series They also noticed that available potassium values and nitric acid soluble potassium values ranged from 0 013 to 0 432 and 0 28 to 0 487 me $100g^{-1}$ respectively

Tandon and Sekhon (1988) reported that the potassium content of Indian soils varied from 0 5 to 3 0 per cent

3 2 <u>*Soil properties and forms of soil potassium*</u>

Choudhari and Pareek (1976) obtained no significant relationship of total potassium with sand and silt fractions in Rajasthan soils Kansal and Sekhon (1976) reported that the potassium status of alluvial soils of Punjab was a function of the clay plus fine silt content Lepsch <u>et al</u> (1978) reported that the total potassium content was greatest in the silt fraction followed by the fine sand, clay and coarse sand in soils of Pindorama, Brazil They also showed that a major portion of the total potassium was present in primary minerals as feldspars and micas

Iwuafor et al (1980) obtained a significant positive correlation of total potassium with silt and also with CEC in surface soils of Sudan Savanna zone of Nigeria In soils of Agra region, Prakash and Singh (1985) reported a positive significant relation between total potassium and clay fraction According to Satyanarayana et al (1985) major part of the total potassium in alluvial and lateritic soils of Andhra was provided by the silt and clay fractions of the soil Habib et al (1986) reported that total potassium content in some soils of Egypt was closely related to silt content Krishnamurthy and Ramakrishnayya (1986) concluded that total potassium content in tobacco soils of Andhra was increased with increase in clay content Tewatia et al (1989) studied the potassium content and mineralogical composition of some salt affected soils and found that total potassium reserve was large in these soils due to the presence of illite in the clay fraction

In black soils of Tungabhadra catchment, Kalbande and Swamynatha (1976) obtained no significant correlation for the water soluble potassium with any of the soil properties studied Kansal and Sekhon (1976) showed that the potassium status of alluvial soils from Punjab was a function of pH In soils of Agra region Prakash and Singh (1985) found that total potassium had no significant relationship with pH and organic carbon but had positive significant relation with CEC In soils of Garhwall hills Singh and Singh (1986) obtained a significant positive correlation between total potassium and organic carbon and a non-significant positive relation with pH He also observed a significant correlation between organic matter and water soluble potassium

The water soluble potassium was higher in sandy loam and loam and lower in silt loam and silty clay loam in Mollisol soils of Nainital Tarai (Chandal et al , 1976)

In acids soils of Karnataka Mithyantha et al (1973) observed a positive and significant correlation of ammonium acetate extractable potassium with clay percentage, pH and electrical conductivity and no relationship with organic matter Lekshminarayanan et al (1973) obtained no significant correlation between available potassium and clay content, pH and electrical conductivity in laterite soils of Tamil Nadu However, Sarkunan et al (1973) noticed an increase in available potassium content with increase in the finer fractions Ram and Singh (1975) noted that in paddy soils of eastern Uttar Pradesh the available potassium had positive significant correlation with clay Wood and Burrows (1980) also noticed the same relation in the soils from South African sugar belt In Vijayapura and Tyamgondulu series Sekhon et al (1985) obtained a significant relation between available potassium and clay content Singh et al (1985) reported a significant relationship of available potassium with silt and clay in western Haryana soils In tobacco soils of Andhra, available potassium content correlated positively with clay content (Krishnamurthy and Ramakrishnayya, 1986) Brar and Sekhon (1985) observed that the content of available potassium was influenced by soil texture in five benchmark soils in northern India and obtained a positive significant relationship with organic carbon

Fixed potassium had a significant positive correlation with clay content in paddy soils of eastern Uttar Pradesh (Ram and Singh, 1975) Brar and Sekhon (1977) observed no relationship between the potassium extracted by boiling with nitric acid and the clay content in Punjab soils In the soils of Simla, Negi et al (1979) obtained a highly significant positive correlation of nitric acid soluble potassium with sand and silt and a negative correlation with clay

Krishnamurthy and Ramakrishnayya (1986) reported that nitric acid soluble K in the tobacco soils of Andhra increased with increase in clay content In light brown sandy soils of arid zone, Joshi (1986) found that the nitric acid soluble potassium was significantly related to silt and fine sand and was non-significant with clay Similar non-significant results with clay was also reported by Kadrekar and Kibe (1972)

Wood and Burrows (1980) concluded that nonexchangeable available potassium (nitric acid soluble potassium-available potassium) could be used as a better measure of the ability of the heavy textured soil to supply potassium on a long term basis and available potassium quite closely predicts the availability in the light textured soils In the alluvial soils of Uttar Pradesh, Sharma and Mishra (1986) obtained higher contents of exchangeable and non-exchangeable potassium in the fine textured soils compared to the coarser ones

4 1 Transformations of applied potassium in soil

Mishra and Shankar (1971) studied the potassium fixation capacity and fate of applied potassium in soils of Uttar Pradesh after incubating them for 3 weeks with 2 5, 5 and 10 mg potassium per 10g soil Potassium fixation capacity varied from 11 92 to 41 52 per cent Only 4 to 6 2 per cent of added potassium remained in the water soluble form and the exchangeable potassium content increased with increasing levels of potassium application

The potassium supplying and fixing capacity of seven latosols and seven andosols from Costa Rica was determined by incubation under wet condition and also by alternate wet and dry cycles Incubation under wet condition favoured fixation of exchangeable K but under wet and dry cycles release of non-exchangeable K resulted (Martinii and Suarez, 1977)

Verma and Verma (1971) studied the potassium fixation in soils of Madhya Pradesh after equilibriation with potassium for 3 days with 5 me $100g^{-1}$ of soil The average K fixing capacities were 0 48, 0 69, 0 71 0 72 0 78 and 1 13 me $100g^{-1}$ soil for alluvial, mixed red and yellow and deep blacksoil respectively

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

Sharpley (1990) studied the distribution of added K in soils of kaolinitic, mixed and smectitic mineralogy A linear increase in water soluble exchangeable and non-exchangeable K content was determined after incubation for 25 weeks There was a significant decrease in water soluble and increase in exchangeable and non-exchangeable K from kaolinitic to mixed to smectitic soils

Kattak et al (1981) performed a laboratory experiment to study the influence of moisture status on the fixation of added potassium and its release in strongly calcareous soils with medium to fine texture Fixation and release were higher with alternate wetting and drying as compared to fixation at field capacity Soils having higher clay content fixed more K than that having a lower one Release of K was observed in untreated plots which increased with clay content

4 2 Potassium availability and fixation in relation to soil clay mineralogy

Rao and Sekhon (1988) studied the potassium status of seven soil series from western India and observed that the influence of texture on available and reserve potassium status was stronger in the illitic soils than in the smectitic ones According to Oncnere (1989) potassium contents in some Kenyan soils were closely related to the mica contents of the clay plus silt fractions Jianchang and Chenglin (1990) studied the potassium supplying characteristics of paddy soils of China and found that there was a rise in potassium level from southern to northern China, due to increase in hydrous micas and decrease in kaolinite soils Datta and Sastry (1991) studied the level of exchangeable potassium in four alluvial soils of India and found that there was an increase in the amount with the increase in trioctahedral mica in the clay fraction in three of the soils and in all the four soils, exchangeable potassium level followed the same sequence of the amount of specifically held potassium and total non-exchangeable potassium reserves

Sreedevi and Aiyer (1975) reported that high content of potassium in the coarser fractions of low level laterites can be released by better soil management practices Kansal and Sekhon (1976) reported that potassium fixation in alluvial soils of Punjab increased with increasing clay content Ramanathan and

Krishnamurthy (1978) showed that magnitude of potassium fixation by the soil was in decreasing order of alluvial soil, black soil, red soil and laterite in the soils of southern India Bajwa and Ponnamperuma (1981) reported that in Philippine rice soils, potassium deficiency and lack of response to potassium fertilisers were observed due to the presence of vermiculite and beidellite as the clay minerals in the clay fraction Ross and Cline (1984) observed potassium deficiency symptoms in grapes grown on soils in the Niagara peninsula The soils ranged in texture from sandy loam to silty clay and the main clay mineral was mica and also vermiculite and these minerals reduce potassium availability by fixation

Ghosh et al *(1976) reported that in acid sulphate soils of Kerala 2 1 minerals were also present in addition to the kaolinitic minerals*

Potassium fixation in lateritic acid soils of Karnataka varied in the range of 23 5 to 27 0 per cent and the reason for low fixation was attributed to the presence of 1 1 type clay mineral (Ningappa and Vasuki (1989)

4 3 Contribution of different forms of potassium to crops

Boguslawski and Lach (1971) reported a characteristic decrease in the non-exchangeable potassium fraction with lapse of time in a pot experiment with clay soil using oats as test crop According to Medvedeva (1972) potassium removal by maize plants in a pot experiment using heavy loamy soil was 1 5 - 2 times greater than the exchangeable potassium content of the soil and plant yield was correlated more highly with removal of non-exchangeable potassium fraction of the soil than with the removal of exchangeable potassium

Mehta (1976) reported that the non-exchangeable fraction replenished the exchangeable fraction at a faster rate when the crop growth advances and an increase in the content of ammonium acetate extractable fraction noticed at the harvesting stage in the soils of Gujarat Wu (1960) reported that rice growth under submerged conditions took up a larger proportion of its total K from the non-exchangeable fraction than it did under upland conditions

From a study on the potassium requirement of high yielding crops in soils with varying mineralogy, Grimme et al (1971) stated that kaolinitic or montmorillonitic soils require only half as much potassium per gram clay than the illitic soils do and it is twice the amount for chloritic soils Tha available potassium content of the soil increased with increase in fertilizer dose at tillering stage while at the later stages the difference was not marked (Ramanathan and Krishnamurthy 1973)for rice According to Talati et al (1974) application of fertiliser to wheat crop influenced the available and non-exchangeable forms of potassium in the soil

Brar and Sekhon (1976) observed a little response to applied fertiliser by wheat in Punjab soils when soil potassium fixation capacity was saturated to 25 50 or 72 per cent Sharma et al (1978) obtained decreased response to the application of fertiliser by wheat with increase in soil potassium contents

Nair et al (1981) obtained lack of response to phosphate and potassium fertilisers applied once in two seasons and once in three seasons as compared to the continuous application in the acidic lateritic sandy loam soils of Patambi Fang and Wang (1981) obtained a high correlation between sugar cane yield and non-exchangeable soil potassium in soils of Taiwan Singh et al (1981) suggested that the presence of large amounts of illite mineral in the clay fraction of the soil served as a reserve of potassium and the release from this reserve was adequate to maintain the minimum required levels of potassium throughout the growing season of a wheat crop grown in an illitic soil in Punjab

Soils with low available potassium showed non-response of crops to small applications of potassium fertiliser due to high potassium fixation in soils of northern Greece (Simonis, 1984)

Chang and Feng (1960) reported that rice plants absorb a larger percentage of K^+ from the non-exchangeable form and vigorous rice growth was obtained in a flooded soil than under non-flooded conditions

Krishnakumari et al (1984) reported that in an exhaustive cropping with wheat and pearl millet the level of ammonium acetate extractable potassium reached a minimum value and 90 percent of the total potassium uptake was from the non-exchangeable form In a green house experiment on alluvial soils with maize, cowpea and wheat, Singh and Ghosh (1984) showed that in the absence of applied potassium, its non-exchangeable form contributed to total potassium removal by the crops than was the case with potassium treated soils

Ganeshamurthy and Biswas (1985) observed pronounced changes in the non-exchangeable potassium content without much changes in the exchangeable potassium and obtained a significant positive correlation between potassium removal in crops and non-exchangeable potassium released to the soil in two soils (Typic Ustochrepts) subjected to continuous cropping According to Deol et al (1985) in a long term field experiment on a maize-wheat rotation no response to potassium was observed and the reason was attributed to release of non-exchangeable potassium which decreased by over a half in the surface layer and accounted for 96 per cent of crop uptake

Under continuous cropping potassium uptake by rice from the exchangeable form decreased and that from the non-exchangeable pool increased indicating a dynamic equilibrium between reserve, non exchangeable and exchangeable potassium (Chakravorti et al ,

1987) Sharma and Mishra (1987) reported that non-exchangeable and exchangeable potassium decreased rapidly with the growing of crops in coarse textured soils of western Uttar Pradesh in a pot experiment with wheat and maize

Prasad and Rajamannar (1987) working on soils with varying potassium releasing power, reported that soils with high potassium releasing property recorded higher amounts of all potassium fractions and there was no constant rate of decline with the advancement of crop growth Chakravorti and Patnaik (1990) reported that contribution of non-exchangeable potassium towards the total potassium uptake in flooded rice soils was increased towards the later stages of cropping and the release from non-exchangeable form was more in the case of alluvial and red soils than that from the lateritic and black soils

From a study on the release of potassium from the non-exchangeable sources by exhaustive cropping of Nandi Setaria in soils collected from the Inceptisols of northern and eastern districts of Sikkim, Patiram and Prasad (1991) reported that about 32.3 to 65 7 per cent of the total potassium taken up by the crop were accounted by the non-exchangeable form The amount of non-exchangeable form released during cropping was highly correlated with cumulative potassium uptake anddry matter yield

5 1 Potassium and nutrient uptake

Muthuswamy et al (1974) reported that higher levels of potassium application increased the uptake of N, P and K by rice Mengel et al (1976) reported that N, P and K uptake and their translocation were highest with application of 60 kg K_2O ha^{-1} The total uptake and percentage of translocation of N, P and K by rice increased significantly with increasing levels of potassium (Singh and Singh 1987)

Ishizuka (1965) reported that the response to potassium application was increasing with increasing levels of potassium application Panda (1984) reported that potassium absorbed after panicle initiation is solely utilised in increasing grain production

5 2 Dry matter production and grain yield

Increase in dry matter production with increase in the levels of potassium upto 50 kg K_2O ha^{-1} was observed by Mishra (1980) Enhanced dry matter production due to potassium application up to 60 Kg K_2O ha^{-1} was reported by Hati and Misra (1983) Senthivel and Palaniappan (1985) also reported similar effects of potassium on dry matter production

Mondal (1982) reported a 16 per cent yield increase in rice by the combined application of N and K fertiliser over the application of N alone Gupta et al (1971) reported that there is a positive effect of potassium on the absorption of N and may be due to the ability of potassium to reduce the fixation of NH_4^+ in the soils

Potassium application increased the rice yield in lateritic soils under submergence and it was even more in soils which were subjected to wetting and drying (Nad and Goswami, 1981) De Datta and Gomez (1982) found that obsorption of P was maximum at the flowering stage and the response to P was more when potassium was applied

Venkatasubbaiah et al (1982) observed highly significant increases in grain yield due to applied potassium in potassium depleted soils Results of the experiment conducted at Jorhut showed that application of 40 to 80 kg K_2O ha^{-1} could increase the grain yield of rice considerably over the control (Barthakur et al 1983) Gurmani et al (1984) reported a significant increase in grain yield with increase in the level of potassium from 0 to 83 kg K_2O ha^{-1}

Data from the AICARP for a large number of experiments on cultivators field all over the country showed a progressive increase in the response of rice to applied potassium The yield response of rice to applied potassium was significant at 40 and 60 kg K_2O ha^{1} in most soils (Bhargava et al 1985) Robinson and

Rajagopal (1977) obtained a linear response of rice upto application of 60 kg K_2O ha^{-1} in soils of Tamil Nadu and Agarwal (1980) observed a significant yield increase up to 80 kg K_2O ha^{-1} in rice Sakeena (1988) reported an yield increase in rice for 35 kg K_2O ha^{-1} over control

Singh et al (1976) observed that application of 120 kg K_2O ha^{-1} gave the highest straw yield Singh and Prakash (1979) reported an increase in straw yield with increase in level of potassium from 0 to 60 kg K_2O ha^{-1} Similarly significant increase in yield of grain and straw were observed due to applied potassium by Venkatasubbiah et al (1982) According to them the effect of potash application was more on grain yield compared to straw yield

The response to potash application on grain yield of dwarf high yielding varieties of rice was obtained by Sen et al (1969) in lateritic soils of Midnapore with application of 50 kg of K_2O ha^{-1}. Goswami et al (1971), Sahu (1971) Rao et al (1971) on medium fertility soils at Bhubaneswar also reported similar results

Materials and Methods

MATERIALS AND METHODS

The content of potassium in soils and its availability to plants depends on the textural characteristics of the soil. The present investigation was carried out to determine the potassium dynamics, in soils of varying texture, properties of soils related to potassium availability and the nutrient uptake by rice as influenced by various proportions of clay using rice as the test crop.

1. Selection of soils for the study

Since the availability of potassium is related to the content of colloidal fraction contributed by clay and organic matter in the soil the soils were selected in such a way that maximum variation in the content of clay was obtained among the samples selected for the study. Thus sixty surface samples were collected from three panchayats viz., Madakkathara, Ollukkara and Thekkumkara. The particle size distribution and the content of organic carbon in these sixty soils were determined.

In general, the organic carbon content of the soil is increased with the content of clay and therefore it is difficult to partition the effect of organic matter from that of clay content in relation to the fixation and availability of K^+ in the soil. Therefore in order to select soils for the detailed study on K availability a regression equation of the model $Y = aX + b$ was fitted taking clay as the independent variable and organic carbon as the dependent variable (Fig.1). From the sixty soils, 20 soils showing maximum adherence to the regression model with maximum variation in the content of clay were finally selected for detailed study.

1.1. Soil analysis

1.1.1. Particle size analysis of the samples were carried out using Bouyoucous hydrometer method (Piper, 1942).

1.1.2. Organic carbon content of the samples were determined as per Walkely and Black's method (Jackson, 1958).

2.1. Physical constants

Particle density, apparent density, maximum water holding capacity and percentage pore space were determined according to the Keen-Razkowski method (Wright, 1939).

2.2. Chemical characteristics

2.2.1. Soil reaction, (1:2.5 soil water ratio) determined using pH meter (Jackson, 1958).

2.2.2. Electrical conductivity (1 2.5 soil water ratio) measured using conductivity bridge (Jackson, 1958).

2.2.3. Total nitrogen - microkjeldahl digestion - distillation method (Jackson, 1958).

2.2.4. Total phosphorus, potassium, calcium and magnesium

One g of the air dried soil sample was digested with diacid mixture (1 2 perchloric acid - nitric acid mixture) and this extract was used for the determination.

The phosphorus content from this extract was determined colorimetrically by the vanado-molybdo phosphoric yellow colour.

method in nitric acid system (Jackson, 1958) Potassium in the acid extract was determined using flame photometer (Jackson, 1958) Calcium and magnesium were estimated using EDTA titration method (Hesse, 1971)

2.2 5 Cation exchange capacity

Determined as per the method given by Jackson 1958) Soil was leached with neutral normal ammonium acetate and the excess acetate was removed by washing with ethyl alcohol The absorbed ammonium was estimated by distillation with alkali

2 2.6 Exchangeable cations

The leachate obtained from cation exchange determination was made up to a known volume In a portion of this leachate, calcium and magnesium were determined by EDTA titration method (Hesse, 1971) Sodium and potassium were estimated using a flame photometer (Jackson, 1958)

2 2 7. Ammonium acetate extractable potassium

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

2 2 8 Water soluble potassium

Air dried soil was shaken with distilled water in the ratio

1:5 for one hour and in the filtered extract, potassium was determined using flame photometer (Jackson, 1958).

2.2.9. Nitric acid soluble potassium

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

3. Laboratory incubation experiment

A laboratory incubation experiment was carried out in five selected soils, having varying clay content, for finding out the transformations of applied potassium in rice soil condition simulated at field capacity.

The requirement of K in soil is mainly dependent on the colloidal fraction contributed by clay and organic matter. Therefore the 20 soils selected for the study were categorised into 4 groups viz., soils with clay content less than 20, 20-30, 30-40 and above 40 per cent. Five soils were selected for the incubation study with at least one soil from each group.

In order to give sufficient weightage to the content of clay in soil in relation to potassium availability, the levels of K application in the incubation study were derived from the content of clay as well as the level of exchangeable K present in the soil. Since these 5 soils originally contained exchangeable K ranging from 0.0959 to 0.4730 me 100 g^{-1}, the first level of K application (T_1) was fixed as 0.5 me 100 g^{-1}. The actual quantity of K applied at this level is then derived by multiplying the K deficit (0.5 me 100 g^{-1}-exchangeable K originally present in the soil) by the clay per cent. The second level of K (T_2) was taken as 0.55 me 100 g^{-1}. Though the two levels viz., 0.5 and 0.55 me 100 g^{-1} appeared to be closer, the amount of K to be added at these levels was relatively high covering the normal range of K application

Exactly 600 g of each soil was taken in plastic containers Potassium was applied in the form of muriate of potash as per the treatment levels fixed The soils were incubated at field capacity for 90 days at room temperature Soil samples were taken regularly at 15 days interval throughout the incubation period These samples were analysed for water soluble, ammonium acetate extractable and nitric acid soluble potassium fractions as per the standard procedures

4. *Mineralogy of fine sand*

Fine sand fractions of the soils selected for the incubation study were separated by sedimentation during particle size distribution analysis, and treated with $SnCl_2$ *to remove iron oxide coatings The dried samples were separated to heavy and light mineral suites using bromoform of specific gravity 2 8 (Carver, 1971) The heavy and light fractions were sampled by cone and quartering and mounted on a microscopic slide using Canada balsam as outlined by Krumbein and Pettijohn (1938) Identification of minerals was carried out using a petrological microscope and the grains were counted by the method described by Carver (1971)*

5 *Pot culture experiment*

A pot culture study was conducted in four selected soils, varying in clay content and with four levels of potassium using rice variety, Jyothi during the virippu season of 1990

Levels of clay (%)		Levels of potassium application (kg ha^{-1})	
S_1	< 20	K_1	0
S_2	20 - 30	K_2	20
S_3	30 - 40	K_3	40
S_4	> 40	K_4	60

Total number of treatments	16
Number of replications	3
Design	Completely Randomised Design

Treatment combinations

$S_1 K_1$	$S_2 K_1$	$S_3 K_1$	$S_4 K_1$
$S_1 K_2$	$S_2 K_2$	$S_3 K_2$	$S_4 K_2$
$S_1 K_3$	$S_2 K_3$	$S_3 K_3$	$S_4 K_3$
$S_1 K_4$	$S_2 K_4$	$S_3 K_4$	$S_4 K_4$

Earthern pots of uniform size were used for the study Exactly 7 kg of the powdered soil was filled in each pot The soil was flooded and puddled well before planting the seedlings Nitrogen and phosphorus were applied as per the Package of Practices (90 kg N 45 kg P_2O_5 ha^{-1}) recommendation by Kerala Agricultural University (Anon, 1989) Potassium was added as per the treatments in two split doses

Rice seedlings were raised by wet method Twenty one days old seedlings were transplanted at the rate of 3 hills per pot

Plant protection and other intercultural operations were carried out as per the recommendations of Kerala Agricultural University (Anon, 1989) Constant water level was maintained upto 15 days before harvest

6. *Destructive sampling*

Destructive sampling was done at tillering and flowering stages Both soil and plant samples were collected for analysis at each stage

7 *Final harvest*

The crop was harvested after 110 days The soil and plant samples were collected for further studies

8 *Yield attributes*

Dry matter yield was recorded at the tillering, flowering and the harvesting stages Grain yield was also recorded at the harvesting stage

9. *Analytical procedure*

9.1 *Soil samples*

Samples drawn at tillering, flowering and harvesting stages were analysed for the water soluble and ammonium acetate extractable potassium contents Nitric acid soluble potassium content was estimated only at the end of the experiment

9 2. Plant samples

Plant samples were dried, powdered and stored in labelled containers and the uptake of nutrients was estimated

For the determination of phosphorus, potassium, calcium and magnesium, a triacid mixture was prepared by mixing nitric acid, sulphuric acid and parchloric acid in the ratio 10 1 4 One gram of the powdered plant sample was digested and an extract was prepared The phosphorus content in this extract was determined colorimetrically by the vandomolybdophosphoric yellow colour method in nitric acid system (Jackson, 1958) In the acid extract, potassium was determined using a flame photometer (Jackson, 1958) Calcium and magnesium were estimated using EDTA titration method (Hesse 1971) Nitrogen content was determined by the microkjeldahl digestion - distillation method as described by Jackson (1958)

6 Statistical analysis of the data

Statistical analysis was carried out by adopting the standard methods described by Panse and Sukhatme (1967)

Results and Discussion

RESULTS AND DISCUSSION

With a view to study the effect of soil texture and other physico-chemical characteristics on potassium availability the present study was undertaken The results obtained are discussed under the following sections

1 General characteristics of the soils

Sixty surface soil samples were collected from the major rice growing areas of Thrissur district These samples were analysed for the particle size distribution and organic carbon content The analytical data are presented in Table 1

