POTASSIUM RELEASE AND EXCHANGE CHARACTERISTICS OF THE SELECTED WETLAND RICE SOILS OF KERALA

By

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DECLARATION

I hereby declare that this thesis entitled "Potassium Release and Exchange Characteristics of Selected Wet Land Rice Soils of Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

LOUIS JOSEPH

Vellayani,
23-6-1994.

CERTIFICATE

Certified that this thesis entitled "**Potassium Release and Exchange Characteristics of Selected Wet Land Rice Soils of Kerala**" is a record of research work done independently by Mr. LOUIS JOSEPH under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

Rice lands in India mainly include flood plains, deltas, coastal low lands and interior alluvial areas. The low lands are considered to be hydromorphic or its associates. Of the major plant nutrients, Potassium is found to be the most abundant in soil (1.7 to 2.5% in soil). There is always a universal response for nitrogen, where as the response for P and K are often doubtful in nature and quite often controversial opinion of their behaviour is expressed. It has become an imperative need of the day to study the nutrients of least response.

The study of soil potassium is complex, as several interacting factors are involved in its availability, besides a series of electrochemical properties associated with soil submergence. Soils developed under humid conditions contain less K than those developed under arid and semi-arid conditions. Virgin soils are often rich in K. The dynamic equilibrium that exist in the soil is influenced by many factors like alternate wetting and drying, nature and amount of primary and secondary minerals, texture of soil, soil moisture regime and soil reaction. Response of the rice to potassium is being increasingly felt with more and more cultivation of high yeilding varieties.

Predicting the availability of potassium in the soil has become little more difficult when the soils are submerged. The process causes drastic changes in the physical, chemical and biological properties of soil. Due to the reduced conditions prevailing during submergence considerable redox-reactions takes place in soil resulting in the release and fixation of nutrient elements.

The important factors determining the capacity of a soil to provide for potassium requirement of plants are - potassium concentration in the soil solution, buffering capacity, amount of potassium in soil and water. Soils with very high total and exchangeable K need not provide a high supply rate which is required in the case of fast growing crops.

Kerala soils being situated in the humid tropical climate, are subjected to intense weathering and high leaching. This situation is accentuated by the undulating topography and consequent heavy erosion. Under these pedogenic environments, the soils of Kerala are inherently deficient in potassium. Exchange and release characters of the three major rice soils are studied here to throw light on the status of different forms of potassium and their capacity to maintain the potassium supply to crops.

Moreover, rice crop has been reported to show variable response for applied potassium fertilizers in Kerala and hence a knowledge about the potassium supplying capacities and potassium release patterns are of immense help to rationalise the use of potassic fertilizers to get maximum returns from the given input. The present study is therefore taken up with a view to study :-

1. The status of different forms of potassium in the black cotton, sandy Onattukara and lateritic alluvial soils of Kerala.

2. The pattern of release of potassium under continuously flooded condition.

3. To estimate and to compare the cumulative removal of potassium due to leaching and by exhaustive rice cropping.

4. To determine the response of graded levels of potassium to rice in the above soils with the potassium content depleted to threshold values.

REVIEW OF LITERATURE

1. Exchange and Release pattern of potassium

Exchangeable K^+ is the most readily available form of potassium since it is in direct equilibrium with the soil solution. Potassium releasing power denotes the total availability and not the total uptake because the entire amount that is released is not used by the plants.

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

The weathering of primary minerals resulting in the shift of equilibrium towards the water soluble fractions causes the release of K when the exchangeable K is depleted by crop removal which is replenished from the reserves of non-exchangeable K. The magnitude of K reserve and the rate of displacement of exchangeable form decide the K supplying power of soils. Herliehy and Moss (1970) reported that the lack of response to added K was due to the greater ability of the soil to release non-exchangeable K.

REVIEW OF LITERATURE

The non-exchangeable K released by the soil has been found to be sufficient to meet the entire need of the crop as reported by Kiely and Ryan (1972).

In an experiment to study the release of K as estimated by its uptake by six succesive cropping with maize Kadrekar and Kibe (1972) reported that the first crop removed the largest quantity of potassium with drastic reduction in the exchangeable K and release of K reached an equilibrium at the end of the crop and it indicated that the non-exchangeable K is as important as exchangeable K.

Doll and Lucas (1973) reported that many soils of the temperate region contain little illite K^+ on the exchange phase and are dependent on the transformation from the non exchangeable froms to replenish the exchange or solution phase upon depletion.

Kadrekar and Kibe (1973) studied the release of soil K with different degrees of hydration and drying revealing that in moist conditions the release of K took place only at the end of 50 to 60 days. It was found that at lower mositure levels ie 1/2 the moisture equivalent, was most conducive for the release of soil K.

The fixation and release of potassium are reactions of similar type and so the factors that influence the fixation of potassium also influence the release of potassium into the soil solution. The trend of K release by the clay fractions of the soil is by diffusion and the sand fraction released the K through the process of dissolution (Pal and Mondal, 1980).

Ganeshmurthy and Biswas (1985) observed pronounced changes in the non-exchangeable K content without much changes in the exchangeable form and obtained a significant positive correlation between potassium removal in crops and non-exchangeable potassium.

Pal and Durge (1987) suggested that biotite not only influenced K fixation, but also the release of K by its presence. Goulding (1988) reported that the release of K from the soil was affected by the type and particle size of the primary and secondary minerals, soil stucture, pH and liming, manuring, temperature, wetting and drying and the action of plant roots.

Deshmukh and Khera (1990) evaluated the potassium supplying power of 11 Ustrochrepts and reported that the total potassium uptake came from the non exchangeable K source of soil.

Datta and Sastry (1991) defined the threshold level of potassium as the level of exchangeable K in the soil below which potassium is released from non labile form which is usually non extractable with ammonium acetate and located in the inter-layers of clay. It is released to the exchangeable form when the level of exchangeable K is sufficiently lowered by crop uptake.

Patiram and Prasad (1991) studied the release of non exchangeable source of potassium in Inceptisols by growing Setaria and boiling with 1 N HNO_3. The amount of K released and taken up by the crop accounted for 32.3% to 65.7% of non-exchangeable forms, and the amount released during cropping was highly correlated with cumulative K uptake and dry matter yield.

Pal and Mukhyo padhyay (1992) conducted a green house study to investigate the relationship between K supplying power and K releasing power. Significant positive correlations were observed between cumulative K release and initial level of exchangeable potassium as well as non-exchangeable potassium indicating that potassium status is governed by potassium release characters of the soils.

Factors controlling the process of K release

The correlation between the K status as determined by soil analysis and crop response is not always satisfactory. This is due to the fact that soil analysis determines the potassium status of soil where as K availability is governed by a number of processes. Only a small fraction of potassium is present in the immediate vicinity of roots. The bulk of it has to move to the roots by means of convection and diffusion. There is not one optimum level of K availability but a range of optimum levels depending on the crop growth potential, yield level, soil moisture, type of clay, temperature and cation exchange capacity.

The greater the proportion of clay minerals high in K, greater the potential of potassium availability in soil.

Pierre and Bower (1943) evaluated the effect of high lime on the uptake of potassium by corn plants and it was reported that a marked decrease in the uptake of K was found in high lime soils and also the weight of corn plants dropped drastically.

Wetting and drying, freezing and thawing cycles have an influence on the transformation of K^+ between non-exchangeable, exchangeable and solution phases.

Cook and Hutcheson (1960) reported that soils with high initially exchangeable K levels, fixed K, whereas with low exchangeable K levels released K on drying. Bates and Scott (1964) demonstrated the release of fixed K to the exchange phase on drying.

Potassium fixing capacity was found to be dependent on the type of clay minerals and it was found that the soil series under vertisols were generally high than those of Alfisoils and related soils (Godse and Gopalakrishnappa, 1976). Potassium fixing capacity of laterite soils are low (0.6 meq / 100 g) while that of the rest varied form 0.63 - 0.9 meq / 100 g soil (Kadrekar, 1976).

Magnesium is found to compete with potassium for entry into the plants and it was reported by Spratt (1979) that high magnesium levels decreased the potassium concentration in the ear leaves of corn.