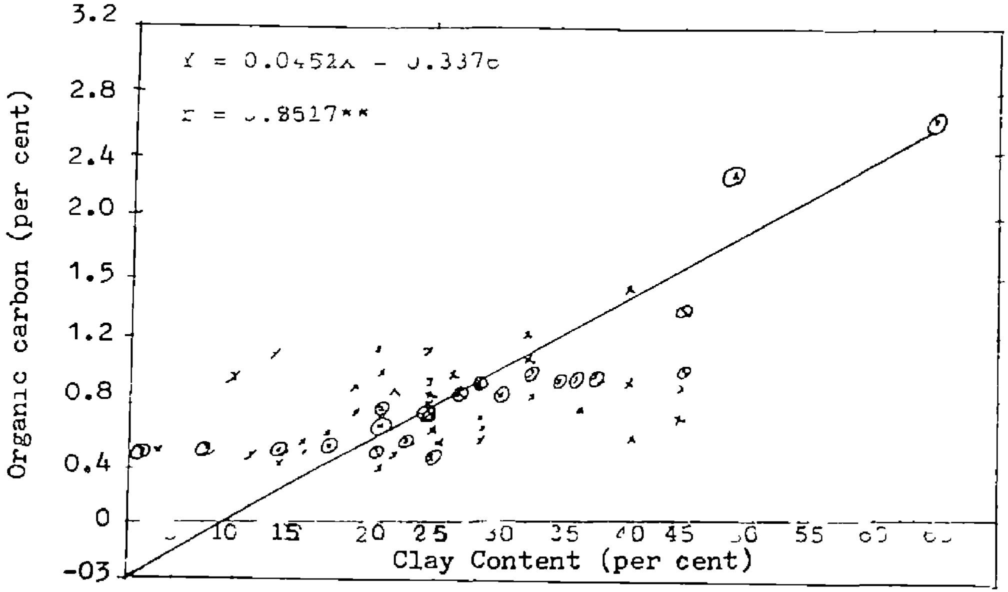
Wide variation was noticed in the clay content which ranged from 1 to 64 from 2 to 40 and from 10 to 44 per cent in the soils of Ollukkara, Madakkathara and Thekkumkara respectively. Organic carbon content varied from 0 44 to 2 6, 0 4 to 1 1 and 0 4 to 1 51 in the three locations The variation, noticed in the above variables may be due to the differences in the weathering of the parent material and soil environment

Generally there tends to be a positive correlation between the clay content of soil and the organic carbon But in certain situations, this relationship is not followed The availability of potassium or any other nutrient in soil is directly related to the

Table 1 Clay percentage and organic carbon content of surface soil samples

Sl No	Soil sample No	Clay (%)	Organic carbon (%)	Sl No	Soil sample No	Clay (%)	Organic carbon (%)	Sl No	Soil sample No	Clay (%)	Organic carbon (%)
1	O_4*	0 88	0 44	21	O_5	19 99	0 35	41	T_{19}	27 99	0 67
2	M_6	1 99	0 44	22	T_{10}	19 99	0 47	42	O_9	29 99	0 84
3	O_3	5 99	0 44	23	T_{18}	20 79	0 81	43	T_{12}	31 99	1 2
4	M_{13}**	7 99	0 99	24	M_2	21 20	0 44	44	T_{17}	31 99	1 13
5	T_1***	9 99	0 4	25	M_{18}	21 99	0 53	45	O_8	31 99	0 81
6	O_6	11 99	0 38	26	M_7	23 99	0 604	46	T_6	31 99	1 07
7	M_5	11 99	1 08	27	M_8	23 99	0 75	47	T_8	33 99	0 94
8	O_{11}	11 99	0 44	28	T_{11}	23 99	0 75	48	O_7	35 94	0 73
9	O_1	12 39	0 41	29	T_{14}	23 99	1 13	49	M_{11}	35 99	0 94
10	O_2	13 99	0 44	30	O_{20}	23 99	0 85	50	M_{12}	37 19	0 99
11	O_{14}	13 99	0 47	31	O_{15}	23 99	0 609	51	T_5	39 99	1 51
12	M_{15}	15 99	0 56	32	M_3	23 99	0 41	52	O_{12}	39 99	0 53
13	O_{19}	15 99	0 697	33	M_{20}	23 99	0 70	53	M_{19}	39 99	0 90
14	M_{17}	17 99	0 50	34	O_{18}	24 00	0 99	54	T_9	43 99	0 94
15	O_{10}	17 99	0 85	35	M_{16}	24 79	0 52	55	T_{13}	43 99	1 053
16	M_{10}	19 99	1 10	36	T_3	25 99	0 93	56	T_{15}	43 99	1 43
17	M_1	19 99	0 697	37	M_{14}	25 99	0 82	57	T_{16}	43 99	0 65
18	M_9	19 99	0 70	38	M_4	27 99	0 55	58	T_{20}	43 99	2 26
19	T_7	19 99	0 62	39	O_{13}	27 99	0.67	59	O_{16}	47 99	2 26
20	T_2	19 99	0 99	40	T_4	27 99	0 90	60	O_{17}	63 99	2 60

* samples with notation 'O' are collected from Ollukkara
** samples with notation M' are collected from Madakkathara
*** samples with notation 'T are collected from Thekkumkara



⊗ Soil selected for physico-chemical analysis.

Fig. 1 Relationship between clay content and organic carbon content of surface soil samples.

clay content and organic matter Hence the interpretations on the K availability can be made clearly only in those soils, where a linear relationship is present between them In order to locate soils which are perfectly following such a positive relationship the linear regression equation Y =aX+b was fitted into the data Clay content of the soils was taken as the independent variable (X) and the organic carbon values were worked out for each soil (Table 1 and Fig 1) Based on the above, twenty samples of varying clay content were selected for further studies These soils were analysed for the following physico-chemical characteristics

1.1 Physical properties

Particle size distribution, apparent density, particle density water holding capacity and percentage pore space were estimated The data are given in Table 2

1.1.1 Particle size distribution

In Ollukkara soils, sand, silt and clay fractions ranged from 28 to 86, 8 to 16 and 1 to 64 per cent For Madakkathara soils it ranged from 44 to 76, 2 to 20 and 16 to 37 per cent respectively for the sand, silt and clay separates In the soils of Thekkumkara region, the contents of sand, silt and clay ranged from 40 to 64, 2 to 30 and 20 to 44 per cent respectively The soils of Thekkumkara showed a higher clay content as compared to that of the other two regions

Table 2 Physical properties of soils

Sl No	Soil sample	Textural class	Particle size distribution(%) sand	silt	clay	Particle density (g cm^{-3})	Apparent density (g cm^{-3})	water holding capacity (%)	percentage pore space
1	O_3	Sand	86 0	11 0	3 0	2 63	1 63	19 5	38 8
2	O_4	Sand	83 0	16 0	1 0	2 60	1 54	14 1	40 8
3	O_9	Sandy loam	56 0	14 0	30 0	2 68	1 34	36 3	52 7
4	O_{11}	Loamy sand	80 0	8 0	12 0	2 66	1 53	23 2	42 5
5	O_{16}	Sandy clay	44 0	8 0	48 0	2 48	1 18	45 8	52 5
6	O_{17}	Clay	28 0	8 0	64 0	2 58	1 16	46 0	56 0
7	M_1	Sandy loan	72 0	12 0	16 0	2 67	1 38	33 3	48.6
8	M_{11}	Sandy clay loam	44 0	20 0	36 0	2 66	1 24	39 2	54 5
9	M_{12}	Sandy clay loam	44 0	19 0	37 0	2 65	1 22	35 0	54 3
10	M_{14}	Sandy loam	73 0	2 0	25 0	2 66	1 36	31 5	49 9
11	M_{17}	Sandy clay loam	76 0	4 0	20 0	2 69	1 37	30 2	48 3
12	M_{18}	Sandy loam	74 0	4 0	22 0	2 69	1 44	27 9	46 4
13	M_{20}	Sandy loam	60 0	16 0	24 0	2 68	1 30	35 0	52 7
14	T_4	Sandy loam	64 0	8 0	28 0	2 62	1 32	34 1	49 8
15	T_5	Sandy clay loam	40 0	20 0	40 0	2 80	1 21	38 1	57 3
16	T_7	Loamy sand	50 0	30 0	20 0	2 66	1 32	34 1	49 4
17	T_8	Sandy clay loam	64 0	2 0	34 0	2 69	1 37	33 2	50 4
18	T_{13}	Sandy clay	52 0	4 0	44 0	2 59	1 26	38 3	52 1
19	T_{15}	Sandy clay loam	40 0	16 0	44 0	2 59	1 19	40 8	54 6
20	T_{17}	Sandy clay loam	56 0	12 0	32 0	2 79	1.20	39 9	57 3

Almost all the soils from the three panchayats were coming under the textural classes, sandy loam and sandy clay loam

The laterite soils are formed by the _in situ_ weathering of the parent materials and by the high leaching of the bases. High variation noticed in the proportion of the soil separates may be due to the different type of parent materials from which it is formed It could also be due to the extent of weathering of the parent materials as influenced by the prevailing local climate

1 1 2. Particle density

The particle density ranged from 2.48 to 2 69, 2 65 to 2 69 and 2 59 to 2 80 g cm^{-3} for soils collected from Ollukkara, Madakkathara and Thekkumkara respectively The slight variation among the soils could be attributed to the variation in the organic matter content and soil minerals

1 1 3 Apparent density

The apparent density varied from 1 16 to 1 63 g cm^{-3} for the soils collected from the three panchayats The value was minimum in the clay soils and increased with decrease in the content of clay. Thus the sandy soil of Ollukkara i e , O_3 recorded the maximum value of 1 65 and O_{17} of the same region has 1 16 g cm^{-3}, coming under the textural class clay There is a negative relationship between the bulk density and the organic carbon content and it is clear from the data that maximum bulk density is recorded by O_3 (1 63 gm^{-3}) where the organic carbon content is 0 44 per cent as against 2 6 per cent in O_{17} where the bulk density comes to only 1 16 g cm^{-3}

1 1 4 Percentage porespace

The percentage pore space of Ollukkara soils varied from 40 8 to 56 for Madakkathara soils, it was 46 to 54 and for Thekkumkara soils it was 49 to 57 per cent Soils with a high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space From the table it is clear that sandy soils have a lower pore space than their clayey counter parts

1.1 5 Water holding capacity

Water holding capacity ranged from 14 1 to 46, 28 to 39 and from 33 to 41 per cent for the soils taken from Ollukkara, Madakkathara and Thekkumkara respectively The percentage volume occupied by small pores in sandy soils is low, which accounts for their low water holding capacity In contrast, the fine textured soils have more total pore space and hence these soils are giving higher values

1 2 Chemical properties

Tha analytical data on soil reaction, electrical conductivity, sesquioxide percentage, organic carbon, percentage

Table 3 Chemical properties of soils

Soil sample No	pH	EC (mmhos cm^{-1})	Organic carbon (%)	Sesquioxide (%)	Total N (%)	Total P (%)	Total K (%)	Total Ca (%)	Total Mg (%)
O_{3}	5 2	0 041	0 44	30 5	0 108	0 0050	0 175	0 180	0 108
O_{4}	5 2	0 020	0 44	20 5	0 125	0 0050	0 225	0 090	0 030
O_{9}	5 2	0 006	0 84	12 0	0 197	0 0175	0 550	0 124	0 116
O_{11}	5 8	0 025	0 44	16 5	0 143	0 0050	0 300	0 120	0 107
O_{16}	5 4	0 050	2 26	17 5	0 233	0 0175	0.750	0 224	0 181
O_{17}	5 5	0 085	2 60	14 5	0 287	0 0250	0 800	0 189	0 106
M_{1}	5 5	0 023	0 69	18 5	0 125	0 0325	0 350	0 060	0 086
M_{11}	5 3	0 009	0 94	24 0	0 197	0 1900	0 400	0 136	0 109
M_{12}	4 9	0 015	0 99	30 9	0 125	0 1750	0 550	0 146	0 120
M_{14}	5 6	0 085	0 82	23 5	0 135	0 2850	0 445	0 124	0 087
M_{17}	5 7	0 014	0 50	12 5	0 189	0 0200	0 350	0 140	0 085
M_{18}	6 0	0 060	0 53	5 2	0 161	0 0125	0 250	0 120	0 108
M_{20}	6 1	0 010	0 70	18 5	0 179	0 1600	0 650	0 136	0 125
T_{4}	5 1	0 080	0 90	10 0	0 283	0 0475	0 525	0 186	0 135
T_{5}	5 8	0 061	1 51	22 5	0 179	0 3175	0 875	0 148	0 139
T_{7}	5 7	0 025	0.62	10 0	0 225	0 0375	0 550	0 124	0 128
T_{8}	5 4	0 095	0 94	16 0	0 208	0 2375	0 550	0 134	0 120
T_{13}	5 3	0 065	1 05	31 0	0 161	0 2225	0 650	0 131	0 116
T_{15}	5 7	0 082	1 43	23 5	0 197	0 0375	0 725	0 139	0 105
T_{17}	5 1	0 015	1 13	16 5	0 197	0 0250	0 620	0 136	0.114

values for total nitrogen, phosphorus, potassium, calcium and magnesium are furnished in Table 3

1.2.1. Soil reaction

The soils in general were acidic in nature The values ranged from 4 9 to 6 1 for the soils of these three regions The variation noticed may be due to the acidic parent rocks and the extent of submergence during cultivation The acidity of these soils may be attributed to its formation from acidic crystalline rocks, its intensive weathering under tropical conditions and the leaching of the bases Jacob (1987) also reported similar results

1 2 2 Electrical conductivity

The electrical conductivity was found to be very low and ranged from 0 006 to 0 095 mmhos cm^{-1} The soils from all locations belonged to the lowland regions and were practically nonsaline

1.2 3 Organic carbon

The organic carbon content varied from 0 44 to 2 6, from 0 5 to 0 99 and from 0 62 to 1 51 per cent in the soils of Ollukkara, Madakkathara and Thekkumkara Soil organic matter exists as a complex with the clay fraction of the soil A positive correlation (r = 0 8903*) existed between these two The sandy soils can retain less of organic matter as against the clayey soil In the analytical data, the organic carbon is only 0 44 per cent for O_3 where the clay is 1 per cent as against O_{17} for which it comes to 2 6 per cent where the clay content is 64 per cent

1 2 4 Sesquioxide percentage

Sesquioxide percentage varied from 10 to 30 9 per cent for all except one soil for which it was 5 2 (M_{18}) The content of sesquioxide is an index of the degree of weathering of the soils and depending on the content of kaolinite the sesquioxide percentage could vary widely

1.2 5. Total nitrogen

Total nitrogen varied from 0 108 to 0 287, 0 125 to 0 197 and 0.161 to 0 283 per cent in the soils of Ollukkara, Madakkathara and Thekkumkara Panchayats The variation noticed within each location was attributed to the content of organic matter

1 2 6 Total phosphorus

The values ranged from 0 005 to 0 025, 0 013 to 0 285 and 0 025 to 0 317 per cent for soils of Ollukkara, Madakkathara and Thekkumkara respectively Soils with a high content of organic matter recorded a high value of total phosphorus However slight variations were observed which may be due to the quantity and nature of clay minerals in the soil

1.2.7. Total potassium

The total potassium content ranged from 0 175 to 1 075, 0 250 to 0 550 and 0 525 to 0 875 per cent for the soils of Ollukkara, Madakkathara and Thekkumkara The parent material, CEC and organic carbon are the determining factors of total K in soils The variation reflected in the content could be due to the differences in the composition of the parent rocks from which they are formed and the nature of weathering. There was a significant positive correlation for the total K content of the soils with clay content (r = 0 8903**) CEC (r = 0 8162**) and organic carbon (r = 0 8426**) Similar relationships of total potassium with clay content and CEC were reported by Prakash and Singh (1985) in soils of Agra region and with organic carbon by Singh and Singh (1986) in soils of Garhwall hills

1,2 8 Total calcium

The values ranged from 0 C9 to 0 224, 0 06 to 0 146 and 0 124 to 0 186 per cent for the soils of Ollukkara, Madakkathara and Thekkumkara

1.2 9. Total magnesium

For the soils of Ollukkara it varied from 0 03 to 0.10, and for the soils of Madakkathara and Thekkumkara it ranged from 0.018 to 0 125 and from 0 105 to 0 139 per cent respectively

The total reserve of plant nutrients is mainly a function of the mineralogical composition of the soils As the soils are formed from acid crystalline rocks, quartz is the major primary mineral in the fine sand fractions of the laterite soils The easily weatherable ferro-magnesium minerals constitute only minor fraction of the total content Hence these soils are expected to contain less of plant nutrients This is true for upland laterites of Kerala (Jacob, 1987, Venugopal, 1980) However in lowland laterites the level of nutrients is greater than that in the upland laterites as noticed in the present study The reason for this may be the high content of clay and the presence of some 2 1 minerals Similar results have been reported in the acid sulphate soils of Kerala (Ghosh et al , 1976)

4.3 Forms of potassium in soils (Table 4)

4.3.1 Water soluble potassium

The water soluble potassium varied from 0 0065 to 0 310 from 0 0029 to 0 060 and from 0 0184 to 0 0448 me 100 g^{-1} in the soils of Ollukkara, Madakkathara and Thekkumkara This fraction is relatively low in these soils and formed less than 1 per cent of the total K This is in conformity with the findings of Nambiar (1972) and Rao et al (1988). There was no significant correlation for this fraction with any of the soil properties except the ammonium acetate extractable potassium (r = 0.5153**) This indicated that water soluble fraction was independent of these soil

Table 4 Potassium extracted using different extractants (me 100 g^{-1})

Soil sample No	Extractant		
	Distilled water	Ammonium acetate	1 N nitric acid
O_3	0 0312	0 0959	0 6394
O_4	0 0281	0 1048	0 5115
O_9	0 0065	0 1356	2 5580
O_{11}	0 0319	0 0651	1 0230
O_{16}	0 0318	0 6773	7 3670
O_{17}	0 0281	0 4875	8 9120
M_1	0 1407	0 4730	1 9410
M_{11}	0 0248	0 2426	3 8360
M_{12}	0 0512	0 2366	2 3010
M_{14}	0 0135	0.1879	0 8210
M_{17}	0 0029	0 1458	2 3010
M_{18}	0 0670	0 1176	1 2780
M_{20}	0 0096	0 1356	0 7670
T_4	0 0448	0 1918	2 5580
T_5	0 0301	0 2315	2 6392
T_7	0 0256	0 1279	0 6392
T_8	0 0218	0 2289	3 8352
T_{13}	0 0184	0 1023	3 5800
T_{15}	0 0256	0 1662	3 0690
T_{17}	0 0239	0 1534	3 5800

Table 5 Correlation matrix obtained for different soil parameters

	Clay	Silt	Organic carbon	CEC	Total K	HNO_3 -K	NH_4 OAc -K	Water soluble K
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	--							
2	0 0439	--						
3	0 8904**	0 0176	--					
4	0 9216**	0 1174	0 8760**	--				
5	0 8178**	0 1935	0 8426**	0 8162**	--			
6	0 2629	-0 1651	-0 0686	0 1173	-0 0027	--		
7	0 4293	0 1128	0 4376	0 5169**	0 2133	0 0720	--	
8	-0 0438	0.2058	0 0654	0 0864	-0 1157	-0 0556	-0 5153*	--

* Significant at 5% level

** Significant at 1% level

properties Kalbande and Swamynatha (1976) reported similar results in the soils of Tungabhadra catchment

1 3 2. Ammonium acetate extractable potassium

This fraction showed variation from 0 9651 to 0 5773 0 1176 to 0 4730 and 0 1023 to 0 2315 me 100 g^{-1} in Ollukkara, Madakkathara and Thekkumkara soils respectively In these samples this fraction constituted 0 9 to 2 2 per cent of total potassium. Singh *et al* (1983) in soils of Haryana and Singh and Datta (1986) in soils of Mizoram have reported that ammonium acetate extractable potassium constituted only a small proportion of the total potassium In the present study a positive significant correlation was obtained with CEC (r = 0 51694**) and water soluble potassium (r = 0 51532**) (Table 4) Significant correlation with CEC was also reported by Negi *et al* (1979) in soils of Simla and with water soluble potassium was reported by Singh *et al* (1983) in soils of eastern Haryana

1.3.3 Nitric acid soluble potassium

The values ranged from 0 5115 to 8 912 from 0 760 to 3 836 and from 0 630 to 3 835 me 100 g^{-1} in the soils of Ollukkara, Madakkathara and Thekkumkara Ramanathan and Krishnamurthy (1982) in soils of Tamil Nadu, Rao *et al* (1988) in soils of Andhra and Prakash and Singh (1986) in soils of western Uttar Pradesh have reported similar values for this fraction Although the soils are *predominant in 1 1 type of minerals, the higher value of nitric acid soluble fraction indicates the presence of 2 1 type of minerals in these soils Moreover, the high content of clay also contributes some fraction towards the total potassium*

1 4 Cation exchange properties of soils

1 4 1 Cation exchange capacity

The exchange properties of the soils are given in Table 6 The cation exchange capacity of Ollukkara, Madakkathara and Thekkumkara soils ranged from 4 12 to 34 02, 12 36 to 22 55 and 15 6 to 27 27 me 100 g^{-1} respectively

The cation exchange capacity depends on the content of organic matter and the clay fraction On comparing the different soils under study, a maximum of 34 02 me 100 g^{-1} was noticed for O_{17} This higher value is attributed to the high clay percentage (64 per cent) and the organic carbon (2 65 per cent)

*A significant positive correlation was obtained for the CEC of the soils with clay content (r = 0 9216**) and with organic carbon (r = 0 8903**) (Table 5) Except for soils O_{16} and O_{17}, most of the soils have CEC in the range of 12to25 me 100 g^{-1} The CEC of the highly weathered laterite soils is usually low (Coleman and Thomas, 1967) However, in acid sulphate soils of Kerala Ghosh et al (1976) reported that smectite is also present in addition to*

Table 6 *Exchange characteristics of soils*

Soil samples No	CEC (me 100 g^{-1})	Exchangeable bases (me 100 g^{-1}) Ca	Mg	K	Na	PBS (%)
O_3	4.85	0 88	0 108	0 065	0 038	22 44
O_4	4 15	0 72	0 080	0 077	0 013	21.61
O_9	15 60	2 54	0 216	0 084	0 011	18 28
O_{11}	9 00	2 16	0 108	0 033	0 011	25 69
O_{16}	31 06	6 76	2 581	0 525	0 212	32 45
O_{17}	34.02	7 24	2 650	0 486	0 205	31 10
M_1	12 36	2 16	0 294	0 384	0.016	23 08
M_{11}	21 78	3 08	0 920	0 298	0 045	19 01
M_{12}	22 55	3.38	0 920	0 174	0.084	20 21
M_{14}	15 15	2 56	0 490	0 038	0 011	20 43
M_{17}	18 00	3 24	0 308	0 095	0 009	20 28
M_{18}	14 95	2 21	0 390	0.041	0 008	16 18
M_{20}	14 75	2 58	0 308	0 046	0 015	19.99
T_4	17 36	2 88	0 345	0 174	0 015	19 66
T_5	27 27	5 04	1 390	0 123	0 051	24 39
T_7	15 60	2 80	0 129	0 102	0 031	19 63
T_8	20 78	2 79	0 486	0 184	0 013	16 80
T_{13}	26 38	4 48	1 316	0 064	0.031	22 33
T_{15}	25 36	4 32	1 305	0 115	0 081	22 95
T_{17}	20 09	2 98	0 916	0 089	0 928	19 99

kaolinite The higher values recorded in some samples of the present study envisages the presence of varying amounts of 2 1 minerals in these soils

1 4 2 <u>Exchangeable Bases</u>

The exchangeable Ca varied from 0 72 to / 24, 2 16 to 3 38 and 2 79 to 5 04 me 100 g^{-1} respectively for the soils of Ollukkara, Madakkathara and Thekkumkara The exchangeable magnesium ranged from 0 08 to 2 65, 0 0294 to 0 92 and 0 129 to 1 39 me 100 g^{-1} for the soils collected from Ollukkara, Madakkathara and Thekkumkara Exchangeable potassium ranged from 0 028 to 0 525, 0 038 to 0 384 and 0 064 to 0 184 me 100 g^{-1} and the exchangeable sodium varied from 0 011 to 0 212, 0 008 to 0 084 and from 0 013 to 0 081 me 100 g^{-1} respectively in the soils of Ollukkara, Madakkathara and Thekkumkara

Exchangeable Ca and Mg were the predominant bases in the exchange complex The content of exchangeable cations decreases in the order of Ca> Mg> K> Na for Ollukkara, Madakkathara and Thekkumkara soils The soils showed relatively high amount of exchangeable Ca and Mg due to their preferential adsorption on the colloidal surfaces and their smaller hydrated radius compared to other ions It is seen that the per cent potassium saturation of the CEC shows a decreasing trend with clay content and CEC Similar results were also reported by Tarafdar <u>et</u> <u>al</u> (1989)

1.4.3 Percentage base saturation

The percentage base saturation ranged from 18 29 to 32 5, 16 2 to 23 1 and 16 8 to 24 4 for the soils of Ollukkara, Madakkathara and Thekkumkara

The percentage base saturation generally followed the pattern of exchangeable Ca distribution The values were generally low for almost all the soils due to their extremely weathered condition However, it is slightly higher than that of upland soils

Based on the analytical data of the above 20 samples, five soils viz , M_1, O_3, T_4, M_{12} and T_{15} were selected for the laboratory incubation experiment and four soils viz , O_3, T_4, M_{12} and T_{15} for the pot culture experiment The mineralogical investigation of fine sand was also done for the soils selected for incubation study

1 5. Mineralogy of fine sand (Table 7)

In M_1, quartz was the dominant mineral in the light fraction Intergrowth of orthoclase and plagioclase known as perthite was also present in lesser amounts Orthoclase and plagioclase feldspars were showing cloudy appearance due to alteration Muscovite and biotite were also present in minute quantities In the heavy fraction, which was only very small in amount, opaques were dominated followed by hornblende, pyroxene, zircon and sillimanite

Plate 1. *Light Fraction*

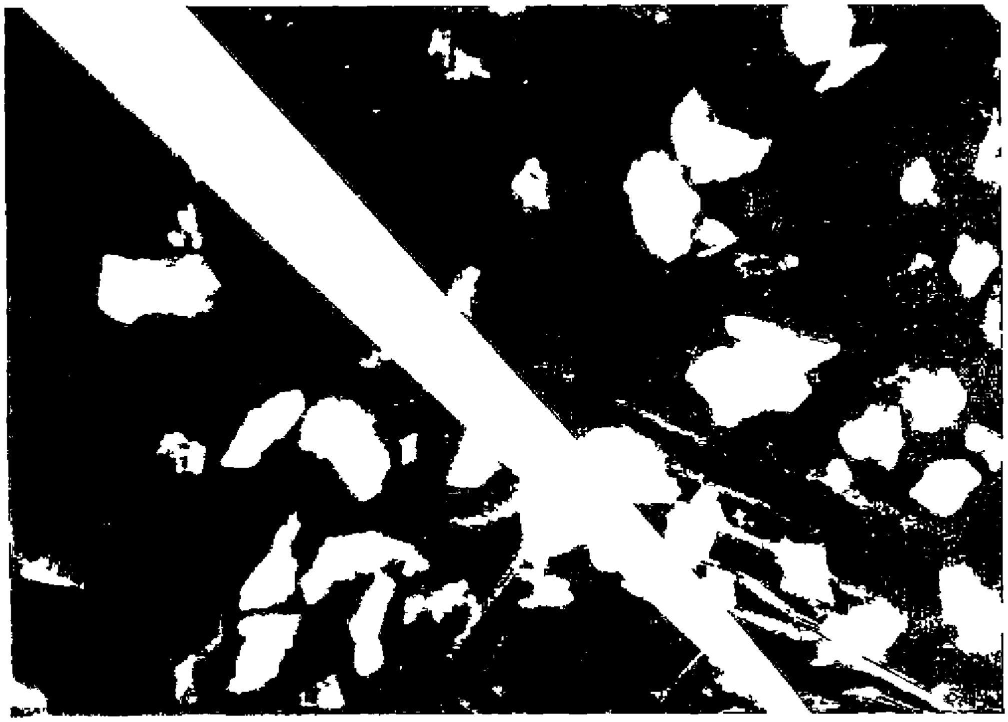


Plate 2. Opaques

Plate 1. Light Fraction

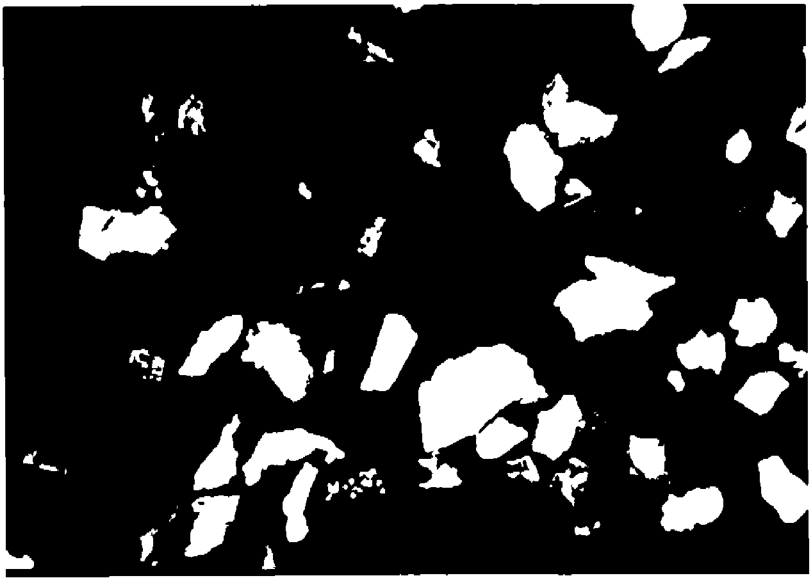


Plate 2. Opaques

In O_3 light fraction was dominated by quartz (plate 1) Orthoclase was present in minor quantities followed by muscovite and plagioclase The heavy fraction was dominated by opaques Hornblende, pyroxenes, zircon and monazite were present in smaller quantities

In T_4, quartz and feldspar (Perthite) were present in more or less equal quantities in the light fraction Plagioclase, muscovite and biotite were seen in subordinate amounts The heavy fraction was dominated by opaques (plate 2) Hornblende, pyroxene, rutile, zircon and biotite were also present

In M_{12}, the light fraction was dominated by quartz followed by plagioclase feldspar Perthite and muscovite were present in lesser amounts Opaques constituted the major fraction in the heavy mineral suite Hornblende pyroxene and zircon were seen in lesser amounts Highly altered biotite mica was also seen

In T_{15} the light fraction was dominated by quartz, immediately followed by feldspars-perthite and plagioclase and muscovite were also present (plates 3 and 4) Heavy fraction was dominated by opaques followed by hornblende, pyroxene, zircon, biotite and epidote Titanium minerals were present in subordinate amounts

Plate 3. Perthite with quartz

Plate 4. Plagioclase with a basal section of Opaque

Table 7 Mineralogy of find sand

Soil	Light fraction			Heavy fraction		
	Minerals present	No of grains*	per cent contribution	Minerals	No of grains*	per cent contribution
S_1	Quartz	230	76 6	Opaques	246	82 0
	Perthite	40	13 3	Hornblende	23	7 7
	Orthoclase	10	3 3	Pyroxene	13	4 3
	Muscovite	5	1 6	Zircon	8	2 7
	Plagioclase	7	2 5	Sillemanite	4	1 3
	Biotite	8	2 7	Others	6	2 0
S_2	Quartz	255	86 0	Opaques	254	84 7
	Orthoclase	28	9 0	Zircon	13	4 3
	Plagioclase	3	1 0	Hornblende	15	5 0
	Muscovite	14	4 0	Pyroxene	18	6 0
S_3	Quartz	156	52 0	Opaques	237	79 0
	Perthite	108	36 0	Hornblende	15	5 0
	Plagioclase	18	6 0	Pyroxene	17	5 7
	Muscovite	11	3 7	Biotite	9	3 0
	Biotite	7	2 3	Zircon	16	5 3
				Rutile	6	2 0

*Total number of grains counted = 300

contd

Table 7 (contd)

S_4	Quartz	187	62 3	Opaques	228	76 0
	Plagioclase	72	24 0	Hornblende	12	4 0
	Perthite	19	6 3	Pyroxene	14	4 7
	Muscovite	22	7 4	Zircon	10	3 3
				Biotite	36	12 0
S_5	Quartz	181	60 3	Opaques	232	80 0
	Plagioclase	21	7 0	Hornblende	15	5 1
	Perthite	90	30 0	Pyroxene	18	3 3
	Muscovite	8	2 7	Zircon	12	4 0
				Biotite	20	6 6
				Epidote	3	1 0

Plate 5. Amphibole grain

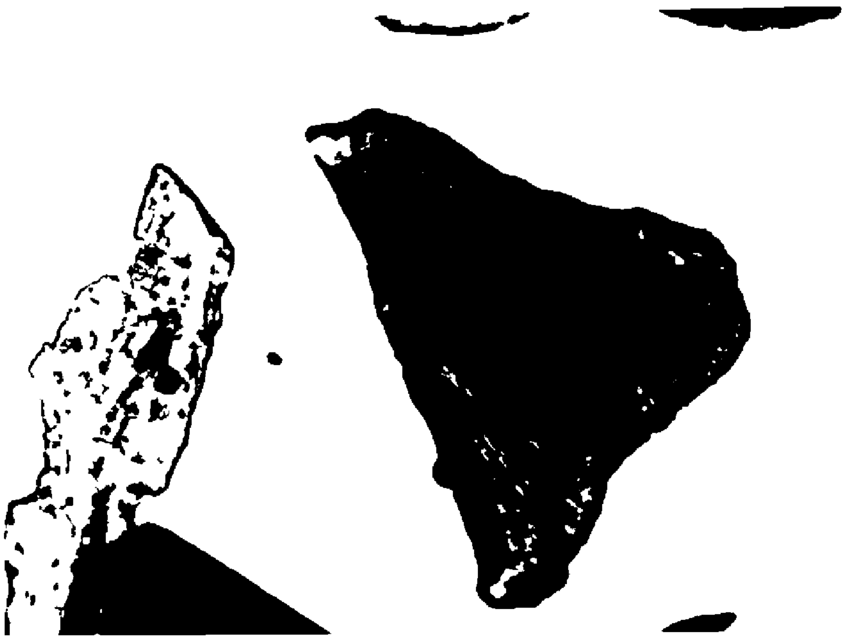


Plate 6. Zircon

Information on mineralogy of fine sand fraction gives an idea about the primry mineral assemblage of the parent material of the soils Being low land laterites, the soils contain few weatherable minerals apart from the resistant minerals like quartz This may be due to the difference in the pedogenic environment and nature of parent material from which these soils are formed

In all the five samples, light mineral suite was dominated by quartz Similar results have been reported by Nair (1978) in the rice soils of Wynad and Iyer (1979) in his studies on the red and laterite soil associations of Kerala Manickam (1977) in the laterite soils of Tamil Nadu and Venugopal (1980) and Jacob (1987) in the laterite soils of Kerala

The heavy minerals accounted only a very minute fraction of the total This includes the weatherable minerals like hornblende, pyroxenes (plate 5) and biotite Zircon, the most resistant mineral (plate 6) was also present invariably in almost all the soils The weatherable minerals hornblende and pyroxenes dominates in this fraction which accounts for the subsequent formations of 2 1 type minerals The proportions of the different heavy mineral fractions indicate the intensity of weathering The presence of perthite in all the samples proved that the soils have undergone only a moderate degree of weathering as compared to the upland laterites

LABORATORY INCUBATION EXPERIMENT

A laboratory incubation experiment was carried out to assess the dynamics of applied K in soils differing in their clay content The various treatments received different amounts of potassium based on their clay content and level of exchangeable K. Potassium was applied in the form of muriate of potash to raise the exchangeable potassium to the level of 0 5 and 0 55 me 100 g^{-1} in each soil and the initial level of exchangeable K was taken as the control The details of the selected soils are given in Table 8

The soils were incubated for 90 days at field capacity Soil samples at 15 days interval were taken throughout the period of incubation, and analysed for water soluble exchangeable and nitric acid soluble K fractions The results are discussed hereunder

2 1 Water soluble potassium

The data on the level of water soluble K at different periods of incubation are given in Tables 9 and 10 and their analysis of variance in Appendix 1

From Table 9, it is clear that for soils S_2, S_3, S_4 and S_5 water soluble K increased after the application of potassium fertiliser at the first fortnight The increase was marked till the

Table 8 Important physico-chemical characteristics of soils selected for incubation experiment

Soil No	Notation	Location	Textural class	Clay (%)	Silt (%)	Forms of K (me 100 g^{-1}) Water soluble	Exchangeable	HNO_3 soluble	Total K
M_1	S_1	Madakkathara	Sandy clay loam	16	12	0 1407	0 4730	1 940	8 951
O_3	S_2	Ollukkara	Sand	3	12	0 0312	0 0959	0 639	4 476
T_4	S_3	Thekkumkara	Sandy loam	28	8	0 0448	0 1918	2 558	13 427
M_{12}	S_4	Madakkathara	Sandyclay loam	37	18	0 0512	0 2366	2 301	14 066
T_{15}	S_5	Thekkumkara	Sandy clay loam	44	16	0 0256	0 1662	3 069	18 542

Table 9 Water soluble K, as influenced by the treatments at different periods of incubation ($me\ 100\ g^{-1}$)

Treatment No	Notation	Initial level	Period of incubation (fortnight) 1	2	3	4	5	6
1	S_1K_0	0 1407	0 1343	0 1374	0 0799	0 0845	0 1155	0 1806
2	S_1K_1	0 1407	0 1311	0 1439	0 0807	0 1247	0 1466	0 1828
3	S_1K_2	0 1407	0 1215	0 1470	0 0952	0 1280	0 1583	0.1837
4	S_2K_0	0 0312	0 0311	0 0702	0 0495	0 0623	0 0511	0 0799
5	S_2K_1	0 0312	0 0639	0 0863	0 0671	0 0607	0 0799	0 0575
6	S_2K_2	0 0312	0 0863	0 0991	0 0702	0 0163	0 0863	0 0959
7	S_3K_0	0 0447	0 0416	0 0415	0 0352	0 0767	0 1762	0 0767
8	S_3K_1	0 0447	0 0640	0 0702	0 0479	0 0799	0 1471	0 1852
9	S_3K_2	0 0447	0 0671	0 0863	0 0727	0 0591	0 1598	0 1662
10	S_4K_0	0 0512	0 0382	0 0479	0 0353	0 0368	0 1023	0 1523
11	S_4K_1	0 0512	0 0607	0 0735	0 0543	0 0480	0 1343	0 1022
12	S_4K_2	0 0512	0 0767	0 0863	0 0862	0 0415	0 2046	0 1408
13	S_5K_0	0 0256	0 0255	0 0447	0 0223	0 0191	0 0703	0 0543
14	S_5K_1	0 0256	0 0448	0 0703	0 0480	0 0480	0 1087	0 1022
15	S_5K_2	0 0256	0 0543	0 0543	0 0543	0 0764	0 1054	0.1182
	CD (5%)		0 00942	0 02495	NS	0 01483	0 03532	0 04479

end of second fortnight But in these soils, when no fertiliser was applied (control) a slight decrease was noticed in the first fortnight and then it gradually get increased For S_1, which was initially high in the water soluble fraction, a decrease in the content was noticed with and without the application of fertiliser till the end of third fortnight When a soluble fertiliser is applied to the soil, all of it does not exist in the solution form A considerable part of it gets transformed into the exchangeable and fixed form This might be the reason for the significant changes noticed in different soils in the water soluble K fraction within one month of potassium application

At the third fortnight a sudden fall in the content of water soluble K was noticed in all the soils However, in the fourth stage in almost all the treatments there was a slight increase in the level of water soluble potassium In the fifth and sixth stages an increasing trend was noticed in most of the treatments The variation in the level observed is attributed to the mineralogical composition of the soils predominance of trioctahedral or dioctahedral structural units, development of wedge zones, expanded layers and amount of non-exchangeable potassium However, at the end of the incubation period, the water soluble K increased as compared to the initial level

In soil, the equilibrium reactions existing between different forms of potassium profoundly influences the K availability The

Table 10 *Mean values of water soluble K as influenced by soils and levels of K application (me 100 g^{-1})*

Period of incubation (fortnight)	Soils					CD (5%) for soils	Levels of K application			CD (5%) for K levels
	S_1	S_2	S_3	S_4	S_5		K_0	K_1	K_2	
0	0 1407	0 0312	0 0448	0 0512	0 0256	-	-	-	-	-
1	0 1289	0 0671	0 0575	0 0585	0 0415	0 00513	0 0581	0 0729	0 0812	0 00412
2	0.1421	0 0852	0 0660	0 0564	0 0564	0 01448	0 0683	0 0888	0 0946	0 01113
3	0 0852	0 0623	0 0586	0 0415	0 0415	NS	0 0444	0 0596	0 0797	NS
4	0 1124	0 0697	0 0719	0 0421	0 0478	0 00092	0 0959	0 0722	0 0782	0 00073
5	0 1403	0 0724	0 1598	0 1470	0 0948	0 02052	0 1023	0 1233	0 1429	0 01574
6	0 1824	0 0777	0 1427	0 1317	0 0916	0 02593	0 1087	0 1258	0 1409	0 02121

content of each fraction at any time depends upon the rate and direction of these reactions (Sparks and Huang, 1985) The reaction between soil solution K and exchangeable K is strongly dependent on the type of clay mineral present The exchange reactions are rapid in soils where kaolinite is predominant than the 2 1 type of clays (Sparks and Jardines, 1984) The greater fluctuations noticed on this fraction within 90 days of incubation imparts the presence of 1 1 type minerals in these soils

When soils were compared (Table 10) for the content of water soluble K, it was seen that the amount increased significantly with increasing clay content The more clay the soil contains, the higher the potash contents should be, in order to maintain constant level of available K (Braunschweig, 1980) The significant differences noticed between soils at all the stages of analysis also confirmed this statement

When different levels of K were compared (Table10) a linear increase was noticed with increasing levels of K This significant difference between levels could be expected when more of water soluble fertiliser is applied to the soil

The interaction between soil clay and potassium application has also shown significant effect at many of the stages The difference in the water soluble fraction noticed in these soils at different levels of K application is attributed to the variation in the clay percentage of CEC of the soils

2 2 Ammonium acetate extractable K

The content of ammonium acetate extractable potassium at different periods of incubation are presented in Tables 11 and 12 and their analysis of variance in Appendix II

After the first fortnight this fraction was found to increase significantly in all the soils with different levels of treatments In the control there was a decrease noticed in all the soils except S_4 It could be due to the conversion to slowly available form Except S_2, for all other soils the same trend was observed in the second fortnight also This decrease in the content is accounted by a corresponding increase in the water soluble fraction at this stage

The increase in the content at these stages is due to the increase in the availability by the addition of soluble form of fertiliser Moreover, the immediately unavailable form will also contribute a fraction after one month

In the third fortnight in all the soils, the NH_4OAc extractable potassium increased to a higher level than the initial value One month after application of water soluble form of fertiliser if it is not absorbed by plant, or not subjected to leaching get converted to exchangeable form and this could be the reason for increase in this fraction [illegible] for these soils at

Table 11 Ammonium acetate extractable K as influenced by the treatments at different periods of incubation (me 100 g^{-1})

Treatment No	Notation	Initial level	Period of incubation (fortnights)					
			1	2	3	4	5	6
1	$S_1 K_0$	0 4730	0 4750	0 4180	0 4990	0 4912	0 4955	0 4571
2	$S_1 K_1$	0 4730	0 4833	0 4960	0 4981	0 3998	0 4988	0 4156
3	$S_1 K_2$	0 4730	0 4837	0 4973	0 4989	0 4253	0 5246	0 5723
4	$S_2 K_0$	0 0959	0 0955	0 1149	0 1750	0 0892	0 1341	0 1279
5	$S_2 K_1$	0 0959	0 1183	0 1215	0 1469	0 1024	0 1567	0 1215
6	$S_2 K_2$	0 0959	0 1185	0 1288	0 1662	0 1056	0 2205	0 1280
7	$S_3 K_0$	0 1918	0 1599	0 1726	0 1950	0 2043	0 3164	0 2653
8	$S_3 K_1$	0 1918	0 2396	0 2337	0 2717	0 2397	0 3292	0 3134
9	$S_3 K_2$	0 1918	0 2403	0 2368	0 2973	0 2462	0 3420	0 3005
10	$S_4 K_0$	0 2366	0 2403	0 1759	0 2111	0 1852	0 3100	0 2751
11	$S_4 K_1$	0 2366	0 2408	0 2430	0 2653	0 2397	0 3420	0 3388
12	$S_4 K_2$	0 2366	0 2590	0 2748	0 3518	0.3612	0 3648	0 3566
13	$S_5 K_0$	0 1662	0 1375	0 1406	0 1663	0 1665	0 2361	0 2813
14	$S_5 K_1$	0 1662	0 2142	0 2461	0 3037	0 2669	0 3069	0 3366
15	$S_5 K_2$	0 1662	0 2334	0 2462	0.2977	0 2798	0 3520	0 3538
CD (5%)		-	0 01814	0 01621	0 00803	0 03241	0 03652	0 07724

this stage The K content in soil solution and the clay percentage are the major determining factors of available potassium

In the fourth stage, however, a decreasing trend was obtained in almost all the soils This decrease in the exchangeable fraction could be either due to the movement to the non-exchangeable form or due to the water soluble form In the fifth fortnight, all the soils have a higher content of NH_4 OAc -K than that of the previous fortnight This shows that the dissociation of water soluble potassium is over by 2½ months and the increase in the exchangeable fractions can be from the water soluble form or from the fixed form depending on the clay minerals present in each soil At the sixth stage although the level is much higher than that in the initial level in all the soils it was less than that of the fifth fortnight The increase in the other fractions at this stage accounts for the decrease in the concentration of this fraction

When the soils were compared a significant difference was obtained between them The values were increased with increase in clay content Exchangeable K is the intermediate stage between soluble form and non-exchangeable form and the availability depends on the K concentration in the soil solution and the K saturation of the CEC This may be the reason for the fluctuations noticed during the incubation period

Table 12 Mean values of ammonium acetate extractable K as influenced by soils and levels of K application (me $100g^{-1}$)

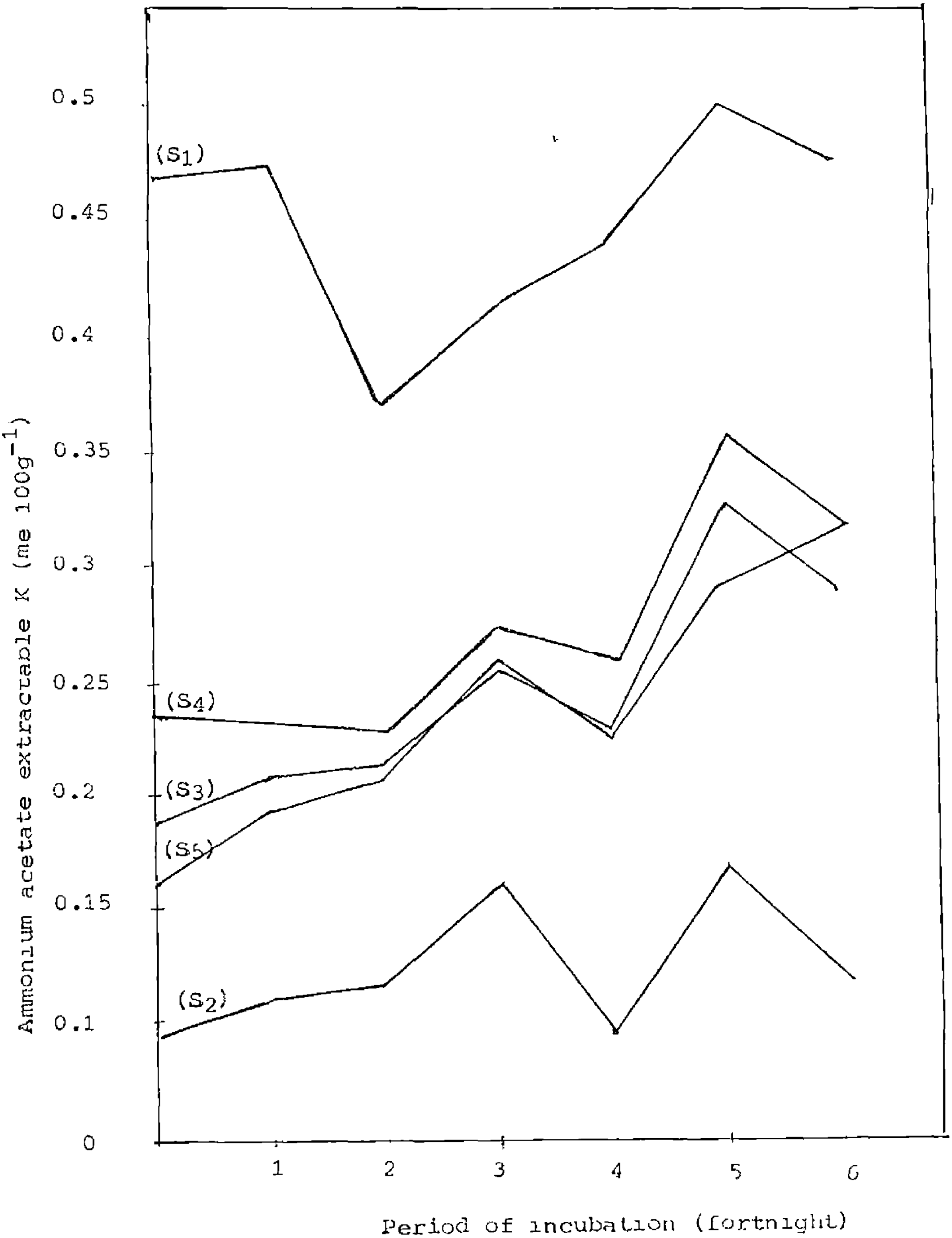
Period of incubation (fortnight)	Soils					CD (5%) for soils	Levels of K application			CD (5%) for K levels
	S_1	S_2	S_3	S_4	S_5		K_0	K_1	K_2	
0	0 4730	0 0959	0 1918	0 2366	0 1662	-	-	-	-	-
1	0 4806	0 1107	0 2132	0 2453	0 1950	0 00812	0 2046	0 2404	0 2307	0 01013
2	0 3771	0 1182	0 2143	0.2312	0 2109	0 00723	0.1956	0 2468	0 2487	0.00932
3	0 4167	0 1627	0 2546	0 2760	0 2559	0 00364	0.2307	0 2787	0 3101	0 00464
4	0 4454	0 0991	0.2301	0 2621	0 2377	0 01451	0 2313	0 2497	0 2836	0 01872
5	0 5063	0 1704	0 3292	0 3622	0 2984	0 01632	0 2984	0 3267	0 3748	0 02113
6	0 4816	0 1258	0 2930	0 3235	0.3236	0 03443	0.2813	0 3050	0.3422	0 04463