Skogley (1981) reported that increasing the soil moisture from 10 to 28 %, the total potassium transport increased by upto 175%. Song and Huang (1988) explained the effect of low molecular weight organic acids on the release of K from K bearing minerals like biotite, muscovite, microcline and orthoclase and it was found that the release from these minerals is in the order of biotite > microcline > orthoclase > Muscovite. Vegetative and organic matter are mainly responsible for the relatively high level of soluble and exchangeable K in the surface layers but labile K pools could be depleted rapidly with rapid decline of organic matter (Juo and Grimme, 1980).

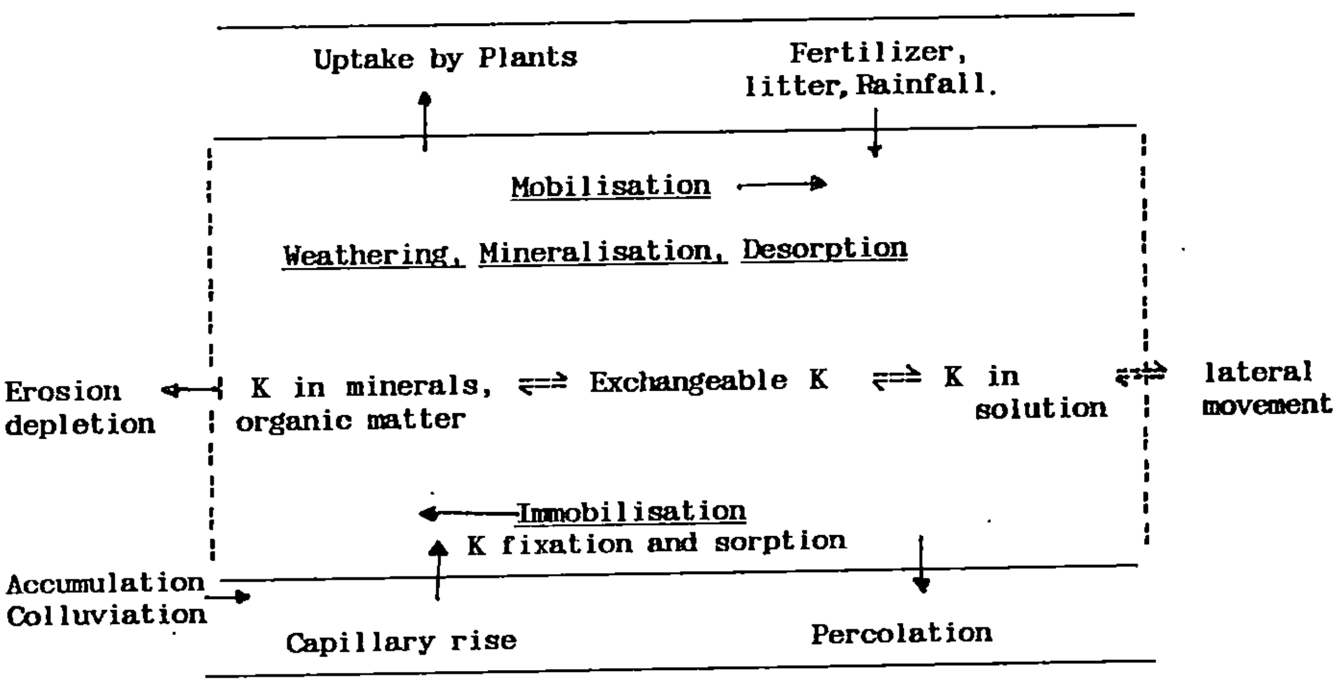
It was also reported that sand fraction provided more of total K in red and red earth soils while silt and clay contributed much of the K in black and alluvial soils (Sathyanarayanan et al., 1985). Non-exchangeable K reserves in 15 soils derived from five different parent materials were evaluated by Stevens and Jones (1986) and it was found that carboniferous shales have considerable non-exchangeable K reserves and that from mica schists have that least.

Sharma and Mishra (1987) observed that the exchangeable and non-exchangeable K decreased with the growing of crops in coarse textured soils and drymatter yield tends to be lowered in the later stages due to depleted status of exchangeable K.

Equilibrium between different forms of K in soils

There is a dynamic equilibrium existing between solution K, exchangeable K and non-exchangeable K and this basic concept was proposed by Hissinke (1925).

A detailed schematic diagram was presented by Schroeder (1972) covering all aspects.



Prabhakumari (1981) reported significant correlation between ammonium acetate K and exchangeable K in red and laterite soils. Similar results were obtained for water soluble K and ammonium acetate K, however between ammonium acetate K and total K a negative correlation was obtained.

A positive correlation between non-exchangeable K and exchangeable K was reported by Bandhyopadhyay et al. (1985). In alluvial soils of West Bengal all the different forms of K namely water soluble K, exchangeable K, labile K, non-exchangeable K and total K were in positive correlation with other except inter-layer K which did not significantly correlate with total K (Tarafdar and Mukhopadhyay, 1986).

Ravikumar et al. (1987) found that all the forms of K namely water soluble, exchangeable, HNO_3 extractable, HCl soluble and total are interrelated except total K with water soluble K and HNO_3 extractable fractions. Inter relationships in Neyyattinkara - Vellayani associations showed that water soluble K, exchangeable K and available K were in dynamic equilibrium. Non exchangeable K did not show any relation with available K, indicating that it is a poor source of available K (Valsaji, 1989).

Pal and Mukhyopadhyay (1990) showed that in Alfisols of West Bengal all the forms of K were interrelated except water soluble K and available which had insignificant relationships with total K.

In studies on the two soil series of South Kerala (Vellayani and Neyyattinkara) for the different forms of K Devi et al. (1990) found that water soluble K was significantly correlated with exchangeable and available forms of K.

Chakravorti and Patnaik (1990) reported that the contribution of non-exchangeable K towards the total K uptake in flooded soils increased during the later stages of cropping due to the release of non-exchangeable K and it was more in alluvial and red soils than in laterite and black soils.

Critical level of K in various soils for various crops

Critical level of nutrients is the level of the nutrient below which crop yield, crop quality or performance is unsatisfactory.

Loué (1957) reported that the critical level of exchangeable soil K for coffee has been set at 0.2 c mols kg^{-1}. Mehlich (1968) points out that when K response is compared to (Ca + Mg) / K ratio derived from individual K concentration expressed in centimols / kg the range of critical level of K for coffee is set at 0.2 to 0.4 c mol kg^{-1} when the ratio is equal to 10 or above.

Tanaka and Yoshida (1970) reported that for K deficiency at tillering, the critical concentrations in the leaf blade at tillering is 10 g kg^{-1} and 1% K. Orlando Filho and Zambello Jr. (1980) reported that critical level of K in soils planted to sugar cane is 112 mg g^{-1}.

Chang and Lee (1982) reported that optimum K content of 21.1 g Kg^{-1} in the leaves for maximum starch yield and 19.5 g kg^{-1} for maximum starch content.

When the relative yields reported by Brazilian Cassava Center were plotted against exchangeable K level in soils, Gomes (1982) obtained a critical K level concentration of 0.13 c mol kg^{-1}. Jones et al. (1982) reported that the critical level of exchangeable K^+ for rice is 8.3 meq/100g soil and when it is less than this amount, deficiency of K is likely to occur. Moberly (1982) suggests that 200 mg g^{-1} K as the critical level of K in soil containing > 40% clay for coffee.

Howeler (1985) reported that in the case of potassium the cassava plant can be considered deficient (<80% maximum yield) when its tissue contains less than 10g of K kg^{-1}, the content of K is considered low when it is between 10-13 g of K kg^{-1}, sufficient in the range of 13-20 g of K kg^{-1}.

Brar and Brar (1992) reported that critical levels of K at the flag leaf and in straw at maturity for rice were worked out to be 1.3 to 1.1 % K.

Plant K content as a function of K level in soil

Kimura and Chiba (1943) considered that the time at which nutrients were applied influenced the yield more than the amount of nutrients absorbed by the crop. Kiuchi (1951) observed that weight of rice grain increased with split application of potash.

Izhizukha and Tanaka (1951) studied the influence of K concentration in the culture solution on the growth of rice plants, especially on the amount of K in plants and reported that potassium content increased logarithmically with time.