When the levels of potassium were compared the content was significantly higher with higher levels of application of K This result was in agreement with the findings of Misra and Shankar (1971) in the soils of Uttar Pradesh Prasad and Rajamannar (1987) in soils of slow and moderate K releasing capacity and Prakash and Singh (1989) in the loam and clay loam soils

The interaction between the clay content and fertilizer levels showed a significant effect on NH_4 OAc-K content This may be attributed to the differences in the releasing or fixing capacity of different clay minerals present in the soils Exchangeable K is bound with different bond strength, at the various sites of the clay minerals The release of K to exchangeable form and absorption from soil solution by exchange sites are both forward and reverse (Mc Lean and Watson, 1985) The reactions are regulated by mechanisms that depend on their relative strength for binding K Soils having 2 1 type of clays like illite, vermiculite or montmorillonite have the capacity of both fixation and adsorption of K than that of soils with kaolinitic type of clay

The recovery percentage of applied K in available form was worked out for the soils after 45 days It ranged from 12 to 15, from 25 to 30 from 10 to 37 and from 41 to 34 per cent for S_2, S_3, S_4 and S_5 respectively with each higher level of application Similar results were reported by Talati et al (1974) From the data it is seen that the recovery percentage is maximum in the case

Fig. 2 Mean values of ammonium acetate extractable K in the five soils during the incubation period



of soil with more than 40 per cent clay and it is less in the case of soil with less than 10 per cent clay. This shows that the clay content has a great influence on the availability of K when it is applied for raising crop. In the present study, a decrease in the total content of exchangeable K was noticed after 45 days. So it is advisable to apply potassium fertiliser in splits rather than applying them all as basal especially for short duration crops to meet the immediate requirement. The increase of the exchangeable level on application of K fertilizer according to the clay content along with the initial level of exchangeable K is particularly profitable for soils containing more than 25 per cent clay as illustrated in fig.2. In these soils the K availability to the plants is often over-estimated. Only an adequate K supply corresponding to the clay content will lead to the desired yield increase (Braunschweig, 1980).

2.3. Nitric acid soluble K

The data are given in Tables 13 and 14 and their analysis of variance in Appendix III. On incubation for a period of six fortnights after application of water soluble fertilizer, the level of non-exchangeable potassium has become doubled in almost all the

Table 13 Nitric acid soluble K as influenced by the treatment at different period of incubation (me 100 g^{-1})

Treatment No	Notation	Initial level	Period of incubation (fortnight) 1	2	3	4	5	6
1	S_1K_0	1 9400	1 550	2 557	2 556	2 558	2 558	2 717
2	S_1K_1	1 9400	2 558	3 516	2 877	2 879	3 197	3 196
3	S_1K_2	1 9400	2 536	3 518	2 553	2 880	2 717	2 558
4	S_2K_0	0 6394	1 018	1 278	1 279	1 279	1 268	1 278
5	S_2K_1	0 6394	1 278	1 278	0 639	1 278	1 919	1 918
6	S_2K_2	0 6394	1 298	1 278	1 917	1 916	1 277	0 638
7	S_3K_0	2 5580	2 558	2 559	2 556	2 557	3 197	3 515
8	S_3K_1	2 5580	2 877	3 837	2 557	2 558	3 835	4 474
9	S_3K_2	2 5580	3 514	3 198	3 198	3 196	2 555	3 196
10	S_4K_0	2 3010	1 598	1 598	2 556	2 558	1 406	1 278
11	S_4K_1	2 3010	1 918	1 599	1 914	1 918	1 918	2 557
12	S_4K_2	2 3010	2 238	2 558	2 557	2 557	2 557	2 554
13	S_5K_0	3 0690	3 197	2 558	3 835	3 831	3 836	5 114
14	S_5K_1	3 0690	4 156	4 156	3 839	3 839	3 877	6 076
15	S_5K_2	3 0690	5 452	5 434	6 386	6 403	5 753	6 717
	CD (5%)		0 0829	0 0609	0 0247	0 0353	NS	NS

treatments Within this period, greater fluctuations were observed for the different treatments

In the first fortnight an increase in the content of nitric acid soluble fraction was observed in most of the treatments except a few The increase in the content noticed in the soils may be due to the conversion from exchangeable form to the slowly available form The low value obtained in S_1 and S_5 could be attributed to its conversion to the exchangeable form which is confirmed by an increase of that fraction at this stage

In the second fortnight, the content was increased in all the soils except a few, where K is applied at the higher level Normally when potassium is applied in the soil, immediately there will occur the interconversion of different forms of K so as to maintain the equilibrium level

In the third and fourth fortnight, a steady state is noticed except for some minor fluctuations in a few treatments The slight variations noticed could be due to the tendency of the soil minerals to release and fix K according to the soil environment The inter conversion reactions are regulated by mechanism that depend on their relative strength for bonding. In the fifth fortnight the tendency was to decrease the HNO_3 soluble fraction in most soils At the same stage, a corresponding increase was recorded in the exchangeable K that comes from the fixed form of potassium However

Table 14 Mean values of nitric acid soluble K as influenced by soils and levels of K application (me 100 g^{-1})

Period of incubation (fortnight)	Soil					CD (5%) for soils	Levels of K application			CD (5%) for levels of K application
	S_1	S_2	S_3	S_4	S_5		K_0	K_1	K_2	
0	1 9400	0 6394	2 5580	2 3010	3 0690	-	-	-	-	-
1	2 2172	1 4910	2 9830	1 9180	4 2680	0 0371	2 1660	2 5570	3.0040	0 04793
2	3 1971	1 2780	3 1980	1 9090	4 0490	0 0271	2 1100	2 8870	3 1970	0 03532
3	2 6623	1 2780	2 7710	2 3430	4 6870	0 0112	2 5560	2 3150	3 3230	0 01414
4	2 7731	1 4920	2 7710	2 3450	4 6920	0 0157	2 5570	2 4940	3 3910	0 02023
5	2 8774	1 4880	3 1960	2 1790	4 4760	NS	2 8160	2 9420	2 9720	NS
6	2 8242	1 2780	3 7290	2 1300	5 9670	0 0660	2 7800	3 1440	3 5310	0 08534

in some samples a higher value was recorded and this could be due to the varying adsorptive and releasing tendency of the potassium bearing minerals present in the soils

In the 6th stage no linear trend was observed in this fraction In soils of more than 40 per cent clay, the value is much higher than the previous stage When potassium fertiliser is applied to the soil and if the available form was not taken up by the plant or lost by leaching there will be a tendency for the soluble fraction to remain either in exchangeable form or in non-exchangeable form However this change will strongly depend on the type of clay minerals present and also the CEC of the soils

When the soils are compared, there was significant difference in the content of nitric acid soluble K The amount and type of clay mineral determines the capacity of soil to retain or release K The non-exchangeable K reserve can release a smaller extent to the soil solution to augment a soil s K supplying power The ability of laterite soils to fix potassium is higher as compared to red soils (Ramanathan, 1978)

When the different levels were compared a significant difference was noticed in the content At higher levels of K, higher amount of fixation was observed in some soils In soils of varying texture Chakravorti and Patnaik (1990) and Prakash and Singh (1989) also obtained similar trends

The interaction effect between clay content of soils and different K levels was significant This significant difference could be attributed to the soil s ability to adsorb and retain K which will vary according to the clay minerals, CEC and organic matter content The fixation decreases in the sequence illite> vermiculite > smectite > kaolinite Eventhough the clay content is the major factor organic matter with high CEC may be able to hold a substantial amount in exchangeable form In this experiment, in sample S_4, with an organic matter content of 1 per cent showed a decrease in non-exchangeable K at the end of the incubation period

The results of the experiment showed that there was a remarkable increase in the different fractions of K on incubation of the soil for three months Similar results were reported by Sharpley (1990) in soils of differing mineralogy after a 25 week incubation period But there was a wide fluctuation in the levels of different fractions at different sampling stages The significant relationship of the different forms of K, their relative proportion in the soil and soil properties like clay content, mineralogical composition, pH, CEC and organic carbon accounts for these variation

The exchangeable K content of the soils have increased with increasing clay content Nemeth and Harrach (1974) observed a close correlation between the K concentration and the exchangeable form, if the latter is not related as usual to 100 g soil, but to the clay content (mg K_2O per percentage clay) and expressed as the K saturation of the inorganic cation exchange capacity Clay and clay loam soils have high buffering capacity than the light textured soils To achieve a certain K intensity, a soil with a high amount of clay requires a higher dose of potassium fertiliser (Braunschweig, 1980) But this cannotbe applied tolighter soils as these soils possess a low buffering capacity In the present study the soils with high clay content received a high content of K fertiliser to maintain the two levels as the treatment is fixed based on the clay content as compared to the soil with lesser clay content From Fig 2 it is clear that for the lighter soil, the exchangeable K did not increase to the same level as the heavy soils This proved once again that lighter soils require a heavy saturation than heavy soils

At present recommendations are made based on the ammonium acetate extractable K without giving due importance to the proportions of different size fractions of the soils If the soil contains more clay, with secondary clay minerals of 2 1 type, there will be a tendency for the applied K to get adsorbed on the different sites of the clay minerals Application of fertilizer at a rate of 20 mg K_2O 100 g^{-1} soil, no yield increase was obtained whereas a positive effect of fertilisation was well observed at a rate of 50 mg K_2O 100 g^{-1} soil or more depending on the type of soil

(Grimme et al 1971) Not only the total available amounts of potassium in the soil, but also the fraction which is transported to the plant root by diffuson and mass flow plays a decisive role on plant growth (Mengel 1974) This movement of ion to the plant root is greatly influenced by the soil minerals organic matter and CEC So it is worthwhile to keep the recommendations taking into account the clay percentage of the soils

POT CULTURE EXPERIMENT

With a view to studying the uptake pattern of different nutrients in presence of applied potassium, a pot culture experiment was carried out in soils of different textural composition using rice as test up Dry matter yield and content of nitrogen, phosphorus, potassium, calcium and magnesium were determined in the plant parts at the tillering, flowering and harvesting stages The different forms of potassium in soils were also studied at these stages The results brought out in this study are presented and discussed in the following sections

3. Yield of straw and nutrient composition

3 1 Yield of straw

Yield of straw affected by various potassium levels in soils of varying texture are presented in Tables 15 & 16, fig 3 and their analysis of variance in Appendix IV

The yield of straw was found to increase gradually as growth proceeds and was rapid till the flowering stage The increase in the straw weight after flowering was in a lower rate Potassium was absorbed by plants till the later period of growth and the absorption of potassium increased with increasing concentration of the nutrients in the growing medium

Table 15 **Yield of straw as influenced by treatments at different periods of crop growth**

Treatments	Yield of straw (g pot^{-1})		
	Tillering	Flowering	Harvesting
$S_1 K_1$	2 100	14 633	15 333
$S_1 K_2$	2 567	15 700	17 000
$S_1 K_3$	3 533	16 367	18 000
$S_1 K_4$	4 967	16 030	16 333
$S_2 K_1$	5 433	10 167	18 833
$S_2 K_2$	5 667	17 200	27 833
$S_2 K_3$	6 683	25 667	34 333
$S_2 K_4$	4 900	37 833	47 167
$S_3 K_1$	3 067	9 400	11 667
$S_3 K_2$	4 967	12 603	14 333
$S_3 K_3$	5 433	12 000	14 667
$S_3 K_4$	3 367	14 533	17 000
$S_4 K_1$	5 267	10 033	16 667
$S_4 K_2$	5 050	17 333	27 833
$S_4 K_3$	5 633	24 433	30 667
$S_4 K_4$	7 650	39 467	53 167
CD (5%)	NS	7 3188	NS

When the soils were compared, there was a significant difference in the yield of straw at all the stages The highest response was obtained for the soil with 28 per cent clay in all the three stages Since this soil was relatively of a coarser texture, the added potassium was available in the soluble form for the plant uptake The next higher straw yield was recorded for the soil with more than 40 per cent clay The highest content of slowly available K which is the source of K at the later stages partially accounts for this yield increase compared to the other soils Rice plants are known to absorb a larger percentage of total absorbed K^+ from the non-exchangeable form and vigorous rice growth was obtained in a flooded soil than under non-flooded conditions (Chang and Feng, 1960)

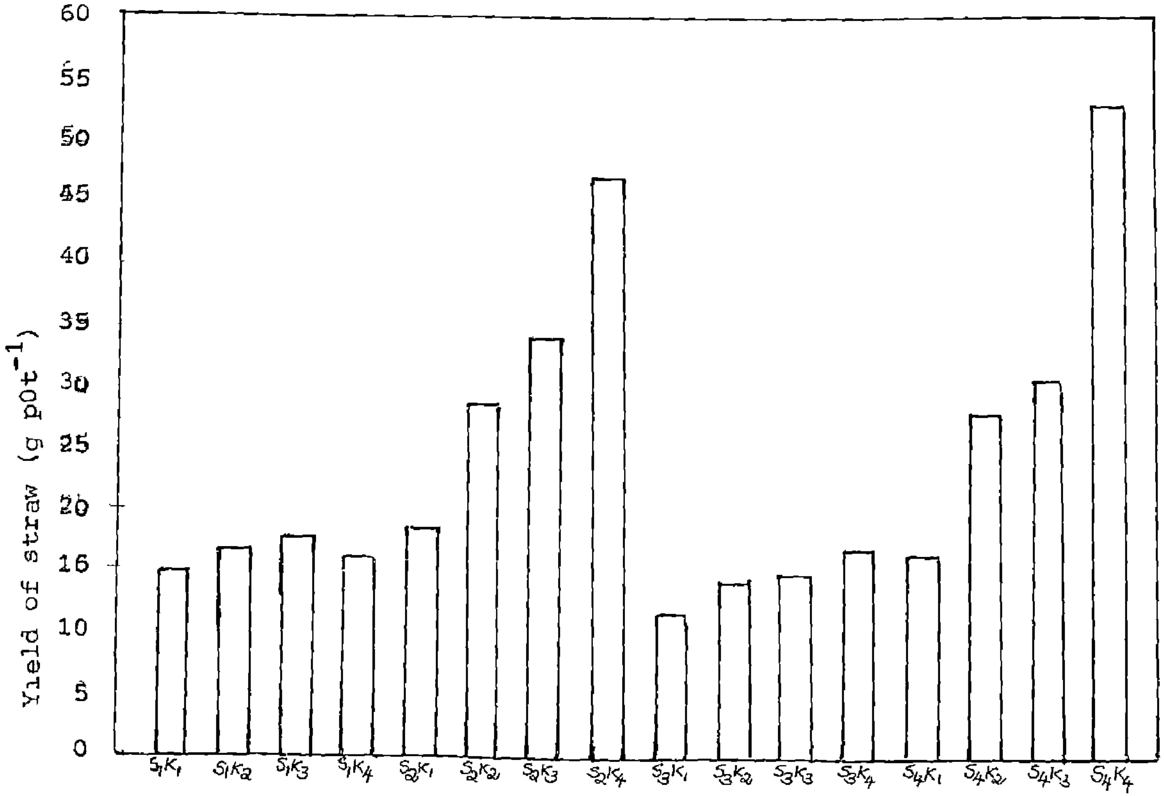
When the different levels of K application were compared, there was a significant difference in the weight of straw at the flowering and harvesting stages The increase in weight over control was 38 9 74 and 94 per cent for 20, 40 and 60 kg K_2O ha^{-1} applied, respectively for the flowering stage and it was 46 64 and 91 per cent increase at the harvesting stage This indicated that vegetative growth is much influenced by the increasing levels of potassium Increase in dry matter production with increase in the level of K up to 50 kg K_2O ha^{-1} was observed by Mishra (1980), and up to 60 kg K_2O ha^{-1} by Hati and Misra (1983) Senthivel and Palaniappan (1985) also reported similar effects of K on dry matter production

Table 16 **Mean values of straw yield as influenced by soils and levels of potassium application ($g\ pot^{-1}$) at different stages of crop growth**

Stages	Soils				K levels			
	S_1	S_2	S_3	S_4	K_1	K_2	K_3	K_4
Tillering	2 542	6 171	4 208	5 650	3 967	4 563	4 571	4 471
Flowering	15 685	22 717	12 142	17 900	11 392	15 717	19 617	21 958
Harvesting	15 917	32 042	14 417	32.083	14 875	21 750	24 417	33 420

CD (5%) for soils		CD (5%) for levels of K application	
Tillering	1 7234	Tillering	NS
Flowering	3 6594	Flowering	3 6594
Harvesting	7 2828	Harvesting	7 2828

Fig.3 Yield of straw as influenced by different treatments (g pot^{-1})



The interaction was significant at the tillering and flowering stages In the soils of low clay content lower levels of K gave maximum yield but for soils with higher clay contents highest level of K gave maximum straw yield

3 2 Nutrient composition of straw

3 2 1 N content in the straw

The analytical data on N content of straw determined at three different stages are given in Tables 17 and 18 and their analysis of variance in Appendix V

As given in the table N content was maximum during the tillering stage But the treatments did not give significant difference between soils or between different levels of K application at this stage For the highest level of K application (60 kg ha^{-1}) maximum N content was recorded in the soil with 44 per cent clay In the tillering stage, metabolic activities are also on a high rate and the maximum absorption of nutrients take place But during flowering and harvesting stages, a gradual decrease can be noticed in all the treatments This is due to the increased dry matter accumulation The nutrients taken up by the plant get distributed between the part of the plant for which the crop is mainly grown that is grain, and the rest of the plant which is often of less economic value

When the treatments were pooled together, a significant difference was noticed between soils in the N content of the straw at the flowering and harvesting stages (Table 18). Coarse textured soils recorded low content of N (2 206 per cent) in the straw than in the fine textured ones (3 284 per cent) This is because the organic matter content and nitrogen present in a soil is influenced by its texture Because of the lower moisture content and the more ready oxidation occurring in the lighter soils they are having less organic matter and nitrogen than the heavier soils So the absorption of N was less in the lighter soils

When different levels of K applications were compared significant differences were obtained in the flowering and harvesting stages This indicates that potassium is essential for ensuring efficient utilisation of N Nitrogen and potassium being the essential nutrients for rice crop, both have to be applied together so as to get maximum returns from the crop Mondal (1982) reported a 16 per cent yield increase in rice by the combined application N and K fertiliser than the application of N alone The positive effect of potassium on the absorption of N might be due to the ability of potassium to reduce the fixation of NH_4^+ in the soils(Gupta et al , 1971)

The interaction of soils and levels of K application did not give any significant effect on the N content of the straw

Table 17 Mean values of N content (%) and N uptake (g pot^{-1}) as affected by different treatments at different stages of crop growth

Treatments	N content			N uptake		
	Tillering stage	Flowering stage	Harvesting stage	Tillering	Flowering	Harvesting
$S_1 K_1$	2 3610	2 0120	0 4960	0 0489	0 3140	0 0620
$S_1 K_2$	2 4740	2 0010	0 5100	0 0639	0 5400	0 0870
$S_1 K_3$	2 8030	2 0960	0 5300	0 1020	0 3310	0 0960
$S_1 K_4$	3 1280	2 7100	0 6400	0 0617	0.4400	0 1170
$S_2 K_1$	3 2520	2 8800	0 5760	0 1766	0 2940	0.1170
$S_2 K_2$	3 3740	3 0570	0 6200	0 1925	0 5270	0 1690
$S_2 K_3$	3 5410	3 0600	0.6440	0 2376	0 7850	0 2140
$S_2 K_4$	3 6430	3 0590	0 7420	0 1791	1 1600	0 3420
$S_3 K_1$	3 2420	2 9720	0 7430	0 0993	0 2800	0 0870
$S_3 K_2$	3 3130	3 0600	0 7450	0 1642	0 3870	0 1070
$S_3 K_3$	3 4410	2 9700	0 9330	0 1868	0 3620	0 1350
$S_3 K_4$	3 7300	3 3400	0 9360	0 1258	0 4920	0 1570
$S_4 K_1$	3 4500	3 1900	0 9340	0 1821	0.3340	0 1450
$S_4 K_2$	3 6540	3 1300	0 9400	0 1847	0 5410	0 2510
$S_4 K_3$	3.8320	3 3180	1 0360	0 2157	0 8180	0.3370
$S_4 K_4$	3 8910	3 4890	1 0230	0 3001	1 3780	0 5330
CD (5%)	NS	0 2879	NS	NS	NS	NS

3.2.2. N uptake by the straw

Effect of various treatments on the uptake of N by the rice straw is presented in Tables 17 and 18 and their analysis in Appendix V

In all the treatments, the uptake of N was found to increase till flowering stage and then it get decreased at the stage of harvesting The highest uptake at flowering was noticed for the soil with 44 per cent clay, for the 60 kg K_2O application The increase in the first two stages was due to the increased dry matter accumulation But at the harvesting stage, N in the straw get translocated into the grain and the content in the straw was less which resulted in the low uptake of N at this stage

When the soils were compared for the uptake of N, significant differences were noticed at the tillering and harvesting stages Vigorous absorption of the nutrients in the tillering stage and the rapid translocation at the harvesting stage accounted for this effect

When the various levels of K were compared, significant differences were noticed at the harvesting stage When no K fertiliser was applied the uptake of N was only 0 103 g pot^{-1} which increased to 0 237 g pot^{-1} with the highest level of K application (60 kg K_2O ha^{-1}) at this stage Increased uptake of N with

Table 18 Mean values of N content and N uptake by the rice straw as influenced by soils and different levels of K application

	Soils	Tillering	Flowering	Harvesting	Levels	Tillering	Flowering	Harvesting
N content (%)	S_1	2 560	2 206	0 5430	K_1	3 075	2 764	0 6880
	S_2	3 452	3.018	0 6460	K_2	3 070	2 816	0.7030
	S_3	3 429	3 086	0.8390	K_3	3 404	2 861	0.7860
	S_4	3.707	3 284	0.9830	K_4	3 599	3 149	0.8350
	CD (5%)	NS	0.1445	0 08181		NS	0.1445	0 08181
N uptake (g pot^{-1})	S_1	0 0691	0 4060	0.0900	K_1	0 1592	0 3050	0 1030
	S_2	0 2126	0 6910	0 2110	K_2	0 1510	0.9990	0 1530
	S_3	0.1432	0 3800	0 1210	K_3	0 1590	0 5740	0 1950
	S_4	0 2111	0 5730	0.3170	K_4	0.1670	0.6920	0.2870
	CD (5%)	0 4413	NS	0.05671		NS	NS	0 05671

application of K was reported by Muthuswamy et al (1974) and Mengel et al (1976)