Kiuchi and Izhizuka (1961) stated that optimum K content for higher number of grains was 2% at the booting stage. According to them, for good ripening and higher thousand grain weight the potassium content of the plant should be kept around 2% at the heading stage. At harvest the K content should be around 1%.

Sircar (1963) observed that in potassium deficient soils most of the rice tillers were unproductive and susceptible to many fungal diseases. Babe et al. (1965) reported that K deficiency lowered the existing activity of rice roots.

Sen et al. (1969) observed that response to potash application on grain yield of dwarf high yielding varieties was obtained on laterite soils of Midnapore with the application of 50 kg of K_2O / ha. Singh et al. (1976)

observed that application of 120 kg K_2O / ha gave the highest straw yields. Singh and Prakash (1979) reported an increase in the level of potassium from 0 to 60 kg K_2O/ha.

Mishra (1980) observed an increase in the dry matter production with increase in the level of potassium up to 50 kg ha^{-1}.

Nod and Gowsami (1981) reported that potassium application increased the rice yields in lateritic soils under submergence and it was high on soils which were subjected to alternate weting and drying. Venkatasubiah _et al_. (1982) observed highly significant increase in yield due to applied potash in potassium depleted soil. Hati and Mishra (1983) reported enhanced dry matter prodcuction due to potash application upto 60 kg K_2O/ha. Gurumani _et al_. (1984) reported a significant increase in the grain yield with increase in the level of potassium from 0 to 83 kg ha^{-1}. The yield response to applied potassium was significant at 40 and 60 kg ha^{-1}.

MATERIALS AND METHODS

MATERIALS AND METHODS

The details of collection and analysis of soil and experiments conducted to achieve the objectives envisaged in the study are presented in this chapter.

1. Selection of soils for study

Typical soils from selected regions as shown below were collected by traversing across each area and taking the surface layer (0-20 cm) at intervals of 15 - 20 m, and by compositing them to give a representative sample of that area.

Soil type (Common name)	Location	Great group
Sandy Onattukara	Kayamkulam	Ustic Quartzipsamment
Laterite alluvium	Pattambi	Kandic Aqult
Black cotton	Chittoor	Chrom Ustert

The samples were air dried, powdered and sieved through a 2 mm sieve. The samples were analysed for the following physical and chemical characteristics using standard procedures.

2. Soil Analysis

a. Mechanical Analysis :

The mechanical composition of the samples was determined by the International pippette method (Piper, 1966).

b. Soil Reaction :

The pH of the samples was measured in 1:2.5 soil water suspension using a pH meter - (Perkin Elmer) (Jackson, 1972).

c) Cation exchange capacity :

Ten gram soil was treated with 50 ml neutral normal ammonium acetate and kept overnight. The excess ammonium was removed by washing with ethyl alcohol. The absorbed ammonium was estimated by distillation with MgO. (Jackson, 1972).

d) Potassium fixing capacity :

Ten milligram of potassium was added in the form of KCl solution to 10 g soil. It was then subjected to alternate wetting and drying ten times and then extracted with neutral normal ammonium acetate and the amount of K was determined. A second 10 gm soil was treated similarly with 10 mg of K and was immediately extracted with neutral normal ammonium acetate and potassium was determined by aspirating in a flame photometer. The difference in the values is expressed as meq of K fixed /100gm of soil. (Jackson, 1972)

e. Forms of potassium

1) Water soluble potassium:

Ten gram of air dry soil was shaken with 50 ml distilled water for 10 minutes and filtered. The amount of K in the filtrate was determined using a flame photometer (Jackson, 1972).

ii) Ammonium acetate extractable K

Ten gram soil was shaken with neutral normal ammonium acetate in the ratio 1:5 for 10 minutes and filtered. The amount of K in the filtrate was determined using a flame photometer. (Jackson, 1972)

iii) Nitric acid extractable K

Ten gram soil was boiled with 50 ml 1N HNO_3 for 10 minutes and filtered. The filtrate was made up to 250 ml using 0.1N HNO_3 and the amount of K in the filtrate was determined using flame photometer (Jackson, 1972)

iv) Total potassium.

0.1 gm soil sieved through a 0.2 mm sieve was fused with a mixture of 0.5 ml perchloric acid and 5 ml hydro fluoric acid in a platinum crucible. The amount of K was determined using flame photometer (Jackson, 1972).

3. Cumulative potassium removal by continuous flooding & leaching

One kilogram each of the soil sample (with three replications), was kept under water logged condition in two litre procelain pots with a device at the bottom to facilitate the removal of leachate at intervals. It was kept as such for one month for attaining equilbrium and drained afterwards to collect the leachate.

The soil was immediately treated with 1 litre of neutral normal ammonium acetate and allowed to equilibrate for a period of 12 hours and then drained to the same bottle. The excess ammonium acetate was leached out with 30% alcohol and the leachate was collected along with the orginal leachate.

The different leachates were mixed well and made up to a known volume. A sample of 10 ml was evaporated to dryness in a silica dish, treated with aqua regia and the total potassium in it was determined. The process was repeated seven times and the cumulative removal of potasium from each soil type was computed.

4. Total potassium supplying capacity of soil.

The potassium supplying capacities of the above mentioned soils were determined by subjecting it to K depletion by raising a pot culture experiment with rice.

a. Pot culture experiment :

Rice was grown in each type of soil till the soil potassium was reduced to traces.

(i) Preparation of pots :

Earthern pots which could hold 2 kg of soil were coated with bitumen on the inner side and the holes were sealed. Each type of soil was filled in 24 pots and there were thus 72 pots for study.

(ii) Preparation of nursery :

Rice seeds (Var. Jaya) were soaked in water for 12 hours, drained and tightly packed in a cloth and frequently watered until the seeds sprouted. The sprouted seeds were then spread over acid washed sand kept in a tray. NP and micronutrients were applied for the healthy growth of seedlings.

(iii) Transplanting of the seedlings to pots

The seedlings at the three leaf stage were then transplanted to the prepared pots. Nitrogen (0.5 g/pot), Phosphorous (0.25 g/pot) and secondary and micronutrient solutions were supplied in the following combinations [$CaCl_2$ (20ppm) - 5 ml, $MgCl_2.6H_2O$ (20 ppm) - 5 ml, H_3BO_3 + $ZnSO_4$ + $CuSO_4$ + H_2MoO_4 - 5 ml, Sodium Silicate (5 ppm) - 10 ml and Ferric citrate + Sodium EDTA (2ppm) - 10 ml]. Rice was grown for a period of one month and then uprooted without loosing any soil from the pot.. The soil present in the root was removed and returned to the same pots. The experiment was continued until the plants developed K deficiency symptoms and failed to establish.

(iv) Soil and plant samplings :

After each crop the uprooted plants were air dried, powdered and K content estimated. Soil samples were also collected after each crop and analysed for water soluble K, exchangeable K, fixed K and total K.

5. K response studies

Response studies at different levels of potassium were carried out in the above potassium depleted soils. Rice (var. Jaya) was used as the test crop.

There were six treatments giving different levels of potassium and four replications as mentioned below. Sandy onattukara and lateritic alluvium soils alone were used for the study since the black cotton soils was not depleted of K by the successive cropping with rice for seven times.

Treatments

1) 0 K

2) 1/4 K

3) 1/2 K

4) 1K

5) 1 1/2 K

6) 2 K

K represents the cumulative K removed by rice plants from each soil type.

Rice was planted at three leaf stage in each of the pots at the rate of three plants / pot. Nitrogen (0.5 g/pot) phosphorus (0.25 g/pot) and micronutrients as described above were applied. Observations on the growth characters were taken at regular intervals. yield and yield attributes were recorded at the time of harvest.

6. Growth characters of Rice plant

1) Height of the plant :

The height of the plant was recorded on the 40th and 60th days after transplanting and at harvest. Height was taken from the base of the plant to the tip of the longest leaf.

2) Total number of tillers :

Total number of tillers were recorded on the 40th and 60th days after transplanting and at harvest.

Yield and yield attributes

1) Number of Productive tillers/plant

Productive tillers were recorded on the 60th day after transplanting and at harvest and expressed as the number of productive tillers/plant.

2) Panicle weight

All the panicles were weighed and the weight of panicles /pot was recorded for each pot.

Grain yield :

The grains harvested from each pot were dried, cleaned and weighed. The weight was expressed in g /pot.

Percentage filled and unfilled grains :

Total number of filled and unfilled grains from the panicles were separatly weighed and the percentage of filled and unfilled grains was recorded.

Fertility percentage

The fertility percentage was estimated from the amount of filled grains and total grains using the equation Filled grains/total grains x 100.

Straw yeild :

The straw harvested from each pot was sun dried, weighed and expressed in g/pot.

Plant analysis

The straw and grain samples were analysed for N.P and K following standard analytical procedures.

Statistical analysis

The data obtained were subjected to statical analysis according to the procedures of Panse and Sukhatme (1967).

RESULTS

RESULT

The results of chemical analysis of the soils used and of the various experiments conducted with the above soils are presented in this chapter.

Study of the soils used:

The soils used for the study were analysed for pH, Mechanical composition, CEC, potassium fixing capacity and forms of potassium and the results are presented in Table 1.

Soil reaction:

Sandy Onattukara and Lateritic alluvium soils are acidic with a pH of 4.2 and 4.7 respectively. While the Black cotton soils are in the alkaline range with a pH of 8.2.

Mechanical composition:

Mechanical analysis of the soils revealed the amount of coarse sand, fine sand, silt and clay present.

Black cotton soils are high in clay content (35 %) while it was low in coarse sand (7.9%). The silt and fine sand fractions amounts to 11.3 % and 40 % respectively. Sandy Onattukara soil was rich in coarse sand (68.3%) and was low in clay (15%). The silt and fine sand fractions amount to 5% and 12% respectively. In the lateritic alluvium the coarse sand fraction accounts for 44% while it is low in fine sand (13.1%). The silt and clay fractions amount to 20 % and 25 % respectively.

Cation exchange capacity:

The cation exchange capacity was found to be high in Black cotton soils (47.5 c mols kg^{-1}) while it was low in lateritic alluvium (8.25 c mols kg^{-1}) and sandy Onattukara (3.31 c mols kg^{-1}) soils.

Potassium fixing capacity:

Black cotton soil was found to have high K fixing capacity of 2.64 meq/100 gm soil while lower values were recorded in the case of lateritic alluvium (0.81 meq/100 gm) and sandy Onattukara (0.27 meq/100 gm).

Forms of potassium:

a) Water soluble K:

The water soluble K in Black cotton soil, lateritic alluvium and in sandy Onattukara soils are 8.5, 4.5 and 6 ppm respectively.

b) Exchangeable K:

Black cotton soil recorded high exchangeable K (0.197 c mols kg^{-1}) while in sandy Onattukara and laterite alluvium it was 0.074 c mols kg^{-1} and 0.064 c mols kg^{-1} respectively.

c) Fixed K.

Fixed Potassium was found to be higher in black cotton soils (0.021%) compared to lateritic alluvium (0.0056%) and sandy Onattukara (0.0052%).

d) Total K.

The total potassium content was high in black cotton soils (0.90%) while in lateritc alluvium it was 0.53% and in sandy Onattukara it accounted to only 0.22%.

Table 1. Analysis of soil sample used for study

Parameters	Type of soil		
	Black Cotton	Sandy Onattukara	Lateritic alluvium
pH	8.2	4.7	4.2
Mechanical Composition			
Clay(%)	35.00	15.00	25.00
Silt(%)	40.00	5.00	20.00
Fine sand(%)	11.30	12.00	13.10
Coarse sand(%)	7.90	68.30	44.00
Potassium fixing capacity (c mol/kg)	2.64	0.27	0.81
Cation exchange capacity (c mol/kg)	47.50	3.31	8.21
<u>Forms of Potassium</u>			
Water soluble K (ppm)	8.50	6.00	4.50
Exchangeable K (c mols/kg)	0.197	0.074	0.064
Fixed K(%)	0.021	0.0052	0.0056
Total K (%)	0.9000	0.2100	0.5300

Cumulative potassium removal by continuous flooding and leaching

The results of the studies carried out in the above three type of soils are presented in Table 2. The cumulative potassium removal after seven successive leachings of one kilogram soil was found to be 12.8 mg in black cotton soil, 2.2 mg in sandy Onattukara soil and 11.4 mg in laterite alluviual soil.

Total potassium supplying capacity of soil:

The potassium supplying capacity of the three soils as determined by subjecting them to K depletion studies by continuous cropping with rice are presented in Tables 3 and 4.

Black cotton soils:

The results of soil and plant analysis after each rice crop are presented in Table 3(a) and 4 (a). It can be seen from table 3(a) that the water soluble exchangeable, fixed and total K were 8.5 ppm, 0.197 c mols kg^{-1}, 0.021% and

Table 2. Cumulative potassium removal by continuous leaching (one kg soil)

No. of leaching	Potassium removed		
	Black cotton (mg)	Sandy Onattukara (mg)	Lateritic alluvium (mg)
1.	4.27	0.80	3.30
2.	4.45	0.76	4.50
3.	2.00	0.26	1.27
4.	1.48	0.29	1.43
5.	0.30	0.08	0.48
6.	0.18	0.06	0.15
7.	0.08	0.03	0.08
Total	12.82	2.28	11.22

Table 3. Potassium supplying capacity
3(a) Soil type - Black cotton

Details of Cropping	Water soluble K (ppm)	Exchangable K (c mol/kg)	Fixed K (%)	Total K (%)
Before cropping	8.5	0.197	0.021	0.90
After 1st crop	8.0	0.154	0.014	0.89
After 2nd crop	5.0	0.154	0.013	0.81
After 3rd crop	4.0	0.128	0.009	0.78
After 4th crop	4.0	0.077	0.009	0.71
After 5th crop	3.0	0.077	0.008	0.70
After 6th crop	3.0	0.077	0.006	0.59
After 7th crop	3.0	0.077	0.005	0.58

3 (b) Soil type Sandy Onattukara

Details of Cropping	Water soluble K (ppm)	Exchangable K (c mol/kg)	Fixed K (%)	Total K (%)
Before cropping	6.0	0.074	0.0052	0.22
After 1st crop	7.0	0.046	0.0036	0.21
After 2nd crop	3.0	0.033	0.0036	0.21
After 3rd crop	2.0	0.028	0.0020	0.20
After 4th crop	1.0	0.013	0.0020	0.20
After 5th crop	1.0	0.005	0.0016	0.20
After 6th crop	-	0.005	0.0008	0.20
After 7th crop	-	0.005	0.0003	0.19

3(c) Soil type - Lateritic alluvium

Details of Cropping	Water soluble K (ppm)	Exchangable K (c mol/kg)	Fixed K (%)	Total K (%)
Before cropping	4.5	0.064	0.0056	0.53
After 1st crop	4.0	0.047	0.0042	0.47
After 2nd crop	2.0	0.026	0.0040	0.45
After 3rd crop	2.0	0.018	0.0036	0.40
After 4th crop	2.0	0.003	0.0012	0.40
After 5th crop	1.0	0.005	0.0008	0.40
After 6th crop	0.1	0.005	0.0008	0.39
After 7th crop	0.1	0.003	0.0004	0.35

0.90% respectively before planting. After the first crop of rice, the water soluble K , exchangeable K, fixed K, and total K were reduced to 8.0 ppm, 0.154 c mols kg^{-1}, 0.014% and 0.89% respectively. After seven repeated plantings the K content was reduced to 3.0 ppm water soluble K, 0.078 c mols kg^{-1} exchangeable K, 0.0052% fixed K and 0.58% total K.

As the K content of the black cotton soil could not be depleted, this soil was not used for further studies envisaged in the technical programme.

Sandy Onattukara soils :

The results on the depletion study of K in these soils are presented in Tables 3(b) and 4 (b). The amount of water soluble K, exchangeable K, fixed K and total K in the initial soil were found to be 6 ppm, 0.079 c mols kg^{-1}, 0.0052% and 0.22% respectively. After completing seven crops of rice in this soil the amount of water soluble K, exchangeable K, fixed K and total K were reduced to 0, 0.005 c mols kg^{-1}, 0.0003% and 0.19% respectively.