Interaction of clay content and K levels did not give significant difference in the N uptake at any of the stages

3.3 P content of the straw

Content of P in the rice straw at various stages as affected by different treatments is presented in Tables 19 and 20 and their analysis in Appendix VI

It is clear from the table that the content was maximum at the flowering stage At the harvesting stage a decrease in the content was noticed Due to the increased dry matter accumulation and translocation to the grains, the content was less at this stage

When the soils were compared for the content in the straw (Table 20) significant differences were noticed at the tillering and the harvesting stages The content was comparatively higher for the coarse textured soils in the initial stages and at the harvesting stage a maximum content 0 22 per cent was noticed for the soil with more than 40 per cent clay Kaolinite is the major mineral in laterite soils and the added phosphate gets fixed in the broken edges of this mineral So the availability will be

Table 19 Mean values of P content (%) and P uptake (g pot^{-1}) in rice straw as influenced by different treatments at different stages of crop growth

Treatments	P content			P uptake		
	Tillering	Flowering	Harvesting	Tillering	Flowering	Harvesting
$S_1 K_1$	0 3240	0 3241	0 1291	0 0069	0 0512	0 0161
$S_1 K_2$	0.3381	0 3563	0 1763	0 0091	0 0611	0 0292
$S_1 K_3$	0 3444	0 3511	0 1132	0 0126	0 0561	0 0210
$S_1 K_4$	0.3442	0 3792	0 2580	0 0064	0 0552	0 0421
$S_2 K_1$	0 2453	0 2432	0 1134	0 0186	0 0253	0 0222
$S_2 K_2$	0 2262	0 2634	0 2451	0 0152	0 0561	0 0694
$S_2 K_3$	0 3191	0 3881	0 1982	0 0263	0 0831	0 0690
$S_2 K_4$	0 3090	0 3730	0 1983	0 0185	0 1081	0 0941
$S_3 K_1$	0 3191	0 3811	0 1311	0 0115	0 0272	0 0152
$S_3 K_2$	0 2362	0 3151	0 0682	0 0159	0 0301	0 0100
$S_3 K_3$	0 2420	0 3082	0 0794	0 0167	0 0422	0 0111
$S_3 K_4$	0 2981	0 3151	0 1323	0 0108	0 0431	0 0552
$S_4 K_1$	0 3030	0 3241	0 1311	0 0172	0 0312	0 0442
$S_4 K_2$	0 2552	0 3100	0 1113	0 0169	0 0411	0 0323
$S_4 K_3$	0 3031	0 3332	0 1342	0 0185	0 0731	0 0471
$S_4 K_4$	0 3810	0 3583	0 1541	0 0280	0 0542	0 1092
CD (5%)	0 05632	0 03714	0 03412	NS	0 02163	NS

initially low Moreover, dissolution of the phosphates in the flooded soil releases P in an available from resulting in more availability towards the later stages However, on comparing all the four soils, in all stages, P content was less in the soil with 37 per cent clay The low availability of P with respect to the soil is attributed to its greater fixation in this soil by the 1 1 type of mineral and some interstratified mineral

When the different levels of K applications were compared (Table 20) for the content of P in the straw, a significant difference was noticed at the flowering and harvesting stages. At the flowering stage the absorption P found to be maximum and the response to P was more when K was applied This is in agreement with the findings of De Datta and Gomez (1982)

Interaction between clay content and potassium applications was significant at all the stages, when the P content in the straw was considered. The response of P was greater when K was applied However some variations could be observed at higher levels of K application in some soils which is due to the differences in the mineralogical composition of these soils

3.4. Uptake of P by straw

Uptake of P at different stages are given in the Tables 19 and 20 and their analysis of variance in the Appendix VI

Table 20 . **Mean values of P content and P uptake by the rice straw as influenced by soils and different levels of K application**

	Soil	Tillering	Flowering	Harvesting	Levels	Tillering	Flowering	Harvesting
P content (%)	S_1	0 3400	0 3520	0 1690	K_1	0 2971	0 3031	0 1710
	S_2	0 2991	0 3422	0 1893	K_2	0 3110	0 3000	0 1501
	S_3	0.2992	0 3303	0 1512	K_3	0 3450	0 3280	0 1710
	S_4	0 2853	0 3311	0 2201	K_4	0 3560	0 3081	0 2760
	CD (5%)	NS	0 02943	0 01723		0 01861	NS	0 01723
P uptake (g pot^{-1})	S_1	0 0088	0 0560	0 0270	K_1	0 0128	0 0341	0 0190
	S_2	0 0214	0 0740	0 0630	K_2	0 0143	0 0480	0 0351
	S_3	0 0134	0 0350	0 0230	K_3	0 0151	0 0631	0 0470
	S_4	0 0196	0 0500	0 0580	K_4	0 0159	0 0680	0 0750
	CD (5%)	0 00672	0.01081	0.01523		NS	0 01081	0 01523

In all the treatments uptake of P was found to increase rapidly till the flowering stage and then a slight decrease was noticed The increase in the uptake may be due to the greater absorption of P till the flowering stage in addition to the dry matter accumulation But at the harvesting stage the uptake was low due to the translocation of the nutrient to the grain

When the soils were compared (Table 20) for the uptake of P, a significant difference was noticed among the soils at all the three stages This could be attributed to the differences in the availability of the nutrient and the dry matter accumulation at each stage

The different levels of K application gave significant differences in the uptake of P at the flowering and harvesting stages With no K application, the uptake of P was only 0 034 g pot^{-1} which increased to 0 048, 0 063 and 0 068 g pot^{-1} at the flowering stage At the harvesting stage also the uptake was high with the application of K fertiliser Increased uptake of P by the application of K fertiliser was also reported by Muthuswamy et al. (1974), Mengel et al (1976) and Singh and Singh (1987).

The interaction effect was significant only at the flowering stage for the uptake of P The differences in the availability of the nutrients in soils with differing clay content resulted in the interaction at this stage

3.5. K content in the straw

The content of K in the straw at the different stages of growth of paddy as influenced by treatments is presented in Tables 21 and 22 and their analysis of variance in Appendix VII

The K content was maximum during the tillering stage and the maximum K content was noticed with the highest level of K application in the soil with more than 40 per cent clay Potassium found to regulate various metabolic processes and absorbed at a rate almost parallel to the dry matter production but there is no marked translocation of this element from the vegetative organs to the grain as compared to N and P However, the content decreased gradually with respect to the growth of the plant and with increased dry matter accumulation This may be the reason for the decreasing trend noticed in the content at the later stages

When soils were compared after pooling the treatments together there noticed a significant difference in the K content in all the stages The maximum K content was recorded for soil with more than 40 per cent clay followed by soils with 28,37 and less than 10per cent clay.The values were 2 9, 2 845, 2 4 and 2 287 per cent respectively (Table 22)

The continuous and adequate potassium nutrition of plants depends not only on the amount of plant available K in soils

Table 21 *Potassium content and potassium uptake of straw as influenced by the treatments at different periods of crop growth*

Treatment	Potassium content (%)			Potassium uptake (g pot^{-1})		
	Tillering	Flowering	Harvesting	Tillering	Flowering	Harvesting
$S_1 K_1$	2 048	1 748	1 531	0 0430	0 2731	0 1881
$S_1 K_2$	2 182	1 901	1 831	0 0460	0 2992	0 3100
$S_1 K_3$	2 313	2 102	1 700	0 0840	0 3574	0 3072
$S_1 K_4$	2 331	2 131	2 090	0 1160	0 3422	0 3390
$S_2 K_1$	2 452	1 471	1 401	0 1330	0 1503	0 2573
$S_2 K_2$	2 961	1 651	1 570	0 1690	0 2900	0 4221
$S_2 K_3$	2 852	1 531	1 501	0 1970	0 3911	0 5092
$S_2 K_4$	2 623	1 701	1 680	0 1280	0 6472	0 7974
$S_3 K_1$	1 971	1 871	1 201	0 0600	0 1763	0 1401
$S_3 K_2$	2 604	2 032	1 881	0 1321	0 2321	0 2712
$S_3 K_3$	2 631	2 091	2 021	0 1430	0 2482	0 2970
$S_3 K_4$	2 702	2 101	1 930	0 0811	0 3013	0 3303
$S_4 K_1$	2 023	1 700	1 320	0 1030	0 1361	0 2091
$S_4 K_2$	2 701	1 701	1 470	0 1370	0 2792	0 4282
$S_4 K_3$	2 802	1 570	1 480	0 1581	0 4303	0 4591
$S_4 K_4$	3 083	1 651	1 610	0 3060	0 3061	0 8350
CD (5%)	NS	NS	NS	NS	0 14962	NS

(solution K) but also on the rapid renewal of its supply The clay minerals like illite, smectite and vermiculite can retain K^+ on their inner and planar surfaces The quantity and type of minerals present in the soils may be varied and this may be the reason for the differences in the response of K in soils of varying texture Such minerals act as the source of non-exchangeable K which will be available during the later stages of crop growth

When the different levels of K applications were compared, a significant difference in the K content was noticed at the harvesting stage The highest K content was noticed at the highest level of K application in all the stages Similar results were reported by Ishizuka (1965) in rice soils This result indicated the luxuriant consumption of potassium by the rice plant with increasing levels of K application

The interaction between clay content and different levels of K application did not give a significant effect on the K content of plants at any of the sampling stages

3 6 <u>Potassium uptake by the straw</u>

Potassium uptake as influenced by different treatments at different stages of growth is presented in Tables 22 and 23 and the analysis of variance in Appendix VII

Table 22 **Mean values of potassium content and potassium uptake as influenced by soils and levels of K application**

	Soils	Tillering	Flowering	Harvesting	Levels	Tillering	Flowering	Harvesting
	S_1	2 287	2 208	1 788	K_1	2 613	1 698	1 361
K content (%)	S_2	2 845	1 645	1 537	K_2	2 613	1 820	1 687
	S_3	2 400	2 050	1 758	K_3	2 650	1 800	1.675
	S_4	2 900	1 654	1 475	K_4	2 683	1 946	1 836
	CD(5%)	0 03052	0 19591	0 22032		NS	NS	0 22032
	S_1	0 0571	0 310	0 286	K_1	0 1487	0 184	0 198
K uptake ($g\ pot^{-1}$)	S_2	0 1811	0.358	0 496	K_2	0.1213	0 273	0 358
	S_3	0 1174	0 240	0 260	K_3	0.1267	0 358	0 393
	S_4	0 1682	0 273	0 483	K_4	0 1271	0 408	0 575
	CD(5%)	0 06041	0 07592	0 12993		NS	0 07592	0 12993

It was found that the uptake of potassium gradually increased as the growth advanced This could be attributed to the increase in the dry matter accumulation at the later stages without much translocation of the nutrient In rice, potassium uptake occur fast and the amount that is absorbed up to the maximum tillering increased both the number of panicles and grain weight whereas K absorbed after panicle initiation only improved the grain weight (Panda, 1984)

When the soils were compared, a significant difference was obtained at all the stages The uptake was maximum for soil with 28 per cent clay in all the sampling stages The increase in the uptake of K is due to the greater dry matter production as influenced by other favourable situations without any grain yield increase It is seen that light textured soils with predominance in kaolinitic clay showed a fair level of available K and plants absorb all the K that is available in the growing medium. This accounts for the increased absorption of K in this soil This finding is in confirmation with that of Bandyopadhyay and Goswami (1988) who observed that the concentrations of K^+ in soil solution increased much in kaolinitic soil with higher levels of K application as compared to alluvial and black soils

When the different levels were compared a significant difference in the K uptake was noticed at the flowering and harvesting stages with increasing levels of K application, Due to the luxury consumption an increase in the dry matter production was also noticed

The interaction between clay and K application gave significant differences at the flowering stage K^{+} that is yet fixed after application of potassic fertilizers got released slowly at the later stages and that helped in restoring the initial level of exchangeable K

3 7. Ca content of straw

The content and uptake of Ca in the straw at different growth stages as influenced by different treatments are given in Tables 23 and 24 and the analysis of variance in Appendix VIII

It has been found that the content was higher in the tillering stage and there was a gradual decrease upto the harvesting stage This may be due to the low level of nutrient absorption at the later stages

When the soils were compared, the content did not give significant difference at any of the stages When the treatments were pooled together a maximum content of 0 4415 per cent was recorded for the soil with 28 per cent clay This may be attributed to the more absorption of Ca in this soil.

Table 23 Calcium content and calcium uptake of straw as influenced by different treatments at different growth stages of rice

Treatment	Calcium content, (%)			Calcium uptake, (g pot^{-1})		
	Tillering	Flowering	Harvesting	Tillering	Flowering	Harvesting
$S_1 K_1$	0 1441	0 1244	0 0947	0 0013	0 0193	0 0090
$S_1 K_2$	0 1472	0 1340	0 1089	0 0017	0 0210	0 0217
$S_1 K_3$	0 1357	0 1152	0 0913	0 0022	0 0116	0 0190
$S_1 K_4$	0 1408	0 1408	0 1040	0 0015	0 0223	0 0176
$S_2 K_1$	0 1344	0 1218	0 1024	0 0062	0 0123	0 0167
$S_2 K_2$	0 1216	0 1024	0 0739	0 0043	0 0280	0 0217
$S_2 K_3$	0 1919	0 1089	0 0895	0 0054	0 0283	0 0193
$S_2 K_4$	0 1408	0 1211	0 1024	0 0052	0 0476	0 0473
$S_3 K_1$	0 1217	0 1441	0 1152	0 0050	0 0126	0 0180
$S_3 K_2$	0 1402	0 1297	0 1088	0 0036	0 0163	0 0160
$S_3 K_3$	0 1409	0 1108	0 0895	0 0019	0 0476	0 0297
$S_3 K_4$	0 1600	0 1111	0 0090	0 0019	0 0156	0 0140
$S_4 K_1$	0 1408	0 1175	0 0884	0 0038	0 0123	0 0160
$S_4 K_2$	0 1280	0 2410	0 1036	0 0037	0 0210	0 0280
$S_4 K_3$	0 1281	0 1024	0 0820	0 0035	0 0250	0 0257
$S_4 K_4$	0 1472	0 1216	0 1024	0 0079	0 0230	0 0327
CD (5%)	0 03272	NS	NS	NS	0 02801	NS

When the different levels were compared, there was no significant difference in the Ca content except at the flowering stage At this stage with the third level of K application, the calcium content was less than the control This may be due to the increased absorption of K which hindered the absorption of Ca But in the other two stages, plants had taken up adequate quantities of Ca to meet the plant requirement

The interaction was significant only at the tillering stage In the event of better supply of one nutrient that is potassium, the uptake of other nutrients may decrease due to the negative interaction

3 8 <u>Uptake of calcium</u>

The uptake of calcium by the straw at three growth stages as influenced by different treatments are presented in Tables 23 and 24 and their analysis of variance in Appendix VIII

Uptake of calcium was found to increase with increase in the dry matter accumulation Though the content get decreased, dry matter weight was increased as the growth advanced, which accounts for the increased uptake Also the translocation of this nutrient is less as compared to N and P

When the treatments were pooled together, the soils of varying texture gave significant differences in the uptake of

Table 24 **Mean values of calcium content and calcium uptake in the rice straw as influenced by soils and different levels of K application**

	Soils	Tillering	Flowering	Harvesting	Levels	Tillering	Flowering	Harvesting
Calcium content (%)	S_1	0 1429	0 1285	0 0997	K_1	0 1368	0 1178	0 1022
	S_2	0 1441	0 1152	0 0963	K_2	0 1343	0 1227	0 0984
	S_3	0 1422	0 1214	0 1013	K_3	0 1449	0.1093	0 0881
	S_4	0 1408	0 1164	0 0941	K_4	0 1475	0 1254	0 0984
	CD (5%)	NS	NS	NS		NS	0 01051	NS
Calcium uptake (g pot^{-1})	S_1	0 0017	0 0201	0.0161	K_1	0 0041	0 0142	0 0137
	S_2	0 0053	0 0270	0 0292	K_2	0 0336	0 0193	0 0100
	S_3	0 0031	0.0147	0 0140	K_3	0 0032	0 0210	0 0220
	S_4	0 0047	0 0202	0 0251	K_4	0 0041	0 0273	0 0280
	CD (5%)	0 00172	0 00431	0 00672		NS	0 00412	0 00672

calcium The uptake was maximum in the soil with 28 per cent clay in all the three stages The increased dry matter production in this soil accounted for this value

When the different levels of K application were compared a significant difference in the uptake was noticed at the flowering and harvesting stages Maximum uptake was noticed at the highest K level. This is attributed to the increased dry matter accumulation noticed at this stage with K application Ca content at the same stage was insignificant

In all the stages interaction of clay content with K application levels do not give any significant difference

3.9. Content of Mg in the straw

The analytical data is given in Tables 25 and 26 and their analysis of variance in Appendix VIII

The content was found to decrease after tillering stage The content was lower when compared to calcium.

When the different treatments were pooled together, there was a significant difference obtained among soils of varying texture and maximum content was noticed in S_3. The differences could be attributed to the variations in the level of exchangeable

Table 25 Magnesium content and magnesium uptake of rice straw as influenced by different treatments at different growth stages of rice

Treatments	Magnesium content (%)			Magnesium uptake (g pot^{-1})		
	Tillering	Flowering	Harvesting	Tillering	Flowering	Harvesting
S_1 K_1	0 0850	0 0844	0 0613	0 0018	0 0130	0 0067
S_1 K_2	0 0844	0 0808	0 0680	0 0022	0 0120	0 0107
S_1 K_3	0 0835	0 0615	0 0600	0 0030	0 0100	0.0106
S_1 K_4	0 0280	0 0606	0 0530	0 0015	0 0100	0 0087
S_2 K_1	0 0746	0 0993	0 0842	0 0083	0 0100	0 0160
S_2 K_2	0 0993	0 0886	0 0835	0 0058	0 0140	0 0230
S_2 K_3	0 0990	0 0837	0 0768	0 0075	0 0200	0 0230
S_2 K_4	0 0837	0 0817	0 0690	0 0044	0 0286	0 0327
S_3 K_1	0 1228	0 1128	0 1075	0 0062	0 0140	0 0127
S_3 K_2	0 1290	0 1042	0 1130	0 0099	0 0140	0 0167
S_3 K_3	0 1297	0 1126	0 1069	0 0064	0 0130	0 0133
S_3 K_4	0 1144	0 1150	0 9930	0 0042	0 0170	0 0160
S_4 K_1	0 1197	0 1075	0 0993	0 0064	0 0130	0 0173
S_4 K_2	0 1197	0 0990	0 0938	0 0062	0 0173	0 0260
S_4 K_3	0 1074	0 0917	0 0845	0 0058	0 0106	0 0253
S_4 K_4	0 1077	0 0846	0 0769	0 0084	0 0167	0 0207
CD (5%)	NS	NS	NS	NS	0 00912	

Mg in these soils The exchangeable bases are normally high in clayey soils

When the different K levels were compared a significant difference was noticed at the flowering and harvesting stages The content was high in the lowest level of K application The antagonism between K and Mg has been noticed in rice at all the stages Generally this "K induced Mg deficiency' has been observed either in soils which are deficient in both K and Mg or under conditions, where high rates of K are applied

3.10 Uptake of Mg by the straw

Uptake of Mg at the different growth stages are presented in Tables 25 and 26 and their analysis of variance in Appendix VIII

Due to the increase in dry weight the uptake was found to increase upto the harvesting stage Though the content in the plant decreased with increase in K availability, the plants were however able to take up adequate Mg for their growth

When the treatments were pooled together, soils of varying texture showed significant differences in the Mg uptake at all the stages Soil with 28 per cent clay showed highest uptake in the first two stages and soil with more than 40 per cent clay showed maximum uptake at the harvest This could be due to the

Table 26 Mean values of magnesium content and magnesium uptake of the straw as affected by soils and levels of K application at different stages of crop growth

	Soils	Tillering	Flowering	Harvesting	Levels	Tillering	Flowering	Harvesting
Mg content (%)	S_1	0 0803	0 0720	0 0608	K_1	0 1025	0 0878	0 0748
	S_2	0 0977	0 0885	0 0785	K_2	0 1082	0 0886	0 0897
	S_3	0 1240	0 1112	0 1067	K_3	0 1033	0 0675	0 0821
	S_4	0 1137	0 0958	0 0886	K_4	0 1019	0 0922	0 0747
	CD (5%)	0 01261	0 01072	0 00922		NS	0 01073	0 00922
Mg uptake ($g\ pot^{-1}$)	S_1	0 0021	0 0140	0 0093	K_1	0 0029	0 0140	0 0132
	S_2	0 0063	0 0180	0 0257	K_2	0 0026	0 0127	0 0191
	S_3	0 0054	0 0130	0 0153	K_3	0 0051	0 0260	0 0209
	S_4	0 0067	0 0180	0 0133	K_4	0 0460	0 0173	0 0195
	CD (5%)	0 00251	0 00482	0 01973		NS	NS	NS

difference in the dry matter accumulation in these soils along with differences in the nutrient absorption

The different K levels and interaction of clay and K treatments did not give any significant effect on the Mg uptake

3 11 Yield and composition of grain

3.11 1 Yield of grain

The yield of grain as affected by the different treatments is given in Tables 27 and 28 and fig 4 and the analysis of variance in Appendix IX

The maximum grain yield was recorded for the soil with more than 40 per cent clay In the first three soils, maximum grain yield was obtained at the third level of K application The values were 13 567, 25 5 and 19 967 g pot^{-1} respectively The soil with more than 40 per cent clay showed an increase in the grain yield at the fourth level of K application (60 kg ha^{-1}) i e , 48 17 g pot^{-1} This shows that potassium applied in excess of the requirement will be absorbed by the plant and utilised for the vegetative growth However, in the soils of high clay content, higher grain yield was obtained at the highest level of K application due to its better K^+ saturation

The response to potash application on grain yield of HYV of rice was obtained by Sen et al (1969) in lateritic soils of

Table 27 Yield, nutrient content and nutrient uptake of grain

Treat-ments	Yield (g)	Nutrient content (%)					Nutrient uptake (g pot^{-1})				
		N	P	K	Ca	Mg	N	P	K	Ca	Mg
S_1 K_1	6 9670	2 2833	0 3160	1 2450	0 0355	0 0127	0 1600	0 0200	0 2881	0 0024	0 0009
S_1 K_2	9 3330	2 3967	0 3203	1 3460	0 0359	0 0150	0 2240	0 0310	0 1272	0 0039	0 0014
S_1 K_3	13 5670	2 6033	0 2670	1 2990	0 0366	0 0150	0 3530	0 0360	0 1731	0 0057	0 0021
S_1 K_4	11 5000	2 6433	0 3603	1 4280	0 0380	0 0127	0 2890	0 0410	0 1640	0 0049	0 0015
S_2 K_1	18.1670	2 1890	0 2736	1 1300	0 0430	0 0130	0 3980	0 0500	0 2141	0 0095	0 0027
S_2 K_2	20 6670	2 5100	0 3203	1 1150	0 0461	0 0161	0 5190	0 0540	0 2480	0 0091	0 0034
S_2 K_3	25 5000	2 2477	0 2937	1 1810	0 0477	0 0157	0 6270	0 0730	0 2880	0 0121	0 0039
S_2 K_4	21 8330	2 5097	0 3403	1 1140	0 0451	0 0150	0 5470	0 0740	0 2880	0 0101	0 0033
S_3 K_1	10 8330	2 5430	0 3113	1 2920	0 0485	0 0193	0 2750	0 0350	0 1350	0 0056	0 0021
S_3 K_2	14 6770	2 6230	0 2243	1 2710	0 0487	0 0219	0 3840	0 0330	0 1790	0 0068	0 0032
S_3 K_3	19 9670	2 7067	0 2633	1 2860	0 0422	0 0216	0 5400	0 0370	0 2000	0 0084	0 0043
S_3 K_4	16 7330	2 7160	0 3610	1 3360	0 0345	0 0206	0 4540	0 0570	0 1700	0 0060	0 0034
S_4 K_1	18 0670	2 5700	0 2603	1 0780	0 0384	0 0196	0 4710	0 0420	0 2130	0 0069	0 0035
S_4 K_2	33 0000	2 7230	0 2563	1 2460	0 0502	0 0184	0 9060	0 0890	0 3870	0 0162	0 0062
S_4 K_3	38 0000	2 7560	0 2227	1 3390	0 0477	0 0184	1 0490	0 0870	0 5500	0 0182	0.0071
S_4 K_4	48 1670	2 8060	0 2453	1 6720	0 0480	0 0196	1 3510	0 0980	0 8032	0 0214	0 0094
CD (5%)	NS	NS	0 05742	NS	NS	NS	NS	NS	NS	NS	NS

Midnapore with application of 50 kg ha^{-1} K_2O, by Goswami et al. (1971), Sahu (1963) and Rao et al (1971) on medium fertility soils at Bhubaneswar Mukherjee (1964) reported the average response to the application of 40 kg K_2O ha^{-1} in soils of Bihar in which clay soils responded best, followed by sandy soils.