Table 4. Potassium removal by successive cropping with rice
4(a) Soil type Black cotton

Crop details	Plant dry weight (g)	Potassium content in plant (%)	Amount of K removed by plant (mg)
1st crop	8.67	2.67	231.4
2nd crop	7.33	1.089	79.8
3rd crop	8.501	1.31	110.5
4th crop	6.54	0.8395	53.6
5th crop	7.08	0.736	52.1
6th crop	5.82	0.597	34.8
7th crop	7.08	0.736	51.1
Total			306.2

4(b) soil type Sandy Onattukara

Crop details	Plant dry weight (g)	Potassium content in plant (%)	Amount of K removed by plant (mg)
1st crop	6.58	0.13	8.94
2nd crop	8.53	0.169	13.60
3rd crop	6.19	0.065	4.04
4th crop	5.69	0.0372	2.11
5th crop	5.82	0.024	1.39
6th crop	4.27	0.0146	0.62
7th crop	3.98	0.0044	0.18
Total			30.88

4(c) Soil type - Lateritic alluvium

Crop details	Plant dry weight (g)	Potassium content in plant (%)	Amount of K removed by plant (mg)
1st crop	4.67	0.246	11.50
2nd crop	4.93	0.206	10.20
3rd crop	4.67	0.064	2.98
4th crop	5.59	0.0332	1.85
5th crop	5.59	0.033	0.75
6th crop	4.47	0.0172	0.77
7th crop	4.52	0.0108	0.49
Total			28.54

The cumulative potassium removal due to seven successive crops of rice in this soil amounted to 30.9 mg of K for two kg soil and the data are presented in Table 4(b).

Lateritic alluvium:

Results of the studies on the depletion of K in this soil are presented in tables 3(c) and 4(c).

The amount of water soluble K, exchangeable K, fixed K, and total K in the initial state of the soil were 4.5 ppm, 0.064 c mols kg^{-1}, 0.006 % ad 0.53% respectively. After repeated planting of seven crops of rice the water soluble K was reduced to 0.1ppm, exchangeable K to 0.003 c mols kg^{-1}, fixed K to 0.00035% and total K to 0.35%.

Cumulative K removal due to seven crops of rice in this soil was 28.6 mg/2kg soil. The data are presented in Table 4 (b).

Potassium response studies

The results of the study on the response of rice to the different levels of K in the depleted soil are presented in Tables 5 to 7.

Biometric characters of the plant:

1) Height of the plant:

The mean height of the plant in the two different soils are presented in tables 5(a) and 5 (b). The height of the plant showed significant variation in these two soils at 40 days after transplanting. The height of the plant increased from level OK (34.15 cm) to 2K (59.8 cm) in sandy Onattukara soils. The plant height at 1/4 K level and 1/2 K level were on par and the height at 1 K and 1 1/2 K were on par and plant height at 1 1/2 and 2K were also on par. There was significant variation in height between the levels 1/2 K (51.9 cm) and 1K (56.6 cm). In lateritic alluvium soils at 40 days after transplanting there was significant variation in height between various levels of K. The variation between 1/4 K and 1/2 K, 1/2 K and 1K, 1 1/2 K and 2 K levels were also found significant. The levels 1 K and 1 1/2 were on par.

At 60 days after transplanting the plant height exhibited significant defference in these two soils at the different levels of K applied. In sandy Onattukara soils the

Table 5. Growth characters of rice. (1) plant height and tiller number
5(a) Soil type - sandy Onattukara

Treatment	Mean plant height (cm) 40 DAT	60 DAT	Harvest	Mean tiller no./plant 40 DAT	60 DAT	Harvest
1	34.15	42.49	47.4	4.53	4.15	3.84
2	51.43	57.85	63.1	4.72	5.25	4.28
3	51.95	59.83	66.58	4.85	5.14	4.28
4	56.65	70.73	78.03	5.25	6.03	4.83
5	58.93	68.29	77.25	5.86	6.88	6.25
6	59.85	68.33	80.4	6.00	7.17	6.97
Mean	52.14	61.18	68.79	5.203	5.77	4.99
CD	2.88	2.63	2.39	0.35	0.42	0.44

5(b) Soil type Lateritic alluvium

Treatment	Mean plant height (cm)			Mean tiller no./plant		
	40 DAT	60 DAT	Harvest	40 DAT	60 DAT	Harvest
1	31.95	38.35	45.28	4.03	3.96	3.50
2	43.90	50.85	57.98	4.81	4.73	4.17
3	48.48	56.58	62.25	5.30	5.88	4.78
4	52.35	59.33	67.10	5.48	6.30	5.28
5	52.73	60.33	68.15	5.98	6.83	5.93
6	57.29	64.75	71.00	6.27	7.64	6.98
Mean	47.78	55.03	69.96	5.31	5.89	5.10
CD	2.88	2.63	2.39	0.35	0.42	0.44

maximum plant height was observed at 1K (70.73 cm) level. At 0K level the plant height was least and the plant height at 1/4K and 1/2K, 1 1/2 K and 2K were on par. In lateritic alluvium 2 K level showed maximum plant height and 0K showed least plant height. However, the levels 1/2 K and 1K, 1K and 1 1/2 K were on par.

At harvest the plant height showed significant variation between the different levels of K applied in both the soils. The plant height was maximum at 2K and least at 0K in both the soils. In sandy Onattukara soils the plant height at 1K (78.03cm) and 1 1/2 K (77.25cm), 1K (78.03 cm) and 2K (80.4 cm) were on par, while in lateritic alluvial soils the plant height at 1K (67.1cm) and 1 1/2 K (68.15cm), 1 1/2 K (68.15cm) and 2K (71cm) were on par.

Mean number of tillers/plant

The number of tillers per plant at various stages in the two soils are presented in Table 6. At 40 days after planting the mean number of tillers was significantly different among different levels of K but not between the two soils. In sandy Onattukara soils tillers at levels 0K, 1/4 K and 1/2 K, the levels 1/2 K and 1K and levels 1 1/2K and 2K were found to be on par, while in the lateritic alluvium soil the levels 1/2 K and 1K, 1 1/2 K and 2K were found to be on par.

At 60 days after planting there was significant variation in tillers between the levels of K but there was no variation between the two soils studied. The mean number of tillers was maximum at 2K (7.18) level and least at OK (4.15) level in both soils. In sandy Onattukara soil the levels 1/4 (5.25) K and 1/2 K (5.14), 1 1/2 K (6.88) and 2K (7.18) were on par. In lateritic alluvium soils the levels 1/2 K (4.78) and 1K (5.23) were found to be on par.

The mean number of tillers at harvest was found to vary significantly between levels of K, in the same soil but no variation was found between soils. In sandy Onattukara soils the levels OK (3.84), 1/4 (4.28) K and 1/2 K (4.28) levels 1 1/2 K (6.25) and 2K (6.47) were found to be on par. In lateritic alluvium soil the tillers at level 1/2K (4.78) and 1K (5.28) were on par. In both the soils the maximum number tillers was found at 2K level and least was observed at OK level.

Table 6. Yield and yield attributes

6(a) Soil type - sandy Onattukara

Treatments	Mean productive tiller/plant	Mean grain yield/pot (g)	Percentage filled grains
1	0.50	1.75	10.65
2	0.75	3.45	22.30
3	1.45	4.79	26.59
4	1.95	5.20	26.95
5	2.30	6.12	28.73
6	3.05	6.37	30.43
Mean	1.67	4.62	24.33
CD	0.33	0.83	4.43

6(b) Soil type Laterite alluvium

Treatments	Mean productive tiller/plant	Mean grain yield/pot (g)	Percentage filled grains
1	0.90	2.93	9.43
2	1.00	2.93	10.49
3	1.39	3.47	16.63
4	1.38	3.92	17.72
5	1.90	4.16	25.22
6	2.10	4.85	26.82
Mean	1.43	3.70	17.72
CD	0.33	0.83	4.43

Number of productive tillers/plant

The mean number of productive tillers/plant as presented in Table 6. The number of productive tillers was found to vary significantly between levels of K in the same soil and between the two soils. The number of tillers was found to be minimum at OK level and maximum at 2K level in both the soils. The number of productive tillers were on par at O K (0.5) and 1/4 K (0.75) levels and at 1K (1.95) and 1 1/2K (2.3) levels in sandy Onattukara soils while in lateritic alluvium 1/4K (1.0), 1/2 K (1.35) and 1K (1.35) 1 1/2K (1.9) and 2K (2.1) levels were on par. The number of productive tillers was significantly higher in sandy Onattukara soils as compared to lateritic alluvium.