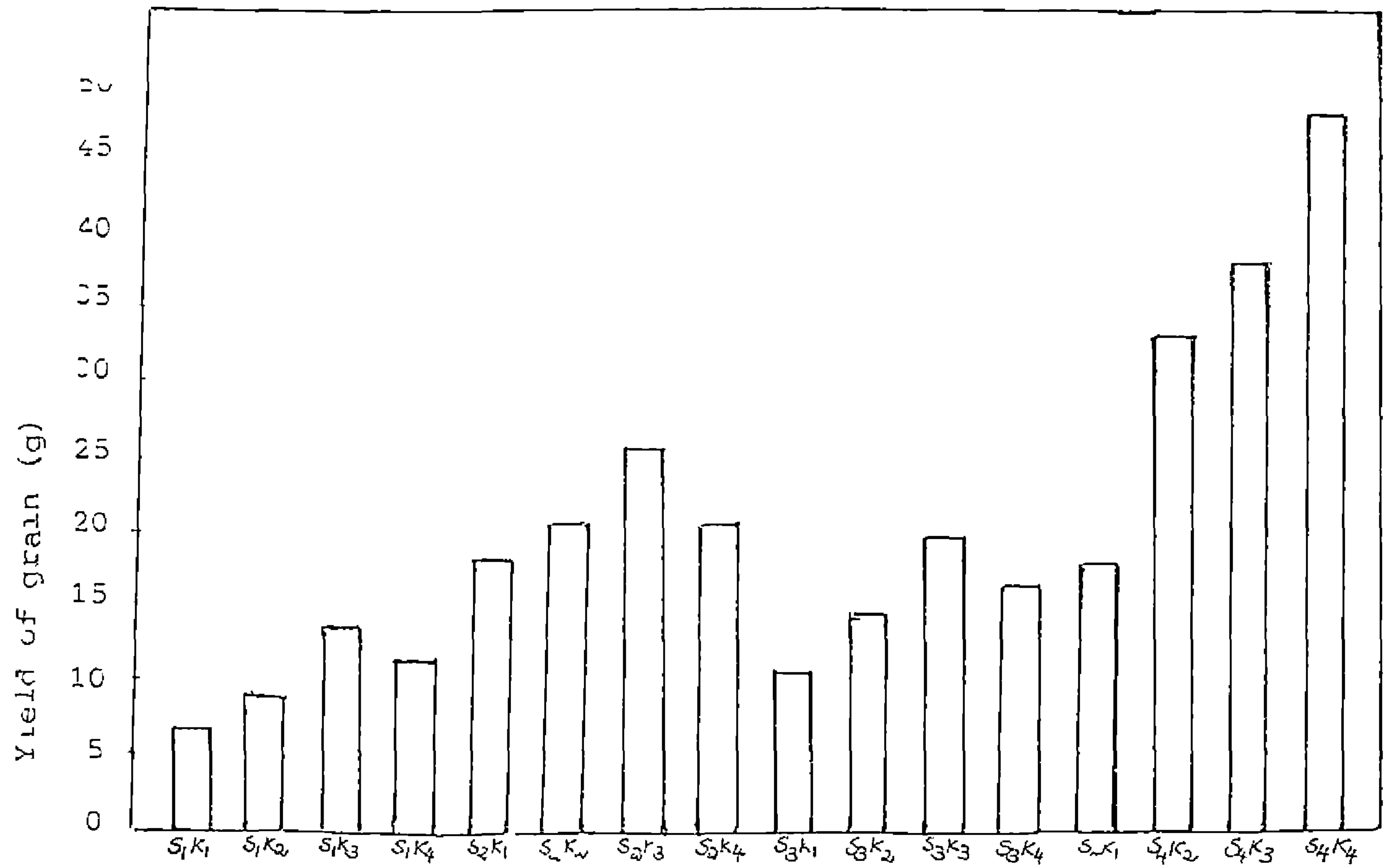
When the soils were compared there was a significant difference in the grain yield for the different soils Maximum yield was recorded for soil with more than 40 per cent clay irrespective of the treatments The next higher yield was recorded for S_2, followed by S_3 and S_1. The yield decrease noticed for S_3 could be due to the poor availability of nutrients in this soil. Eventhough the nutrient composition of this soil is comparable to the other soils, the yield was very low The added nutrients may not be fully available due to the effect of various clay minerals, in this soil .

There was a significant difference in the yield for various levels of K application Maximum yield was recorded in the third level of K application i e., 40 kg K_2O ha^{1} An yield increase of 79 5 per cent was recorded over the control at this level The dose of K that is being recommended by the Kerala Agricultural University for short duration variety in sandy loam soils of Kerala is 35 kg K_2O ha^{-1} (Anon 1989) From the results it appears that the potassium beyond 40 kg K_2O ha^{-1} may not be beneficial in the soils taken for the present study. Sakeena (1988) also reported an yield increase in rice for 35 kg K_2O ha^{-1}

Table 28 Mean values of grain yield, nutrient composition and uptake of nutrients by grain as influenced by soils and levels of K application

	Soils	Grain yield (g)	Nutrient content (%)					Levels	Nutrient content (%)					Grain yield (g)
			N	P	K	Ca	Mg		N	P	K	Ca	Mg	
Nut-rient Con-tent (%)	S_1	10 3420	2 4817	0 3209	1 329	0 0364	0 0138	K_1	2 3964	0 2203	1 1860	0 0416	0.0166	13.5080
	S_2	21 5420	2 4142	0 3170	1 145	0 0457	0.0154	K_2	2 5633	0 2903	1 2550	0 0452	0 0178	19 4170
	S_3	15.5500	2 6472	0 2893	1 296	0.0435	0 0209	K_3	2.6286	0 2609	1.2760	0 0434	0 0177	24 2580
	S_4	29 8080	2.7142	0.2712	1 334	0 0461	0 0190	K_4	2 6689	0 3268	1 3870	0 0414	0 0169	20 0580
	CD(5%)	3.62621	0 76412	0.02881	NS	0 00438	0 01521		0.07641	0 02882	NS	NS	NS	3.62621
Nut-rient up-take (g pot $^{-1}$)	S_1		0.2570	0 0330	0 1380	0 0042	0 015	K_1	0 3260	0 0430	0 1630	0 0061	0 0023	
	S_2		0 5230	0 0680	0.2590	0 0102	0 0330	K_2	0 5080	0 0560	0 2350	0 0090	0 0036	
	S_3		0 4130	0 0450	0 1710	0 0067	0 0330	K_3	0.6420	0 0620	0 3030	0 0111	0.0043	
	S_4		0 8180	0 0800	0 3700	0 0140	0 0570	K_4	0 5340	0 0640	0.2380	0 0088	0 0035	
	CD(5%)		0.10172	0 01161	0 16003	0.01723	0.00893		0 10172	0 01161	0 16003	0.01723	0 00893	

Fig.4 Yield of grain as influenced by different treatments (g pot^{-1})



Grain Yield in Soils Differing in Clay Content

Plate 7.

Plate 8.

Plate 9.

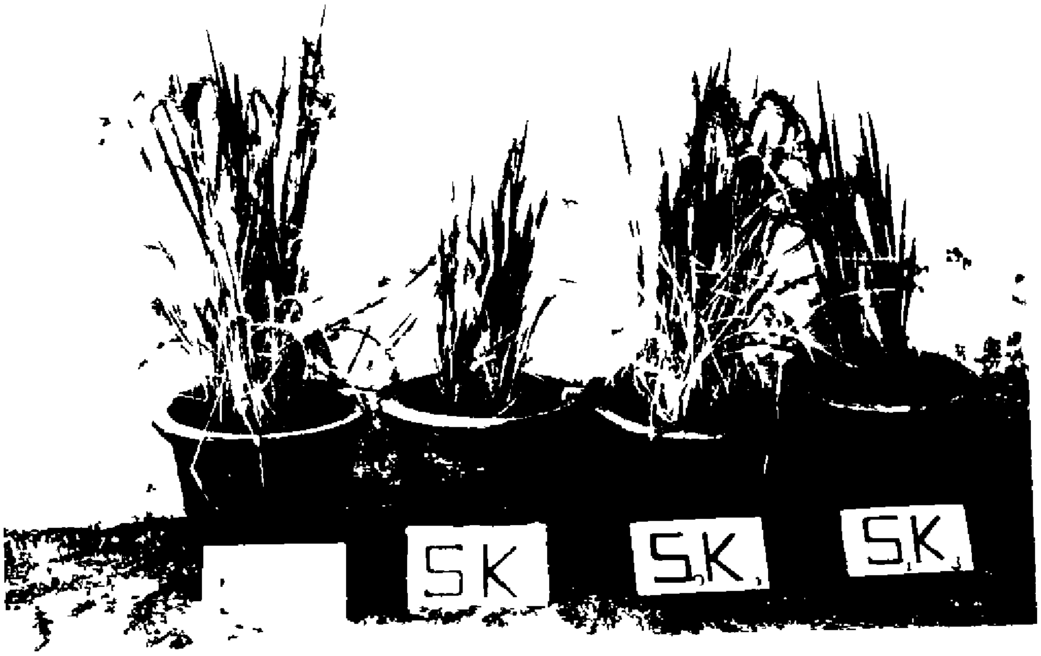


Plate 10.

over control However Robinson and Rajagopal (1977) obtained linear response of rice upto 60 kg K_2O ha^{-1} in soils of Tamil Nadu and Agarwal (1980) observed significant yield increase up to 80 kg K_2O ha^{-1} in rice

The interaction effect was not significant for the grain yield Correlation coefficient was worked out for the grain yield with different fractions of K in soil and was maximum correlated with the nitric acid soluble K fraction ($r = 0.8831^{**}$) indicating the contribution of K^+ from this fraction The rate of replenishment from the non-exchangeable K to exchangeable K is thought to be more rapid under submerged conditions Chang and Feng (1960) observed that while exchangeable potassium varied slightly among flooded soils belonging to different soil groups, non-exchangeable potassium varied much more. Rice grown under submerged conditions took up a larger proportion of its total K from the non-exchangeable fraction, than it did under upland conditions (Wu, 1960)

3 11 2 Nutrient composition of grain

3 11 2.1 Nitrogen content in grain

The nitrogen content of grain as affected by different treatments is presented in Tables 27 and 28 and the analysis in the Appendix IX

The N content of grain was found to increase with higher proportions of clay in soils In soil containing more than 40 per cent clay N per cent of 2 806 was obtained at the highest level of K application as compared to 2 6433 per cent in soil with less than 10 per cent clay

When the soils were compared after pooling all the treatments, a significant difference was noticed Soil with more than 40 per cent clay recorded a maximum of 2 7142 per cent followed by soil with 37 per cent clay

When different levels were compared, the N content was maximum for the highest level of K application i e , 2 66 9 per cent and it was 2 396 per cent in control This showed that K application can increase N content significantly This observation is in agreement with the findings of Koch and Mengel (1977) But the content of N for the third and fourth level of K application did not differ significantly Hence K applied at the rate of 40 kg K_2O ha^{-1} will be more economical for getting maximum protein content

3 11 2.2 Nitrogen uptake by grain

The uptake of N by grain is presented in Tables 27 and 28 and the analysis in Appendix IX

The uptake was found to increase with increasing levels of clay and K application This is due to the increased grain yield obtained for these treatments

When the soils were compared maximum content was observed for soil with more than 40 per cent clay Statistically there was significant difference in the uptake of N in grain The high availability of N to the grain is attributed to the high clay percentage and the organic matter content in these soils The nitrogenous fertilisers applied at the flowering stage is mostly utilised in the grain production and that is reflected by higher value of N in the grain

When the different levels of K were compared, there was significant difference and N uptake was maximum at the third level The soil and potassium interaction did not give much influence on N uptake of grain

3.11.2 3 Phosphorus content in grain

Content of phosphorus in grain is given in Tables 27 and 28 and the analysis of variance in Appendix IX

The data revealed that there is not of much difference in the content of phosphorus in grain The value ranged from 0 2227 per cent for the third level of K application in the soil with more than 40 per cent clay to 0 3610 per cent in the 4th level of K application in the soil with 37 per cent clay

When the soils were compared there was a significant difference in the phosphorus content Highest value was noticed in the soil with less than 10 per cent clay (0 3209 per cent) and the least value was in the soil with more than 40 per cent clay (0 2712 per cent)

The different levels of potassium application gave significant difference in the content of phosphorus in the grain Maximum content was noticed for the highest level of application of potassium Mengel (1976) also reported that phosphorus uptake and translocation were highest with application of 60 kg K_2O ha^{-1}

The interaction between different levels of K application and clay content gave significant differences in the phosphorus content in grain The limited availability of phosphorus at the higher level of potassium in soils of high proportions of clay is attributed to its fixation by the predominant 1 1 type minerals in these soils

3.11 2 4 Phosphorus uptake by grain

The data on the uptake of phosphorus by the grain is presented in Tables 27 and 28 and the analysis of variance in Appendix IX

Uptake showed a variation from 0 02 g pot^{-1} in the control of soil with less than 10 per cent clay to a maximum of 0 089 g pot^{-1} in the second treatment of the soil with the highest clay content

When the soils were compared after pooling all the treatments together maximum was for the soil with more than 40 per cent clay (0 08 g pot^{-1}) and the lowest value was for the soil with less than 10 per cent clay (0 033 g pot^{-1}) This could be due to the variation noticed in the yield of grain

When the different levels were compared, phosphorus uptake was found to be increasing with increasing K levels Phosphorus was found to increase the grain weights and give a higher food value to the rice by increasing carbohydrate production

The interaction was not significant and the uptake did not vary much according to soil-potassium interaction

3 11 2 5 Potassium content in grain

The data on the content of potassium in grain is presented in Tables 27 and 28 and the analysis of variance in Appendix IX

The content of K in grain varied from 1 078 per cent in the soil with more than 40 per cent clay for the control (no K) treatment to 1 672 per cent in the same soil with highest level of K application Major part of potassium required by the plant is absorbed before the booting stage and is mainly utilised for the vegetative growth Only a minor portion is absorbed at the later stage which is solely utilised for the grain production

When the soils were compared irrespective of the given treatments, maximum content was recorded in the soil with more than 40 per cent and the lowest value for the soil with less than 10 per cent clay This may be due to differences in the absorption of the nutrient in these soils

When the levels were compared gradual increase was noticed with increasing levels of potassium application This could be due to increased absorption of K by the plant at higher levels of application and the effect was not significant

The interaction effect was not significant for the K content

3.11 2 6 Uptake of potassium by the grain

The data is presented in Tables 27 and 28 and the analysis of variance in Appendix IX

Maximum potassium uptake (0 55 g pot^{-1}) by the grain was noticed in the soil with more than 40 per cent clay at the third level of K application The lowest value (0 088 g pot^{-1}) was recorded for the control (no K) treatment of the soil with less than 10 per cent clay

When the soils were compared maximum uptake was noticed in the soil with highest clay content and the lowest value was for the soil with less than 10 per cent clay The yield of grain varied according to the soils and hence the uptake was significant with different proportions of clay

When the levels of K applications were compared the maximum uptake was obtained for the 3rd level (40 kg K_2O ha^{-1}) and the yield was also maximum at this level and hence the uptake was higher for that level

The interaction was not significant for the uptake of potassium by grain

3.11.2.7 Content of calcium and magnesium in grain

The data are given in Tables 27 and 28 and the analysis in Appendix IX

The calcium content was maximum for the soil with maximum clay content at the second level of K application (0 502 per cent) and the lowest with 37 per cent clay at the highest level of K application The magnesium content was maximum for the soil with 37 per cent clay at the second level of K application and the lowest in the soil with less than 10 per cent clay.

Highest content of Ca was noticed in the soil with more than 40 per cent clay and of Mg was in the soil with 37 per cent clay The variation could be attributed to the high saturation of the CEC by these elements and its subsequent availability to the growing crop

The different potassium levels did not give significant differences in the Ca and Mg content of grain The interaction was also not significant

3 11 2 8 Uptake of Ca and Mg by grain

The data are presented in Table 27 and 28 and the analysis of variance in Appendix IX

The uptake varied according to the yield of grain and was maximum in the soil with more than 40 per cent clay for the third level of K application i e 0 182 g pot^{-1} in the case of Ca and was 0 071 g pot^{-1} for Mg in the same soil at the same level of K application

When the soils were compared, significant differences were obtained for the uptake due to the differences in yield of grain and the content of these nutrients

The different levels of K application also gave significant differences in the uptake due to the changes in the absorption of these two cations Maximum uptake was obtained for the third *level of K application and at the next higher level a decrease was obtained This could be due to the reduced availability of these nutrients at increased supply of K*

The interaction was not significant for the uptake of Ca and Mg in the grain

3.1. <u>Soil analysis</u>

3.12.1. Water soluble potassium

The changes in the content of water soluble potassium in the soils during the different growth stages of paddy are presented in Tables 29 and 30 and their analysis of variance in Appendix X

The content of water soluble potassium in soils was found to decrease in the tillering stage as compared to the initial level in the soil This may be due the increased uptake of the water soluble form at the active growth stage of rice However, at the flowering stage a slight increase was noticed in many of the treatments and at the harvesting stage a decline was noticed in almost all the treatments

When the soils were compared a significant difference was observed at the flowering and harvesting stages At the later stages of growth the absorption by the plant root is not that vigorous The amount that is present in the soil solution also gets varied due to the differences in the mineralogy of each soil

In the present study, light textured soils have higher concentration of solution K^+ as compared to heavy textured soils This is in agreement with the findings of Nemeth <u>et al</u> (1970) who reported that a slight increase in the exchangeable K content caused a steeper increase in the K^+ concentration of soil solution in sandy

Table 29 **Water soluble, ammonium acetate extractable and nitric acid soluble potassium fractions in soils as influenced by treatments at different stages of crop growth (me 100 g^{-1})**

Treatment	Water soluble K				Ammonium acetate extractable K				Nitric acid soluble K	
	Initial level in soil	Tillering	Flowering	Harvesting	Initial level in soil	Tillering	Flowering	Harvesting	Initial level in soil	At the end of crop growth
S_1 K_1	0 0312	0 0112	0 0240	0 0102	0 0959	0 0624	0 0404	0 0427	0 6394	0 6290
S_1 K_2	0 0312	0 0178	0 0217	0 0149	0 0959	0 0702	0 0757	0 0212	0 6394	0 4260
S_1 K_3	0 0312	0 0180	0 0170	0 0170	0 0959	0 0942	0 0634	0 0532	0 6394	0 3840
S_1 K_4	0 0312	0 0205	0 0287	0 0204	0 0959	0 0737	0 0441	0 0405	0 6394	0 6820
S_2 K_1	0 0448	0 0214	0.0229	0 0170	0 1918	0 1916	0 0550	0 0937	2 5800	2 2970
S_2 K_2	0 0448	0 0243	0 0259	0 0220	0 1918	0 1860	0 0612	0 1129	2 5800	2 7280
S_2 K_3	0 0448	0.0183	0 0162	0 0213	0 1918	0 1638	0 0905	0 1001	2 5800	2 4530
S_2 K_4	0 0448	0 0256	0 0229	0 0206	0 1918	0 1389	0 0644	0 1749	2.5800	2 8130
S_3 K_1	0 0512	0 0177	0 0180	0 0256	0 2366	0 1743	0 1021	0 1001	2 3010	1 7900
S_3 K_2	0 0512	0 0273	0 0251	0 0299	0 2366	0 2085	0 1048	0 1641	2 3010	1 8750
S_3 K_3	0 0512	0 0270	0 0299	0 0341	0 2366	0 1706	0.0914	0 1236	2 3010	1 1500
S_3 K_4	0 0512	0 0247	0 0234	0 0192	0.2366	0 1435	0 1301	0 1640	2 3010	1 1930
S_4 K_1	0 0256	0 0136	0 0141	0 0213	1 6620	0 1617	0 0796	0 1172	3 0690	2 1310
S_4 K_2	0 0256	0 0260	0 0141	0 0107	1 6620	0 1521	0 0819	0 0958	3 0690	4 0920
S_4 K_3	0 0256	0 0255	0 0161	0 0107	1 6620	0 1650	0 1516	0 0897	3 0690	4 1770
S_4 K_4	0 0256	0 0143	0 0182	0 0143	1 6620	0 1629	0 0974	0 0873	3 0690	4 7510
CD (5%)		NS	NS	NS		NS	NS	NS		0 04412

soils as compared to clayey soils

When varying levels of K application in soils were considered no significant differences in the level of this fraction was noticed at any of the growth stages However a slight increase was noticed over the control (no K application) at all the stages (Table 30) Normally when potassium fertiliser is applied to a soil, the potassium gets dissociated into K^+, and it will be either taken up by the plants or subjected to absorption at different sites of clay colloids Moreover, due to the luxury consumption of this element by plants, all that is available in the growing medium will be absorbed by the plant This is the reason for not getting much difference in the level of water soluble K in the soil that has received more of K fertiliser at a particular time

The interaction between clay content and potassium levels did not give any effect on the content of water soluble potassium

Correlation coefficient was worked out for different fractions of K in soil with dry matter yield and maximum correlation for water soluble K was obtained at the flowering stage ($r = {}^{-}0\ 58152$) This is due to the increased absorption of the solution form of potassium from the soil which results in the increase of the dry matter weight

3 12.2. Ammonium acetate extractable potassium

The content of ammonium acetate extractable potassium in the

Table 30 *Mean values of water soluble, ammonium acetate extractable and nitric acid soluble potassium as influenced by soils and levels of potassium application at different stages of crop growth (me 100 g^{-1})*

Name of the fraction	Soils	Initial level in soils	Stages			Levels	Stages		
			Tillering	Flowering	Harvesting		Tillering	Flowering	Harvesting
Water soluble potassium	S_1	0.0312	0.0269	0.0231	0.0171	K_1	0.0159	0.0148	0.0192
	S_2	0.0448	0.0244	0.0220	0.0239	K_2	0.0241	0.0217	0.0216
	S_3	0.0512	0.0242	0.0241	0.0232	K_3	0.0222	0.0210	0.0208
	S_4	0.0256	0.0199	0.0156	0.0142	K_4	0.0222	0.0233	0.0206
CD (5%)			NS	0.00581	0.00622		NS	NS	NS
Ammonium acetate extractable potassium	S_1	0.0959	0.0726	0.0559	0.0394	K_1	0.1500	0.0693	0.0684
	S_2	0.1918	0.1711	0.0678	0.0209	K_2	0.1517	0.0809	0.0785
	S_3	0.2366	0.1742	0.1471	0.1379	K_3	0.1484	0.0992	0.0917
	S_4	0.1662	0.1618	0.1026	0.0975	K_4	0.1297	0.0840	0.1171
CD (5%)			0.03131	0.02662	0.02931		NS	NS	NS
Nitric acid soluble potassium	S_1	0.6394	-	-	0.5300	K_1	-	-	1.8650
	S_2	2.5800	-	-	2.5720	K_2	-	-	2.2810
	S_3	2.3010	-	-	1.5020	K_3	-	-	2.0410
	S_4	3.0690	-	-	3.5380	K_4	-	-	2.1100
CD (5%)					0.02212				0.02212

soils as influenced by the different treatments at different growth stages of rice is given in Tables 29 and 30 and the analysis of variance in Appendix X

Compared to the initial level in the soils the content get decreased both in the tillering and flowering stages (Table 29) in almost all the treatments The decreasing trend continued in the harvesting stage also for some treatments So the decrease in the content could be due to the uptake by the plants But in some treatments an increase in the content can be noticed at the harvesting stage This may be due to the conversion from the non-exchangeable form which as left unutilised by the plant due to the less vigorous absorption at this stage

When the soils were compared, a significant difference was noticed in the content in all the stages At the tillering stage the values were 0 0726, 0 1711, 0 1742 and 0 1618 me 100 g^{-1} for the soils in the order of increasing clay content It get decreased to 0 0559, 0 0678, 0 1471 and 0 1026 me 100 g^{-1} in the flowering stage and in the harvesting stage it was 0.0394, 0 0209, 0 1379 and 0 0975 me 100 g^{-1} It can be seen that the available K content increases with increase in the clay content up to 37 per cent clay. But in the one with more than 40 per cent clay it is less and the reason for this variation in soils could be attributed to the fixation and release of potassium to the water soluble form by the concerned clay minerals present in them Decrease in the content represent a shift towards potassium deficiency while increase in available potassium represents potassium build up and a shift towards K sufficiency

When the different levels of K applications were compared, there was no significant difference in the content at any of the stages But an increasing trend was observed with increasing levels of applied K at the harvesting stage A substantial increase over the control (no K) was noticed in the flowering and harvesting stages with application of K

The interaction was not significant at any of the stages

Correlation coefficient was worked out with the dry matter yield, and the ammonium acetate extractable K was maximum correlated with dry matter yield at the tillering stage (r = 0.7582 **) Potassium content of straw was also correlated significantly with this fraction at tillering stage (r = 0 4746 *) This shows that addition of fertilizers resulted only in the initial utilisation by the plant and at the later stages the contribution from this fraction become less significant

3 12 3. Nitric acid soluble potassium

This fraction was determined only at the harvesting stage The data are presented in Tables 29 and 30 and the analysis of variance in Appendix X

The data revealed that the content of HNO_3- K increased in some treatments at the end of the experiment But in some cases there was a significant decrease observed Fixation of K appears to start instantaneously and tends to decrease with time (Ramanathan and Krishnamurthy, 1981) but the type of clay minerals determined the amount get fixed In the present study, where no fertiliser K was applied, a decrease in the fraction was noticed at the end of the experiment This clearly shows that in the absence of applied potassium the contribution of non-exchangeable potassium to the total potassium removal by crops is much more as compared to the potassium treated soils Similar results were reported by Singh and Ghosh (1984)and Ganeshamurthy and Biswas(1985) Krishnakumari et al (1984) reported that in a wheat-pearl millet rotation the level of NH_4 OAc-K reached a minimum and 90% of the total K uptake was from the non-exchangeable form This indicated that there was a transformation from the non-exchangeable form to the exchangeable form Rice grown under submerged conditions took up a larger proportion of its total K from the non-exchangeable fraction, than it did under upland conditions (Wu, 1960) However, at the later stages of growth the exchangeable potassium was considerably increased in most of the soils. Thus non-exchangeable fraction replenished the exchangeable fraction at a faster rate when the crop growth advances Similar results were reported by Mehta (1976) in Gujarat soils

Interaction between soil clay content and K application also gave a significant effect on the content of nitric acid soluble

Fig.5 Relationship between straw yield and nitric acid soluble K in soil

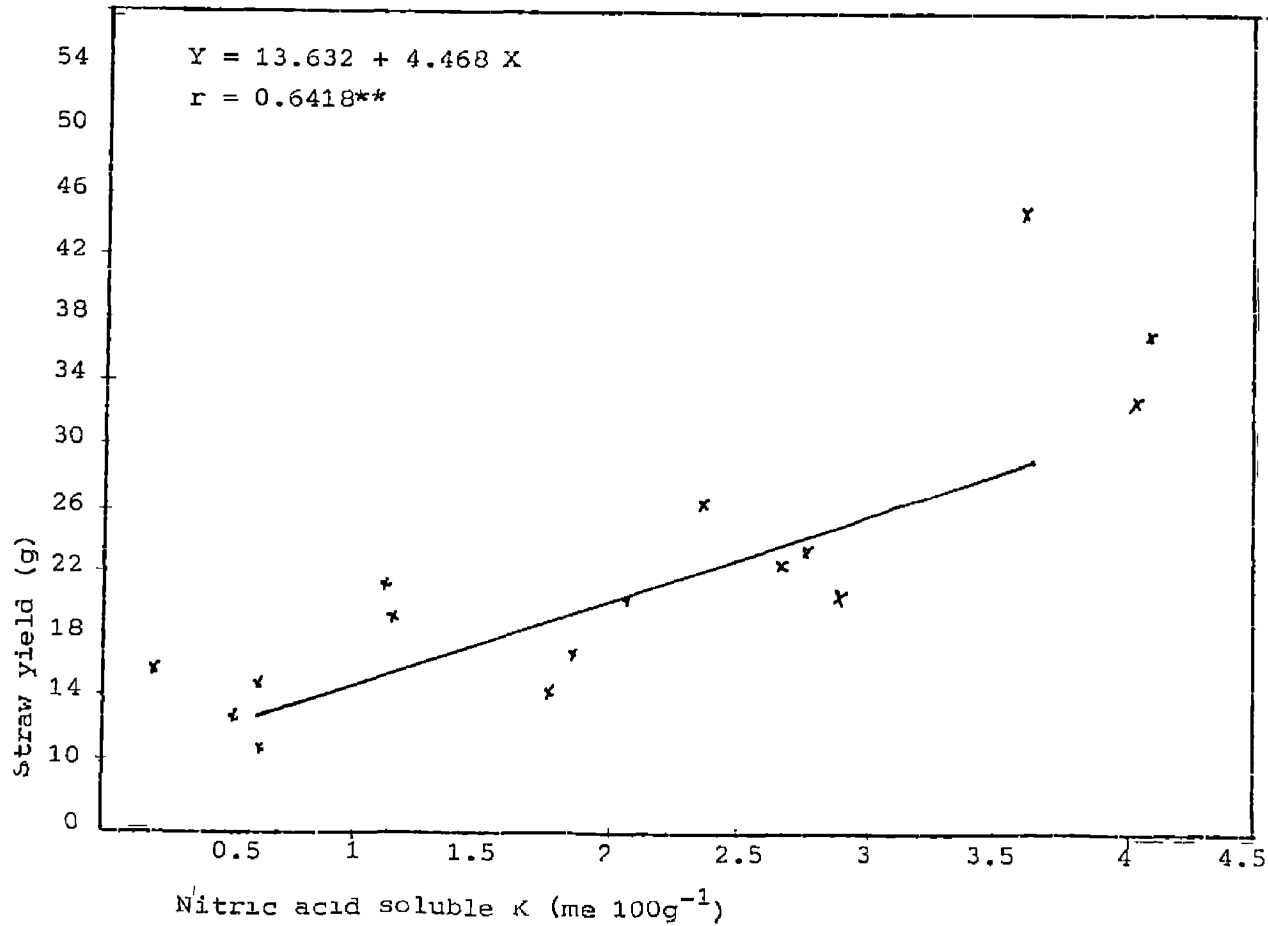
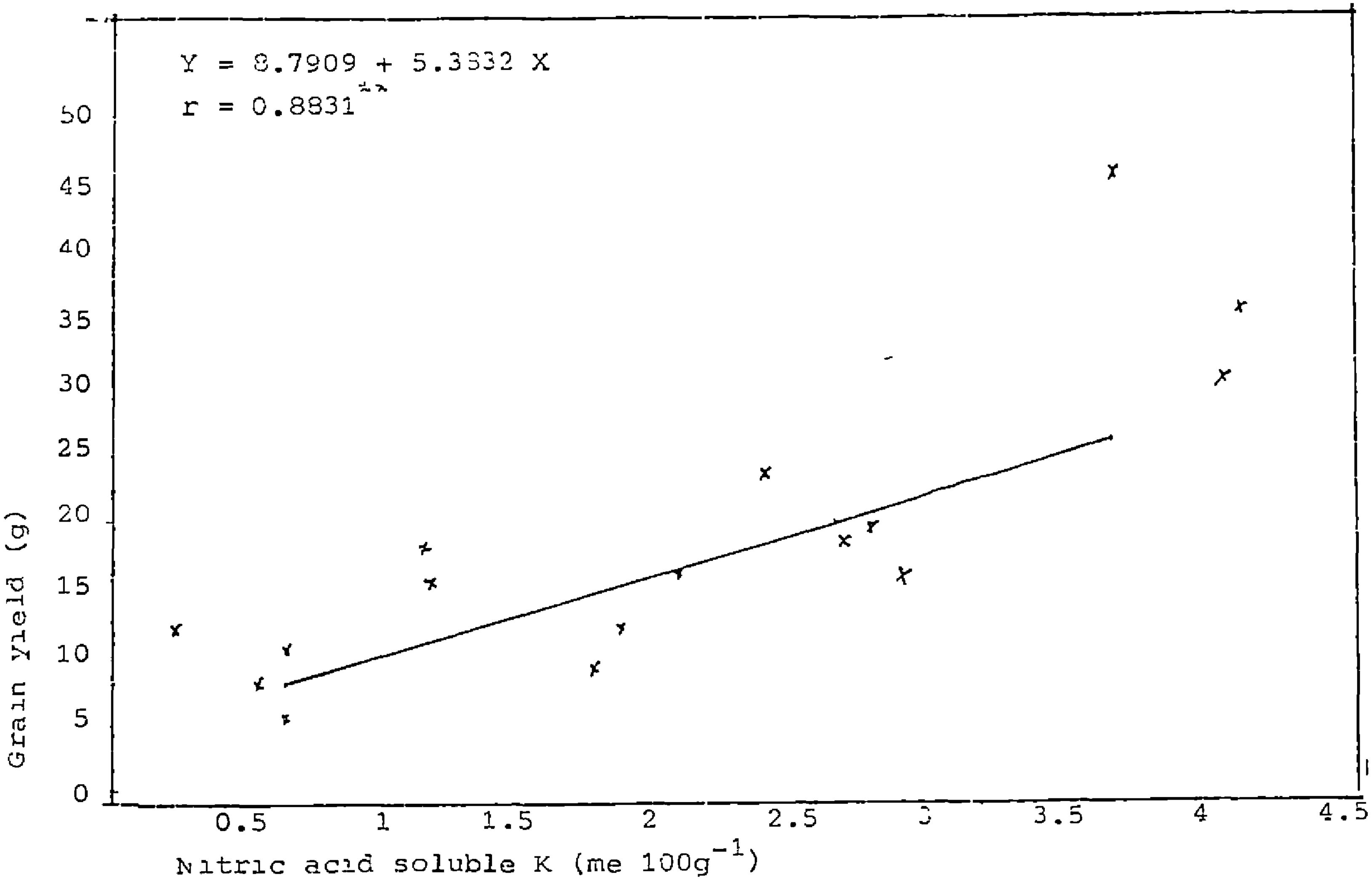


Fig.6 Relationship between grain yield and nitric acid soluble K



potassium This could be due to the differences in the content and nature of clay minerals present, the organic matter content, pH and the presence of complementary cations present

Correlation coefficients were worked out for the dry matter and grain yield with K fractions in soil at different stages of plant growth The nitric acid soluble fraction showed maximum correlation with grain yield ($r = 0\ 8831^{**}$) and straw yield ($r = 0\ 6418^{**}$) at the harvesting stage Similar results were also reported by Patiram and Prasad (1991) for setaria grass grown in the Inceptisol soils of Sikkim This again pointed out to the fact that the non-exchangeable fraction contributed much to the plants at the later stages of growth and the exchangeable K content may not be entirely indicative of the available K^+ status of soils because of the rapid release of HNO_3 -K in soil on flooding The relationship of HNO_3 -K with straw yield and grain yield are illustrated in fig 5 and 6

When the soils were compared, a significant difference was noticed in the content of nitric acid soluble K Soils with high clay could provide more K from the more strongly bound K fraction. This may be the reason for the variation in the level of HNO_3 -K observed in different soils Sharma and Mishra (1987) reported that non-exchangeable form of K decreased rapidly with the growing of crops in coarse textured soils of western Uttar Pradesh Moreover, the rate of nutrient supply to the plant is also determined by the content and type of clay, pH and organic matter These properties greatly determine the solubility rates of soil nutrients

When the different levels were compared, there was a significant difference in the content of HNO_3 -K Greater the amount of K added, greater is the fixation, but the percentage of added K get fixed decreases with higher levels of K application in some soils When no K is added, potassium is released from the non-exchangeable form in these soils But when K is added at different levels, depending upon the type of clay minerals present, some of the added K get fixed in specific sites of the clay lattices As the plant growth advances, potassium depletion continues and in that case potassium uptake is associated with the capacity of the soils to release the non-exchangeable potassium fraction

Rice crop as affected by different rates of potassium applications in soils of differing clay content at the harvesting stage is shown in plates 7 to 10

SUMMARY

In the present study, an attempt has been made to evaluate the influence of soil texture on potassium availability and the uptake of nutrients by rice in the low-lying laterite soils Soil characteristics related to potassium availability were also studied. For this, 60 surface samples were collected from three major rice growing areas of Thrissur district Based on their particle size analysis and organic carbon content, twenty samples were selected for studying the various physico-chemical characteristics related to the potassium availability In order to find out the transformations of applied potassium, a laboratory incubation experiment was carried out in five selected soils for a period of three months Mineralogy of the fine sand fraction was also carried out in the five soils selected for incubation experiments To determine the uptake of various nutrients by rice from soils of varying texture, a pot culture experiment was carried out in four selected soils

The study revealed the following

1 Wide variation was noticed in the clay content of soils collected from the three locations Soils were mainly grouped under the textural classes sandy loam and sandy clay loam

2 The physical constants were showing variations depending on the clay content and organic carbon.

3 In general all the soils were acidic in reaction with low values of electrical conductivity

4 Organic carbon content was showing wide variations and an increasing trend was noticed with clay

5 Sesquioxide percentage was more than 10 per cent in most of the soils, showing the weathered condition of these soils

6 The total reserves of nitrogen, phosphorus potassium, calcium and magnesium were relatively low

7 The total potassium content showed a positive correlation with clay content , organic carbon and CEC

8 The water soluble potassium was low in all the soils and constituted less than 1 per cent of the total K content

9 Ammonium acetate extractable potassium constituted 0 9 to 2 2 per cent of the total potassium and had positive significant correlation with CEC and water soluble potassium

10 Nitric acid soluble potassium constituted a higher proportion of the total potassium in most of the soils indicating the presence of 2 1 minerals in these soils

11 Cation exchange capacity of the soils was moderately high as compared to the upland laterites This has got positive significant correlations with clay content and organic carbon which is again an indication of the presence of 2 1 minerals in these soils

12 Exchangeable bases in the soils were in the order, Ca> Mg> K> Na and higher values of these bases were obtained for soils with high clay content

13 Percentage base saturation was low and was according to the exchangeable Ca distribution

14 Fine sand fraction was dominated by light minerals like quartz and feldspar in all the five soils In the heavy mineral suite, weatherable minerals like hornblende, pyroxenes and biotite were present Zircon was also there The presence of feldspar in the light fraction and weatherable minerals in the heavy fraction accounts for the subsequent formation of 2 1 type minerals in these soils Presence of perthite in all the soils was given an indication that the soil had undergone only a moderate level of weathering

15 From incubation experiment it was found that on application of K fertilizer, the different fractions like water soluble, NH_4 OAc extractable and nitric acid soluble potassium get increased at the end of three months Wide fluctuations were noticed for these fractions during the incubation period.

16 Soils with high clay content required higher level of saturation by potassium fertiliser, to get a better response in the growing crop as proved from the pot culture study

17 The content and uptake of N in the straw was found to be increased with increasing levels of K application and clay content of soils

18 The content and uptake of phosphorus was high with the application of potassium fertiliser as compared to control

19 Potassium content and its uptake by the plant was found to be increasing with increasing levels of K application and was maximum in soil with more than 40 per cent clay followed by the soil with 28 per cent clay.

20 Ca content did not show any significant difference with applied K in soils of varying texture but the uptake was maximum with the higher level of K for the soil with 28 per cent clay.

21 The content of Mg in the straw was high in soils containing 37 per cent clay and decreased with increased level of K application

22 The content of water soluble K in the soil get decreased at the tillering stage, slightly increased at the flowering stage and then again declined towards the harvesting stage The water soluble K was maximum correlated at the flowering stage with the dry matter weight

23 Ammonium acetate extractable K was decreasing with advancement of the crop growth except in some treatments where there was contribution from non-exchangeable fraction Maximum correlation was obtained at the tillering stage for the dry matter weight

24. Non-exchangeable fraction was found to contribute towards the later stages of crop growth A decrease in the nitric acid soluble K content was noticed in the soils with 10 per cent clay and with 37 per cent clay Maximum correlation was obtained for the grain yield and straw yield.

25 Eventhough the positive effect of potassium application on the yield of paddy is very conspicuous the response varied in soils of different textural composition as revealed in the present study In the case of straw yield soil with 28 per cent clay was more or less on par with that in soil with more than 40 per cent clay But when the grain yield was considered, the lighter soils recorded lower values with increasing applications of K fertiliser But in the soil with more than 40 per cent clay at the highest level of K application grain yield was maximum The increase in yield of soil with 37 per cent clay is not in proportion to increase in yield of soil with 28 per cent clay to that soil with less than 10 per cent clay. So it can be concluded that equal response will not be obtained on application of same amount of potassic fertiliser to soils of varying clay content In clayey soils more of potassium fertilisers has to be recommended

As revealed from the incubation experiment, to raise the exchangeable K content to a required level, potassium has to be applied in relation to the clay content and this was more *applicable to soils with more than 20 per cent clay In light soils this is not applicable due to their low buffering capacity They require a heavy saturation at the beginning for the satisfactory crop growth Long term field experiments have to be carried out to assess the optimum potassium content of various soils by taking the clay content into account and to test the reliability of the values obtained in pot experiments under field conditions*

References

REFERENCES

Agarwal, M M 1980 Phosphorus and potassium requirement of rice in relation to the time of application Indian J agric. Res 14 53-56

Anonymous, 1989 Package of Practices Recommendations Kerala Agricultural University, Vellanikkara, pp 239

Bajwa, I and Ponnamperuma F N 1981 Clay mineralogies and available phosphorus and exchangeable potassium status of some Phillippine rice soils Int Rice Res. Newsletter, 5 25

Bandyopadhyay, B K and Goswami N N 1988 Dynamics of potassium in soil as influenced by levels of added potassium calcium and magnesium J. Indian Soc. Soil Sci 36 . 471-475

Barthakur, H P Ahmed, S and Karmakar R M 1983 Response of rice to applied potash in an Assam soil Indian Potash J 8 6-10

Bhargava, P N , Jain, H C and Bhattia, A K 1985 Response of rice and wheat to potassium J. Potassium Res. 1 45-61

*Boyuslawski, E.V and Lach, G 1971. The potassium supply to experimental plants in relation to exchangeable potassium in soil Zeitschrift Fur Acker - und Pflanzenbau 134 135-164

Bolan, N S 1976 Studies on potassium distribution in soil profiles of Nilgiris and its relation to physico-chemical properties M Sc (Ag) thesis, Tamil Nadu Agricultural University, Coimbatore

Brar, M S and Sekhon, G S 1977 Potassium fixation and response of wheat to applied potassium in Punjab soils J. Res. (Punjab) 13 136-139

Brar, M S and Sekhon, G S 1985 Potassium status of five bench mark soil series from northern India J Potassium Res 1 28-35

Braunschweig L C V 1980 Potassium availability in relation to clay content - Results of field experiments Potash Review Suo 16, Suite 82 p 1-8

Carver, R E 1971 Procedures in Sedimentary Petrology Wiley - Interscience New York pp 180

Chakravorti, S P , Biddappa C C and Patnaik, S 1987 Dynamics of potassium in submerged soils growing rice - changes in forms of soil potassium and the relationship with its uptake by rice under continuous cropping J Potassium Res 3 139-148

Chakravorti, S P and Patnaik, S 1990 Fixation and release of potassium in flooded rice soils J Indian Soc Soil Sci 38 243-247

Chandal, A S , Singh, M and Singh, T A 1976 Forms of potassium in Mollisols of Nainital Tarai Bull Indian Soc Sci 10 30-20

* Chang, S C and Feng, M P 1960 Exchangeable and non-exchangeable potassium in the main agricultural soils of Taiwan KUO Li T ai-war Ta Hsieh Nung Hsieh Yuan Yen Chiu Pao Kao 5 11-18

Choudhari, J S and Pareek, B L 1976 Exchangeable reserve potassium in soils of Rajasthan J Indian Soc Soil Sci 24 56-61

Coleman N T and Thomas, G W 1967 The chemistry of soil acidity In Soil Acidity and Liming Agronomy No 12, American Society of Agronomy, Madison, p 1-41

Datta, S C and Sastry, T G 1989 K - threshold levels in relation to K - reserve, release and specificity J Indian Soc. Soil Sci 37 268-275

Datta, S C and Sastry, T G 1991 Potassium-threshold levels in relation to potassium reserve, release and specificity Potash Review, Subj 1, Suite 9 p 1-2

De Datta S K and K A Gomez, 1982 Changes in soil fertility under intensive rice cropping with improved varieties Soil Sci 120 361-366

Deol, Y S , Brar, S P S and Singh, B 1985 Release of soil potassium and its relationship with potassium uptake in maize - wheat cropping sequence J Potassium Res 1 97-108

*Fang, I J and Wang, C C 1981 The significance of soil non-exchangeable potassium in relation to sugarcane growth Soils and Fertilisers in Taiwan p 1-14

Ganeshamurthy, A N and Biswas, C R 1985 Contribution of potassium from non-exchangeable sources in soil to crops J Indian Soc Soil Sci 33 60-66

Ghosh, S K , Das, S C and Kapoor, B S 1976 Physical, chemical mineralogical characteristics of acid sulphate soils from Kerala Indian Soc Soil Sci Bulletin No 11, 117-133

Grimme, H , Nemeth, K and Braunschweig, L C V 1971 Some factors controlling potassium availability in soils Proceedings, International Symposium on Soil Fertility Evaluation 1 33-43

Goswami N N Bapat, S T and Pathak, V N 1971 Nutrient status and response of rice and wheat to fertilisers in different soils Indian Farming 20 29-32

Gupta M B S , Banerjee, N K and Chanda, H 1971 Effect of K and P on retention of ammoniacal nitrogen in soil and its recovery J Indian Soc Soil Sci 19 215-219

Gurmani A H , Bhatt, A and Rehman, H 1984 Potassium fertiliser experiments in farmers fields Int Rice Res Newsletter 9 26

Habib, F M Abdel-Salam, A A and Abdalla, Y N 1986 Evaluating available potassium in some soils of Egypt by chemical, biological and potassium-response tests with reference to clay mineralogy Annals of agric Sci 24 2265-2274

Hassan, M A 1977 Fertility Investigation on the Laterite Soils of Kerala State. M Sc (Ag) thesis Kerala Agricultural University, Thrissur, pp 120

Hati, N and Misra, B P 1983 Effects of levels and split application of potash on the leaching loss and plant uptake of potassium and the yield response of flooded rice *Oryza* **20** 31-35

Hesse, P R. 1971 **A Textbook of Soil Chemical Analysis.** John Murray (Publishers) Ltd London, pp 520

Ishizuka, Y 1965 Nutrient uptake at different stages of growth In **The Mineral Nutrition of the Rice Plant.** Baltimore pp. 199-217

*Iwuafor, E N O , Balasubramanian, V and Mokwunye, A U 1980 Potassium status and availability in the Sudan Zone of Nigeria Potassium Workshop, Ibadan/Nigeria p 97-109

Iyer, M A 1979 **Studies on Laterite and Red Soil Association in Certain Locations in Kerala** M Sc (Ag) Thesis, Kerala Agricultural University, Thrissur

Jackson, M L 1958 **Soil Chemical Analysis** Prentice-Hall Inc USA , pp 498

•Jacob, S 1987 **Characterisation of Laterite Soils from Different Parent Materials in Kerala.** M.Sc. (Ag) thesis, Kerala Agricultural Univerisity, pp 156

Jianchang, X and Chenglin, D 1990 Characteristics of potassium supply in paddy soils and effective application of potassium fertiliser in China Potash Review, Subj 6, Suite, 3 p 1-2

Joshi, D C 1986 Potassium release behaviour of some arid soils J Indian Soc Soil Sci 34 56-63

Kadrekar, S B and Kibe, K M 1972 Soil potassium forms in relation to agro-climatic conditions in Maharashtra J. Indian Soc. Soil Sci 20 231-240

Kalbande, A R and Swamynatha, R 1976 Characterisation of potassium in black soils developed on different parent material in Tungabhadra catchment J. Indian Soc Soil Sci. 24 290 296

Kansal, B D and Sekhon, G S 1976 Influence of amount and nature of clay on potassium availability of some alluvial soils Bull Indian Soc Soil Sci. 10 78-85

Kattak, J K , Pashid, A and Quasim, M 1981 Study of fertiliser fixation in some soil series of tobacco growing areas Potash Review, Subj 4, Suite, 30, 1-5

Kock, K and Mengel, K 1977 The effect of potassium on nitrogen utilisation of spring wheat during grain formation Agron. J 69 477-480.