Grain yield

The mean grain yield per pot is presented in Table 6. The grain yield was found to vary significantly between the levels of K in the same soil and also between the two soils.

The grain yield at levels 1/2 K (4.79) and 1K (5.2), 1 1/2 (6.12) and 2K (6.37) levels was on par in sandy Onattukara while in lateritic alluvium levels of OK (2.93), 1/4 K (2.96) and 1/2K (3.47) and 1K (3.92) and 1 1/2K (4.16) were on a par. The mean grain yield was found to be significantly high in sandy Onattukara as compared to lateritic alluvium. The grain yield was maximum at 2K level and minimum at OK level in both the soils.

Straw yield

The mean straw yield is presented in Table 7. The straw yield varied significantly among the different levels of K in the two soils but no variation was found between the soils. The straw yield at levels 1/4 K (3.61) and 1/2 K (4.16), and (5.2) 1K and 1 1/2 K (5.77) levels were on par in sandy Onattukara, while in lateritic alluvium the levels 1/2 K (4.59) and 1K (4.60) levels and 1K (4.66) and 1 1/2 (5.28) K levels were on a par. The straw yield was maximum at 2K level and least at OK in both soils.

Percentage filled grains

The percentage filled grains is presented in Table 6. It was found to vary significantly among the various

Table 7. Straw yeild, and nutrient content

7 (a) Soil type - Sandy Onattukara

Treatment	Mean straw yield (g)	N	Percentage P	K
1	2.73	0.49	0.18	0.01
2	3.61	0.51	0.18	0.02
3	4.16	0.51	0.18	0.04
4	5.20	0.53	0.16	0.06
5	5.77	0.59	0.20	0.15
6	7.54	0.61	0.20	0.22
Mean	4.83	0.54	0.18	0.8040
CD	0.58	0.01	0.01	0.01

7 (b) Soil type - Lateritic alluvium

Treatment	Mean straw yield (g)	N	Percentage P	K
1	3.07	0.74	0.08	0.01
2	3.35	0.74	0.12	0.01
3	4.59	0.75	0.09	0.01
4	4.66	0.88	0.13	0.03
5	5.28	0.93	0.13	0.04
6	6.71	0.93	0.14	0.10
Mean	4.61	0.83	0.12	0.0310
CD	0.58	0.01	0.01	0.01

levels of K in the same soil and between the two soils. The percentage filled grains at 1/4 K (22.8), 1/2 K (26.59) were on par and 1K (26.9), 1 1/2 (28.73)K and 2K (30.43) levels were found to be on par. The mean percentage of filled grains was found to be significantly high in sandy Onattukara compared to lateritic alluvium. The percentage of filled grains was maximum at 2K level and least at OK level in both soils and the maximum percentage of filled grains was found in sandy Onattukara (30.43) compared to lateritic alluvium (26.82).

K per cent in straw

The percentage of K in straw is presented in Table 7. It was found that the K content in straw varied significantly between the levels of K applied. The variation among the two soils was also significant. In sandy Onattukara soil the K in straw at levels OK (0.01%) and 1/4K (0.02%) were on par while in lateritic alluvium the levels at OK (0.01%), 1/4K (0.01%) and 1/2 K (0.01%). 1/2 K and 1K (0.02%) levels, 1K (0.03%) and 1 1/2K (0.04%) were on par. Among the two soils the percentage K in straw was found to be significantly higher in sandy Onattukara as compared to lateritic alluvium.

Percentage of nitrogen in straw

The percentage N in straw is presented in Table 7. It was found that percentage N in straw varies significantly between the levels of K applied. The variation between the two soils was also significant. In sandy Onattukara soils percentage N at 1/4 K (0.51%) and 1/2 K (0.51%) 1/2 K and 1K (0.53%) were on par while in lateritic alluvium the percentage N at OK (0.74%), 1/4 K (0.74%) and 1/2 K (0.75%), 1/2 K (0.93%) and 2K (0.93%) were on par. Among the two soils percentage N in straw was found significantly higher in lateritic alluvium than in sandy Onattukara.

Percentage phosphorus in Straw:

The percentage P in straw is presented in Table 7. It was found that the percentage P content in straw varied significantly between the different levels of K applied. In sandy Onattukara soils the percentage P at OK level (0.18%), 1/4 K (0.18%), 1/2 K (0.18%) and 1K (0.16%) were on par. Also the percentage P at 1 1/2 K (0.20%) and 2 K (0.20%) were on par. In laterite alluvium the percentage P at 1 K (0.13%), 1 1/2 K (0.13%) and 2K (0.13%) were on par. The percentage P in sandy Onattukara soils was found to be high compared to lateritic alluvium soils.

Percentage potassium in grain

The percentage K in grain is presented in Table 8. The percentage K in grain was found to vary significantly between the different levels of K and between soils. In sandy Onattukara soils the percentage K in grain at OK level (0.01%) and 1/4 K (0.02%) 1/4K and 1/2K (0.03%) were on par while in lateritic alluvium OK (0.01%), 1/4K (0.01%) and 1/2 K (0.01%) were on par. The percentage K at 1/2 K level and 1K (0.02%) on the same soil were on par. The K content was found to be higher in Sandy Onattukara soils compared to laterite alluvium soils.

Percentage nitrogen in grain:

The percentage N in the grain is presented in Table 8. The percentage N in grain was found to vary significantly between the different levels of K. In sandy Onattukara soils the percentage N at OK (1.94) and 1/4 K (1.89) were on par while in lateritic alluvium the percentage N in grain at 1/2

Table 8. Nutrient content in grain
8(a) Soil - sandy Onattukara

Treatments	N(%)	K (%)
1	1.94	0.01
2	1.89	0.02
3	2.28	0.03
4	2.40	0.08
5	2.60	0.11
6	2.64	0.21
Mean	2.29	0.08
CD	0.08	0.01

8(b) Soil - Lateritic alluvium

Treatments	N (%)	K (%)
1	2.09	0.01
2	2.23	0.01
3	2.54	0.01
4	2.62	0.02
5	2.71	0.11
6	2.71	0.16
Mean	2.48	0.05
CD	0.08	0.01

K (2.54) and 1K (2.62), 1 1/2 K (2.71) and 2K (2.72) were on par. However the N content was found to be higher in the lateritic alluvium compared to sandy Onattukara .

Correlation between Potassium and growth characteristics of the plant

Correlations were worked out between applied potassium and growth parameters like height of the plant, mean number of tillers, number of productive tillers, percentage filled grains, straw and grain yield. Significant correlations were noticed between K and all the above growth characters. In sandy Onattukara soils maximum correlation was found between applied K and yield of straw (92%) and and minimum correlation was found between K and % filled grains (42%). In lateritic alluvial soil maximum correlation was observed between applied K and tiller number at harvest (89.5%) and minimum correlation between K and height of the plant at 60 days after planting (69%). The regression equations are presented in Table 9.

A. SANDY ONATTUKARA

Potassium and height of the plant

Significant positive correlation was observed between the height of the plant and applied K at 40 days after planting, 60 days after planting and at the time of harvest. It was found that 62% (0.785) of the variation in plant height at 40 days after planting was shown by the linear regression relation y = 43.525 + 0.185 x, and at 60 days after planting, 61% (0.780) of the variation in plant height was shown by the linear relation Y = 51.632 + 0.204 x and at harvest 74% (0,785) of the variation in plant height was expressed by the linear relation y = 56.33 + 0.2669x.

Potassium applied and tiller number of the plant

Significant correlation was found between potassium applied and tiller number of the plant. At 40 days after planting 87% (0.933) of the variation in tiller no. may be expressed by the regression relation y = 4.53 + 0.0144 x . It was found that 84% (0.918) of the variation in tiller number at 60 days after planting is shown by the linear regression relation y = 4.536 + 0.0264 x . At harvest a variation of 78% (0.884) showed in the tiller number was explained by the linear regression relationship y = 3.806 + 0.0254 x.

Relationship between applied potassium and productive tillers of the plant

A positive correlation was observed between potassium and productive tillers. The major share of the (84 %) (0.918) variation in productive tillers was explained by the linear regression relation of y = 0.5884 + 0.0231 x.

Potassium and grain yield

Grain yield and the applied potassium showed significant positive correlation. It was found that 60% (0.993) of the variation in grain yield was expressed by the linear regression equation y = 2.8444 -0.038 x.

Potassium applied and straw yield

A positive correlation was observed between potassium and straw yield. It was observed that 92% (0.958) of the variation in straw yield was attributed to the variation in applied K and it was explained by the linear regression equation y = 2.896 + 0.0415 x.

Potassium applied and percentage filled grains

Positive correlation was observed between applied 'K' and percentage filled grains. The 42% (0.646) of the variation in percentage filled grains was expressed by the linear regression relation y = 17.917 + 0.1378 x.

Potassium and % K in straw

Percentage K in straw and applied potassium showed positive correlation and 91% (0.955) of the variation in % K was expressed by the linear regression equation y = -0.00911 + 0.00198 x.

Applied potassium and percentage nitrogen in straw

Percentage N and applied potassium showed positive correlation and it was observed that 82 % (0.906) of the variation in the nitrogen content in straw was expressed by the linear negative equation Y = 0.4487 + 1.1197E-03 X.

Applied potassium and percentage phosphorus in straw

Percentage phosphorus and applied potassium showed positive correlation and it was found that 20 % (0.443) of the variation in the percentage phosphorus in straw was expressed by the linear regression equation y = 0.175 + 1.643 E-04 x.

Applied potassium and % K in grain

Significant positive correlation was observed between the applied K and % K in grain. About 70 % of the variation in % K in straw was explained by the linear regression equation y = -7.975E-03 + 1.7418E-03 x.

Applied potassium and % N in grain

Applied potassium and % N in grain showed positive correlation and about 83 % (0.908) of the variation in the percentage nitrogen in grain can be explained by the linear regression equation y = 1.959 + 7.147 E-03 x. .lh9

B. LATERITIC ALLUVIUM

Applied Potassium and height of plant

Plant height and applied potassium showed positive correlation and it was observed that 69% (0.831) of the variation in plant height at 40days after planting was expressed by the linear regression equation y = 38.84 + 0.1702 x. At 60 days after planting 71% (0.842) variation in plant height was explained by the linear regression equation y = 45.768 + 0.176 x. The 74% (0.859) variation in plant height at harvest was explained by the linear regression relation y = 52.62 + 0.1778 x.

Applied potassium and tiller number

Significant positive correlation was obtained between applied potassium and tiller number of the plant. At 40 days after planting 70% (0.835) variation in the tiller numbers was shown by the linear regression equation y = 4.437 + 0.0160 x. It was found that 84% (0.914) variation in the tiller number at 60 days after planting was explained by the linear regression relation y = 4.412 + 0.00281 x. At harvest 89% (0.944) variation in tiller number was explained by the linear regression relation y = 3.705 + 0.0266 x.

Applied potassium and productive tillers

Productive tillers and applied potassium showed significant correlation and 83% (0.912) variation in productive tillers may be explained by the linear regression equation. y = 0.903 + 0.0101 x.

Potassium and grain yield

The grain yield and potassium was found to have significant correlation and 86% (0.926) variation in grain yield was expressed by the linear regression equation y = 2.877 + 0.0159 x.

Applied Potassium and straw yield

Significant positive correlation was noted between applied potassium and straw yield. The 79% (0.891) variation in straw yield was explained by the linear regression relation y = 3.152 + 0.0277 x.

Applied potassium and percentage filled grains

Significant positive correlation was obtained between potassium and percentage filled grains. The 85% (0.920) of the variation in percentage filled grains may be expressed by the linear regression relationship y = 9.728 + 0.152 x.

Applied Potassium and % K in straw

Significant positive correlation was obtained between potassium and percentage potassium in straw. The 80% (0.894) of the variation in % K in straw was shown by the linear regression relationship y = -0.00315 + 0.00067 x.

Applied potassium and % N in straw

Applied potassium and percentage nitrogen in straw showed significant positive correlation. The 89.9 % (0.948) of the variation in percentage nitrogen in straw was explained by the linear regression equation y = 0.725 = 1.97 E-03 x.

Applied potassium and % P in straw

Significant positive correlation was observed between potassium and percentage phosphorus in straw and 54 % of the variation in the percentage phosphorus in straw was explained by the linear regression equation y = 9.1809E-02 + 4.227E-04 x.

Applied potassium and % K in grain

Significant positive correlation was observed between applied potassium and percentage potassium and 83 % (0.914) of the variation in the percentage potassium in grain could be explained by the linear regression equation $y = -1.5472E-02 + 1.326E-03\ x$ **.

Applied potassium and % N in grain

Applied potassium and percentage nitrogen in grain showed significant positive correlation. The 71 % (0.841) variation in the percentage nitrogen in grain could be explained by the regression equation $y = 2.218 + 5.06E-03\ x$.

Table 9. Correlation between applied K and plant characters

Dependent variable	Regression equation	Correlation coefficient	Coefficient of determinant
A. Sandy Onattukara			
1. Plant height (40 DAT)	$y = 43.525 + 0.185^{**}x$	0.785	62
2. Plant height (60 DAT)	$y = 51.631 + 0.204^{**}x$	0.780	61
3. Plant height (harvest)	$y = 56.332 + 0.266^{**}x$	0.861	74
4. Tiller (40 DAT)	$y = 4.530 + 0.014^{**}x$	0.933	87
5. Tiller (60 DAT)	$y = 4.536 + 0.026^{**}x$	0.918	84
6. Tiller (harvest)	$y = 3.806 + 0.025^{**}x$	0.884	78
7. Productive tillers	$y = 0.588 + 0.023^{**}x$	0.918	84
8. Grain yield	$y = 2.844 + 0.038^{**}x$	0.773	60
9. Straw yield	$y = 2.897 + 0.042^{**}x$	0.958	92
10. % filled grains	$y = 17.917 + 0.138^{**}x$	0.646	42
11. % K in straw	$y = -0.009 + 0.084^{**}x$	0.955	91
12. % N in straw	$y = 0.4871 + 1.114E{-}03^{**}x$	0.906	82
13. % P in straw	$y = 0.1754 + 1.643E{-}04^{**}x$	0.443	20
14. % K in grain	$y = -7.975E{-}03 + 1.741E{-}03^{**}x$	0.977	95
15. % N in grain	$y = 1.959 + 7.147E{-}03^{**}x$	0.908	82

Dependent variable	Regression equation	Correlation coefficient	Coefficient of determinant
B. Lateritic alluvium			
1. Plant height (40 DAT)	$y = 38.835 + 0.170^{**}x$	0.831	69
2. Plant height (60 DAT)	$y = 45.768 + 0.176^{**}x$	0.842	71
3. Plant height (harvest)	$y = 52.626 + 0.178^{**}x$	0.859	74
4. Tiller (40 DAT)	$y = 4.438 + 0.017^{**}x$	0.835	70
5. Tiller (60 DAT)	$y = 4.413 + 0.028^{**}x$	0.914	84
6. Tiller (harvest)	$y = 3.705 + 0.027^{**}x$	0.944	89
7. Productive tillers	$y = 0.902 + 0.0101^{**}x$	0.912	83
8. Grain yield	$y = 2.877 + 0.016^{**}x$	0.926	86
9. Straw yield	$y = 3.152 + 0.027^{**}x$	0.891	79
10. % filled grains	$y = 9.728 + 0.152^{**}x$	0.920	85
11. % K in straw	$y = -0.0037 + 0.0006^{**}x$	0.894	80
12. % N in straw	$y = 0.725 + 1.973E-03^{**}x$	0.948	89
13. % P in straw	$y = 9.1809E-02 + 4.227E-04^{**}x$	0.733	54
14. % K in grain	$y = 1.547E-02 + 1.326E-03^{**}x$	0.914	83
15. % N in grain	$y = 2.218 + 5.06E-03^{**}x$	0.841	71

x applied K

** 1% level of significance (0.5168)

* 5% level of significance (0.4061)

DISCUSSION

DISCUSSION

Basic analysis of the three soils viz. Black Cotton, sandy Onattukara and lateritic alluvium used in the study showed that the pH of the black cotton soil was in the alkaline range (8.2). This is probably due to the very high percentage base saturation contributed by cations like Ca^{2+}, Na^{+} Mg^{++} and K^{+} present in the exchange complex. The lateritic alluvium and sandy Onattukara were in the acid range of pH 4.2 and 4.7 respectively. This was because the former was predominant in low activity clays while the latter is low in bases due to heavy leaching.