Krishnakumari, M , Khera, M S and Ghosh, A B 1984 Studies on potassium release in an Inceptisol (Holambi series) at the minimum level of exchangeable potassium Pl. Soil, 79 3-10

* Krishnamurthy S and Ramakrishnayya, B V 1986 Forms of potassium in flue-cured tobacco soils of Andhra Pradesh Tobacco Res 12, 204-207

* Krumbein, W C and Pettijohn, F J 1938 Manual of Sedimentary Petrography. Appleton, Centuary, C , New York, pp 549

Lekshminarayanan, C R , Balasundaram, C S , Rajakkannu, K and Rangaswamy, P 1973 Evaluation of available potassium in soils - exchangeable potassium and thermodynamic approach Madras agric J 60 750-754

*Lepsch, I F , Rotta, C L , Valadares, J M A S 1978 Mineralogy, classification and forms of potassium in soils Pindorama Experimental Station, Sao Paulo, Brazil 2 63-68

Mallikarjuna, C , Vidhyadharan, K T , Pawar, S D , Senthiappan, M and Francis, P G 1979 Geological, geochemical and geotechnical aspects of laterites along the western coast of Kerala, India International seminar of Laterisation Processes, Trivandrum, 1979

Manickam, T S 1977 Studies on the East Coast Laterites. Ph D thesis, Tamil Nadu Agricultural University, Coimbatore

Martinii, J A and Suarez A 1977 Potassium supplying and fixing capacity of some Costa Rican latosols and andosols determined by successive cropping, extractions and incubations Soil Sci 123 37-47

Mc Lean, F O and Watson, M E 1985 Soil measurements of plant available potash Potassium in Agriculture, CSSA-SSSA, Madison, USA p, 277-308

* Medvedeva, O P 1971 Fixation of potassium fertilisers in non-exchangeable form and the availability of the latter to plants Agrokhimiya No 12, 38-45

Mehrotra, C L , Singh, G and Pandey, R K 1972 Fixation of potassium as related to soils and their particle size distribution in some soils of Uttar Pradesh J. Indian Soc. Soil Sci 20 121-128

Mehta, B V 1976 Potassium status of Gujarat soils Indian Soc. Soil Sci. Bulletin No 10, 25-32

* Mengel, K 1974 Die faktoren der kaliverfugbarkeit und deren bedeutung fur die ertragsbildung Landw Forsch, Sonderheft 31/1, 45-58

Mengel, K , Viro, M and Hehl G . 1976 Effect of Potassium on uptake and incorporation of ammonical nitrogen on rice plants Pl. Soil 44 547-558

Mishra, R V 1980 Effect of varying levels of potassium supply on the nitrogen and carbohydrate metabolism of rice plants in water culture Indian Potash J. 2 . 25-32

Mishra, R V and Shankar, H 1971 Potassium fixation and the fate of applied potassium in Uttar Pradesh Soils Indian J. agric. Sciences, 41 238-247

Mithyantha, M S , Rao, B and Perur, N G 1973 Available potassium status and its relationship with other soil properties in some acid soils of Mysore State Symp. on Acid Sulphate and other Acid Soils of India, Trivandrum. p, 120-130

Mondal, S S 1982. Potassium nutrition at high levels of N fertilisation on rice Potash Review, Subj. 9, Suite 52 pp 13-15

Mukherjee H N 1964 Fertiliser tests in cultivator s fields In The Mineral Nutrition of the Rice Plant The John Hopkins Press, Baltimore pp 329-354

Muthuswamy P Raj D and Krishnamurthy K K 1974 Uptake of nitrogen, phosphorus and potassium by high yielding paddy varieties at different growth stages Indian J agric Chem 7 1-5

Nad B K and Goswami M N 1981 Potassium availability effected by its application on rice at two moisture regimes on lateritic soils J Indian Soc Soil Sci 29 481-495

Nair M S , Nair R R Pisharody P N and Seshadrinath S 1981 Investigations on phosphate and potash manuring of transplanted rice Agric Res J Kerala. 9 48-54

Nair T J Nambiar P and Money N S 1966 Studies on Keen - Raczkowski measurements and their relation to soil test values in cultivated soils of Kerala Agric Res J Kerala 4 50-53

Nair, P S 1978 Studies on the Rice Growing Soils of Wynad M Sc (Ag) thesis, Kerala Agricultural University, Thrissur

Nambiar P K N 1972 Studies on Soil Potassium Ph D thesis Tamil Nadu Agricultural University

Negi A S Sharma R C Sud K C and Grewal J S 1979 Forms of potassium and Q/I relationship in the acidic brown hill soils of Simla J Indian Soc Soil Sci 27 268-271

Nemeth K Mengel K and Grimme H 1970 The concentrations of K, Ca and Mg in the saturation extract in relation to exchangeable K Ca and Mg Soil Sci 109 179-185

* Nemeth K and Harrach T 1974 Interpretation der chemischen Bodenunters uchung bei Lossboden verschiedenen Erosionsgrades Landw forsch, Sonderheft 30/1, 131-137

Ninjappa N and Vasuki N 1989 Potassium fixation in acid soils of Karnataka J Indian Soc Soil Sci 37 391 392

Onchere J Goulding K W T Wood I G and Catt J A 1989 Potassium and magnesium in some Kenyan soils their mineral sources and release to Ca-resin J Soil Sci 40 621-634

Palaniswamy, R Ahammed M Subrarayalu G and Potti S N 1978 Characterisation of potassium in rubber growing soils Agronomy, soils, physiology and economics of plantation crops PLACROSYM 1 45-53

Panda N 1984 Fertiliser management in lowland rice Oryza, 21 46-57

Panse V G and Sukhatme P V 1967 Statistical Methods for Agricultural Workers ICAR New Delhi pp 347

Patiram and Prasad R N 1991 Release of non exchangeable potassium and its relation to potassium supplying power of soils J Indian Soc Soil Sci 39 488-493

Piper, C S 1942 Soil and Plant Analysis Asian reprint 1966, Hans Publishers Bombay pp 368

Prabhakumari, P 1981 Soil Testing Methods for Potassium in Relation to Cassava M Sc (Ag) thesis Kerala Agricultural University pp 138

Prakash C and Singh, V 1985 Forms of potassium in alluvial soils of Western Uttar Pradesh J Indian Soc Soil Sci 33 911-914

Prakash, C and Singh, V 1986 Evaluation of soil test methods for available potassium in alluvial soils J Indian Soc. Soil Sci 34, 425-427

Prakash, C and Singh, V 1989 Fate of applied potassium to soils of varying texture Indian J agric Res 23, 175-178

Prasad, P R and Rajamannar A 1987 Changes in forms of potassium during cropping in soils of varied potassium releasing power J Potassium Res 3 40-44

Praseedom, R 1970 Distribution of Copper and Zinc in the soils of Kerala M Sc (Ag) thesis University of Kerala pp 141

Raguraj R 1981 Studies on the Physico-chemical Properties of Major Soil Series of Madurai District M Sc (Ag) thesis Tamil Nadu Agricultural University, Coimbatore

Ramanathan, K M 1978 An evaluation of potassium availability indices of some soils of South India J Indian Soc Soil Sci. 26 198-202

Ramanathan, K M and Krishnamurthy K K 1973 Potassium availability in relation to growth of rice in different soils J Indian Soc Soil Sci 21 181-186

Ramanathan, K M and Krishnamurthy K K 1978 A study of the relationship between certain soil characteristics of potassium fixation J agric Sci 12 69-72

Ramanathan, K M and Krishnamurthy, K K 1981 An appraisal of potasium availability indices in soils of Tamil Nadu J. Indian Soc Soil Sci. 29, 477-480

Ramanathan, K M and Krishnamurthy, K K 1982 Potassium releasing power vis-a-vis potassium supplying power of soils J Indian Soc Soil Sci 30 176-179

Ramankutty, N N 1971 Effect of potassium on growth, yield and nutrient uptake of two exotic rice varieties Agric Res J Kerala, 9 4-5

Ram, P and Singh, B 1975 Potassium in paddy soils of eastern Uttar Pradesh J Indian Soc Soil Sci 23 222-226

Rao, S A , Brar M S and Sekhon, G S 1988 Desorption pattern of potassium from five soil series developed on different parent materials J Indian Soc Soil Sci 36 239-245

Rao, M V , Patnaik, S and Vamadevan, V K 1971 Soil and water management and fertiliser use for optimising rice yields Indian Farming 21 63-66

Rao, A S and Sekhon, G S 1988 Potassium status of seven soil series from western India J Potassium Res 4, 95-103

Robinson, J G and Rajagopal, K 1977 Response of high yielding varieties of rice to graded levels of phosphorus and potassium Madras agric J 64 138-139

Ross G J and Cline, R A.1984 Potassium exchange characteristics in relation to mineralogical properties and potassium uptake by grapes of selected soils in the Niagara peninsula of Southern Ontario Can J. Soil Sci. 64 · 87-98

Sahu, B N 1963 Simple fertiliser trials on rice in cultivator's Fields in Orissa Rice News Tellers. 11 22-24.

Sakeena, I. 1988 Growth and Yield of Rice as Influenced by Potassium and Kinetin. M Sc (Ag) Thesis, Kerala Agricultural University, Thrissur

Sarkar, A N. and Raj, D 1973 Study of mineralogical composition of sand fractions of major groups of soils in South India and West Bengal Madras agric. J. 60 158-163

Sarkunan, V , Ramalingam, T , Reddy V.R , Raghavan, P and Venkataraman, S 1973 Available potassium status and its relationship with other soil factors in soils of South Arcot District. Madras agric. J. 60 · 873-876

Sekhon, G S , Brar, M S , Rao, A S and Maheswari, R K 1985 Soil series as a basis for making potassium recommendation. Soil testing, plant analysis and fertiliser evaluation for potassium PRII Research Review Series 4 111-124

Sen, H S Hazra, S K and Gupta, S k 1969 Response of HYVs of rice to NPK fertilisation in lateritic soil. Proc FAI, Calcutta pp 25-28

Senthivel, T and Palaniappan, S P 1985 Effect of potash top dressing through NK granules on yield and nutrient uptake of rice under lowland conditions J. Potassium Res. 1 166-173

Sharma, K N Brar, J S Kapur, M L Meelu, O P and Rana, D S 1978 Potassium in soil test values and responses of wheat, bajra and gram to fertiliser potassium Indian J. Agron 23 10-13

Sharma, B D and Mishra, B 1986 Potassium reserve and its fractionation in alluvial soils of Uttar Pradesh J. Potassium Res 2 90 95

Sharma, B D and Mishra, B 1986 Release of non-exchangeable potassium in texturally different soils of Western Uttar Pradesh J Potassium Res. 3 89-97

Sharpley, A N 1990. Reaction of fertiliser potassium in soils of differing mineralogy Soil Sci 140 44-51

Simonis, A D 1984 Potassium fixation in soils and recovery of fertiliser potassium by the plants Potash Review Sub 4 Suite 30 4-7

Singh, B P , Singh, M and Shukla, U C 1983 Forms of potassium in some soils of different agroclimatic regions of eastern Haryana J Indian Soc Soil Sci 31, 31-37

Singh, B , Sharma, K N and Kapur, M L 1981 Q/I relations of potassium and response of wheat to potassium fertiliser in illitic soils J Indian Soc. Soil Sci. 29 264-265

Singh, D and Ghosh, A B 1984 Removal of non-exchangeable potassium through intensive cropping in green house study with alluvial soils J Indian Soc Soil Sci. 32 303-308.

Singh, K N and Singh, M 1987 Effects of levels and methods of potassium application on the uptake of nutrients by dwarf wheat varieties Mysore J agric Sci 21 18-26

Singh O P and Datta B 1986 Forms of potassium in some soils of Mizoram J Indian Soc. Soil Sci. 34 187-190

Singh P Y , Singh, M and Singh B 1985 Forms of soil potassium in western parts of Haryana J Indian Soc Soil Sci 33 248-249

Singh, R and Singh, P R 1986 Forms and distribution of potassium in soils of Garhwall hills Indian J agric Chem XIX 207-214

Singh, V and Prakash J 1979 Effect of nitrogen, phosphorus and potassium application on the availability of nutrients to rice Madras agric J 66 794-798

Singh V S , Singh R P and Shukla D N 1976 Effect of rate and time of application of potassium on the yield and nitrogen, phosphorus and potassium turnover by high yielding rice Fert Tech 13 (2/3) 107-109

Sivarajasingham, S , Alexander, L T and Cady, J G 1962 Laterite Adv. Agron. 14 1-60

Sparks, D L and Huang, P M 1985 Physical chemistry of soil potassium Potassium in agriculture ASA - CSSA - SSSA Madion, USA p, 202-265

Sparks, D L and Jardine, P M 1984 Comparison of kinetic equations to describe K- Ca exchange in pure and in mixed systems Soil Sci , 138 115-122

Sreedevi, S , Aiyer, R S and Varghese T 1975 Potassium status of the major rice soils of Kerala State in relation to their granulometric composition Agric Res. J Kerala 13 5-8

Talati, N R , Mathur, S K and Attri, S C 1974 Behaviour of available and non-exchangeable potassium in soil and its uptake in wheat crop J Indian Soc Soil Sci 22 139-144

Tandon H C S and Sekhon G S 1988 Potassium Research and Agricultural Production in India Fertiliser Division and Consultation Organisation New Delhi pp 280

Tewatia R K , Singh, N S K Ghabru, S K and Singh M 1989 Potasium content and mineralogical composition of some salt affected soils J Indian Soc Soil Sci 37 687-691

Valsaji K 1989 Potassium Supplying Capacity of Neyattinkara-Vellayani Soil Association and Its Relationship with Potash Nutrition of Major Crops on Them Ph D thesis, Kerala Agricultural University Thrissur

Varghese T 1981 Studies on the Genesis, Morphology and Physico-Chemical Characteristics of Laterite Soils of Kerala Ph D thesis, Kerala Agricultural University, Thrissur

Venkatasubbaiah, V , Reddy, R G , Rao, Y Y , Seshaiah, R K and Rao S I V 1982 Effect of graded levels of potash application on yield and its components on high yielding Jaya rice grown in potassium depleted soil Indian Potash J 7 2-6

Venugopal, V K 1980 Pedologic studies on Lateritic Catenary Sequence Occuring in Kerala Ph D thesis, Kerala Agricultural University, Thrissur

Venugopal V K and Koshy, M M 1976 Exchangeable cations of some important soil profiles of Kerala Agric Res. J. Kerala. 14 37-42

* Wang Y P 1972 Winter wheat yields and level of phosphorus and potassium in soils and plant tissue as affected by PK fertiliser in Taichung perfecture Part 2 Growth on latosol and sandstone alluvial soil J Agric Forestry. 21 185-204

Wood, R A and Burrows, J R 1980 Potassium availability in soils of the South African Sugar belt Seventeenth Congress of the International Society of Sugarcane Technologists, 1 182-195

Wood, L H and De Turk, E E 1941 The adsorption of potassium in soils in non-exchangeable forms Proc Soil Sci. Soc. Am 5 152-161

Wright, C H 1939 ***Soil Analysis A Handbook of Physical and Chemical Methods*** *Thomas Murby and Co , London pp 190*

*** Wu T Y 1960 Utilisation of exchangeable and non-exchangeable K by rice under upland and flooding conditions B S Thesis National Taiwan University*

** Originals not seen*

Appendices

APPENDIX - I

Water soluble K in soils at different periods of incubation

Abstract of ANOVA

Sources	df	Mean squares					
		Period of incubation (fortnight)					
		1	2	3	4	5	6
Soil type	4	0 006869**	0 007132**	0 001471^{NS}	0 018649**	0 096339**	0 07449**
Potassium levels	2	0 001363**	0 001901**	0 003132^{NS}	0 001509**	0 001055*	0 006872**
Soil x potassium interaction	8	0 000231*	0 000172*	0 000246^{NS}	0 004383**	0 002014	0 002633**
Error	15	0 000019	0.000139	0 001403	0 000049	0 000274	0 000449

APPENDIX - II

Ammonium acetate extractable K in soils at different periods of incubation

Abstract of ANOVA

Sources	df	Mean squares					
		period of incubation (fortnight)					
		1	2	3	4	5	6
Soil type	4	0 06421**	0 052101**	0 050168**	0 092325**	0 087784**	0 096079**
Potassium levels	2	0 003418**	0 009091**	0 016021**	0 007045**	0 01491**	0 009426**
Soil x potassium interaction	8	0 001672**	0 001589**	0 003213**	0 006217**	0 001295**	0 002885*
Error	15	0 000071	0 000058	0 000214	0 00231	0 000294	0 00131

APPENDIX - III

Nitric Acid Soluble K in Soils at Different periods of incubation

Abstract of ANOVA

Sources	df	Mean squares					
		Period of incubation (fortnight)					
		1	2	3	4	5	6
Soil type	4	7.1507**	7.4187**	9.1368**	8.2519**	8.8356	19.3740**
Potassium levels	2	1.7582**	3.1223**	2.5668**	2.4998**	2.1470	1.8864*
Soil x Potassium interaction	8	0.6019*	0.7691**	0.8013**	0.6920**	0.7474	0.6051
Error	15	1.5198	0.0819	0.0135	0.0282	0.0176	0.0481

* Significance at 5% level

** Significance at 1% level

APPENDIX IV

Yield of straw at different stages of plant growth

<u>Abstract of ANOVA</u>

Sources	df	Mean squares		
		Tillering	Flowering	Harvesting
Soils	3	31 811**	232 53**	882 63**
K levels	3	0 584^{NS}	257 663**	389 241**
S x K interaction	9	4 271^{NS}	94 512**	76 232^{NS}
Error	32	4 636	20 921	82 865

APPENDIX V

Content and uptake of N by the rice straw at different stages of growth

Abstract of ANOVA

N content Sources	df	Mean squares		
		Tillering	Flowering	Harvesting
Soil	3	3 3767^{NS}	2 7061**	0 4636**
K level	3	9 3411^{NS}	0 3576**	0 0582*
S x K interaction	9	9 9838^{NS}	0 0581^{NS}	0 0048^{NS}
Error	32	10 4612	0 0321	0 0206

N uptake				
Soil	3	0 05569**	0 573^{NS}	0 079**
K level	3	0 000472^{NS}	0 992^{NS}	0 040**
S x K interaction	9	0 005488^{NS}	1 047^{NS}	0 006^{NS}
Error	32	0 00595	0 958	0 005

APPENDIX VI

Content and uptake of P by the rice straw at different stages of plant growth

Abstract of ANOVA

P content Sources	df	Mean squares		
		Tillering	Flowering	Harvesting
Soil types	3	0 00136^{NS}	0 00948**	0 01061**
K levels	3	0 00454**	0 00222^{NS}	0 050204**
S x K interaction	9	0 00371**	0 00384**	0 017431**
Error	32	0 00054	0 001239	0 000458
N uptake				
Soil types	3	0.000405**	0 00267**	0 00533**
K levels	3	0 000027^{NS}	0.0034**	0 0061**
S x K interaction	9	0 000108^{NS}	0 0012**	0 0007^{NS}
Error	32	0 00007	0 000188	0 000375

APPENDIX VII

Content and uptake of potassium by the rice straw at different stages of plant growth

<u>Abstract of ANOVA</u>

Sources	df	Mean squares		
		Tillering	Flowering	Harvesting
K content				
Soils	3	1 1512**	0 09686**	0 295*
K levels	3	0.0170^{NS}	0 1054^{NS}	0 479**
S x K interaction	9	0 1761^{NS}	0 0460^{NS}	0 070
Error	32	0 1697	0 0599	0.076
K uptake				
soils	3	0 03815**	0 034*	0 146*
K level	3	0 00176^{NS}	0 117**	0 188**
S x K interaction	9	0 00475^{NS}	0 026**	0.020^{NS}
Error	32	0 005697	0 009	0 026

APPENDIX - VIII

Content of Calcium and magnesium and their uptake by the straw at different stages of crop growth

Abstract of ANOVA

Sources		df	Mean square		
			Tillering	Flowering	Harvesting
Content	Soils	3	0.000771^{NS}	0.001332^{NS}	0.000676^{NS}
	Potassium levels	3	0.000212^{NS}	0.002027^{*}	0.001207^{NS}
	Soil x potassium interaction	9	0.003253^{*}	0.000846^{NS}	0.001186^{NS}
	Error	32	0.111258	0.000482	0.000965
Ca uptake	Soils	3	0.0000968^{**}	0.0010^{**}	0.00190^{**}
	Potassium levels	3	0.0000225^{NS}	0.00036^{**}	0.00123^{**}
	Soil x potassium interaction	9	0.00000336^{NS}	0.00033^{**}	0.00037^{NS}
	Error	32	0.0000143	0.000085	0.00021

	Soils	3	0.006563**	0.004802**	0.00664**
	K levels	3	0.000737^{NS}	0.00088**	0.00085**
Mg content	Soil x K interaction	9	0.000108^{NS}	0.000215^{NS}	0.000049^{NS}
	Error	32	0.000852	0.000269	0.000198
	Soils	3	0.000078**	0.00022**	0.00088**
	K levels	3	0.0000035^{NS}	0.0001175^{NS}	0.00022^{NS}
Mg uptake	Soil x K interaction	9	0.00000765^{NS}	0.0001595*	0.000073**
	Error	32	0.00001283	0.000067	0.000106

* Significance at 5% level

** Significance at 1% level

APPENDIX - IX

Content and uptake of nutrients by the grain

Abstract of ANOVA

Sources	Mean squares			
	Soil types (df = 3)	K levels (df = 3)	S x K (df = 9)	Error (df = 32)
Grain yield	839.056**	234.867**	25.471^{NS}	20.543
N Content	0.23484**	0.17305**	0.01178^{NS}	0.00912
P content	0.00669**	0.010997**	0.006804**	0.001287
K content	0.0944^{NS}	0.0837^{NS}	0.0423^{NS}	0.1391
Ca content	0.00024**	0.00004^{NS}	0.00006^{NS}	0.00003
Mg content	0.00012**	0.0000033^{NS}	0.0000022^{NS}	0.0000038
N uptake	0.00673**	0.00207**	0.020^{NS}	0.016
P uptake	0.005**	0.001**	0.0001^{NS}	0.00022
K uptake	0.1300**	0.039**	0.010^{NS}	0.007
Ca uptake	0.00022**	0.00005**	0.0000133^{NS}	0.0000116
Mg uptake	0.00004**	0.00001**	0.0000012^{NS}	0.0000002

** Significance at 1% level

APPENDIX - X

Content of water soluble ammonium acetate extractable and nitric acid soluble potassium in the soil at different growth stages of rice.

Abstract of ANOVA

Sources	df	Mean squares						
		Water soluble Potassium			Ammonium acetate extracable Potassium			HNO_3-K
		Tillering	Flowering	Harvesting	Tillering	Flowering	Harvesting	Harvesting
Soils	3	0.0001178^{NS}	0.000174**	0.0004325**	0.02824**	0.007717**	0.02222**	0.21064**
K levels	3	0.0001472^{NS}	0.000032^{NS}	0.0000144^{NS}	0.00126^{NS}	0.001828^{NS}	0.001983^{NS}	0.003556**
S x K interaction	9	0.0000422^{NS}	0.000054^{NS}	0.000123^{NS}	0.001224^{NS}	0.00131^{NS}	0.00216^{NS}	0.010017**
Error	32	0.0000363	0.000053	0.000061	0.00154	0.001108	0.001347	0.000767

** Significance at 1% level

INFLUENCE OF SOIL TEXTURE ON POTASSIUM AVAILABILITY, FIXATION AND UPTAKE BY RICE IN LATERITE SOILS

By

JESSYMOL, A S

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE

Vellanikkara, Thrissur

1991

ABSTRACT

The present investigation was carried out in order to assess the influence of various proportions of clay on the potassium dynamics in soil on application of potassium fertiliser and its effect on the uptake of nutrients by rice

Sixty surface samples were collected from the major rice growing areas of Thrissur district Based on their particle size analysis and organic carbon content, twenty samples were selected for studying the various physico-chemical characteristics related to the potassium availability In order to find out the transformations of applied potassium, a laboratory incubation experiment was carried out in five selected soils for a period of three months Mineralogy of the fine sand fraction was also carried out in these soils A pot culture experiment was carried out in four selected soils to determine the uptake of nutrients

The soils collected from the three locations showed wide variations in their clay content and majority of them were grouped under the textural classes, sandy loam and sandy clay loam The single value constants were showing variations depending on the clay content and organic carbon

The content and uptake of N, P, and K was found to increase with increasing levels of K application Calcium did not show significant difference with applied K and in the case of Mg a decreasing trend was observed

The water-soluble and ammonium acetate extractable K were decreasing with advancement of the crop growth and these fractions were found to be maximum correlated with the dry matter weight at the flowering and tillering stages respectively Nitric acid soluble fraction was found to contribute towards the later stages of crop growth Maximum correlation was obtained for the grain yield and straw yield with this fraction

Even though the positive effect of potassium application on the yield of paddy is very conspicuous, the response varied with the textural composition In more clayey soils more of potassium fertilisers has to be recommended to get maximum response as revealed in the present study