From the data on mechanical analysis, it was observed that black cotton soils had very high clay content (35%) followed by lateritic alluvium (25%) and least in Sandy Onattukara (15%). The water soluble K, exchangeable K, fixed K and total K were found to be high in black cotton soils (85 ppm, 0.194 c mols kg^{-1}, 0.021% and 0.9% respectively) as compared to lateritic alluvium (9.5 ppm, 0.064 c mols kg^{-1}, 0.0056%, 0.53%) and Sandy Onattukara (6.0 ppm, 0.074 c mols kg^{-1}, 0.0052% and 0.22% respectively). This was due to the high clay content in black cotton soils which is of montmorillonitic type and hence can fix large quantity of K. In lateritic alluvium even though the clay content is high (25%) they are low activity type of low charge and non-expanding hence adsorption and fixation of K is low. In sandy Onattukara the clay content is low and hence K is lost mostly by leaching.

The potassium fixing capacity is very high in black cotton soil (2.64 meq/100gm). Because of the expanding and contracting nature of the clay, K gets entrapped in the clay lattices. The clay in lateritic alluvium is non-expanding, Kaolinitic in nature and hence fixation is low (0.81 meq/100g). Fixation is very low in sandy Onattukara (0.27 meq/100g) as the clay content is low.

The high CEC of black cotton soils (47.5 c mols kg^{-1}) as compared to lateritic alluvium (8.21 c mols kg^{-1}) and Sandy Onattukara (3.31 c mols kg^{-1}) is due to its high 2:1 clay content. In lateritic alluvium even though the clay content is high and it is of Kaolinitic type which comes under the low activity group.

Cumulative K removal by continuous flooding and leaching

The soils when flooded with water for a continuous period of one month resemble field conditions during rice cultivation. The flooding conditions have enabled the attainment of equilibrium between the K in solution and K in the solid phase of the soil. The K content in the soil solution provide an estimate of the K that becomes available to the rice crop. Further leaching of the drained soil with ammonium acetate has helped to flush out the exchangeable K also from the soil. The amount of K in the leachate (flood water + ammonium acetate together) represent the actual amount of K that can become available to a growing rice crop. Repeated flooding with water and leaching with ammonium acetate help to determine the maximum amount of K that can be supplied or released to a rice crop by a soil under a given set of conditions.

The data obtained for black cotton, sandy onattukara and lateritic alluvial soils after seven flooding and successive leaching sequences and the cumulative removal of K from each soil are presented in Table No.2 and the pattern of removal is presented in Fig.1.

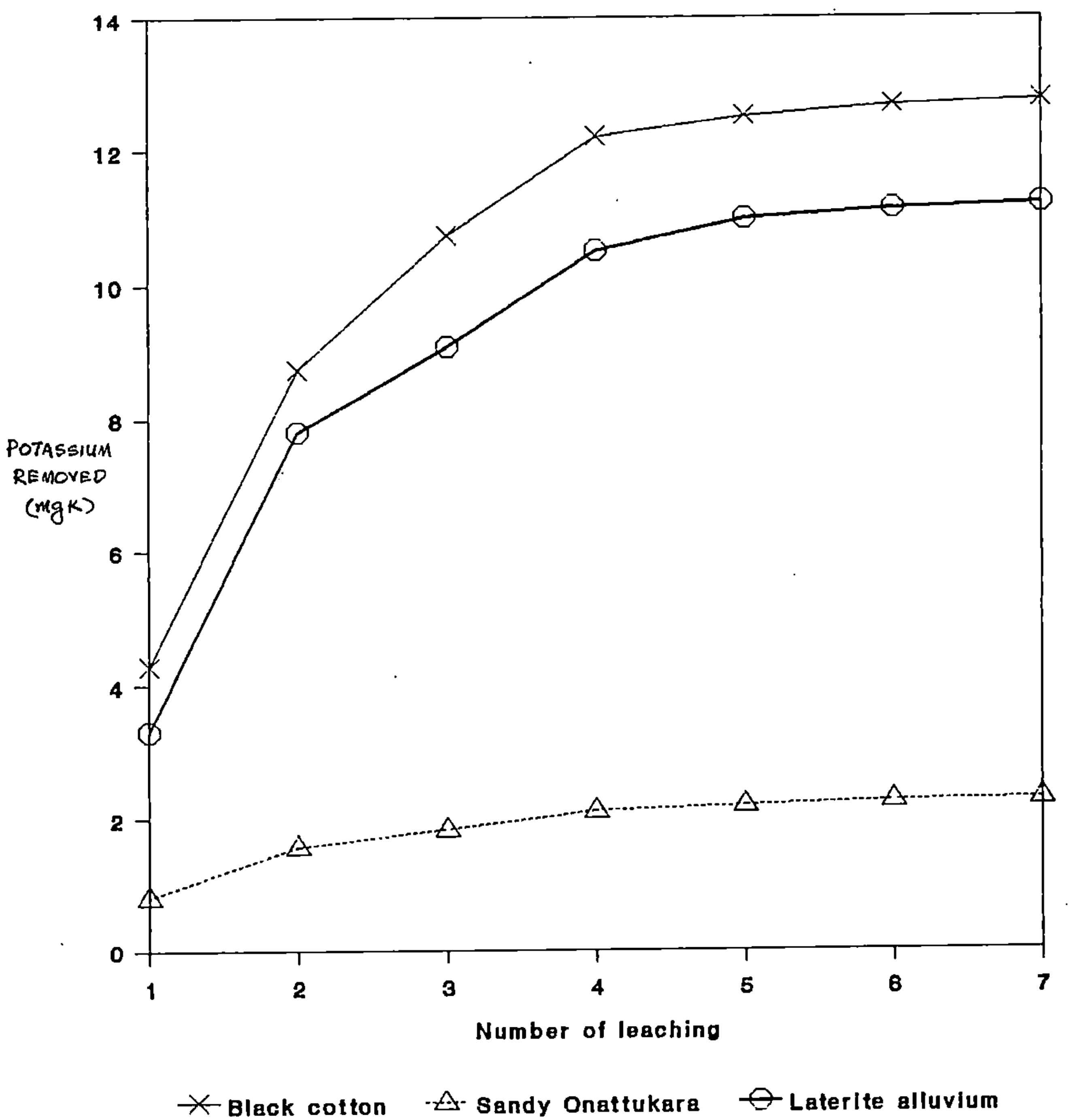


Fig. 1. Cumulative potassium removal by continuous flooding and leaching

Black cotton soil

The amount of K removed after first flooding and leaching was 4.27 mg/kg. The value gradually decreased and at the end of the seventh consecutive flooding it was reduced to 0.08 mg/kg soil. The water soluble K was initially estimated to be 8.5 mg/kg soil and exchangeable K to be 77 mg/kg soil. The Black cotton soils thus seems to be potentially capable of supplying 85.5 mg K/kg soil. However repeated flooding and leaching with water and ammonium acetate have brought a value of 12.8 mg K/kg soil which is only a very small portion of the total exchangeable K content. This indicates a situation where the analytical estimates are much higher than the actual available figures under field conditions.

Sandy Onattukara

The amount of K removal after first flooding and leaching is 0.8 mg/kg soil. The value decreased at the end of the seventh consecutive flooding and leaching and it was reduced to 0.03 mg K/kg soil. The cumulative removal due to the seven leachings accounts to 2.28 mg K/kg soil. The water soluble K in the soil was estimated to be 6 mg/kg soil and exchangeable K to be 29 mg K/kg soil. The sandy Onattukara soil thus seem to be potentially capable of supplying of 35 mg K/kg soil, however with repeated leaching only 2.28 mg K/kg soil was obtained. As in the case of the black cotton soil here also the actual amount of water soluble + exchangeable K released under flooded condition is only a very small fraction of the estimated value.

Laterite alluvium:

In this soil after the first leaching the amount of K removed was estimated to be 3.3 mg K/kg soil and the value decreased by the end of seventh leaching and it was estimated to be 0.08 mg K/kg soil. The cumulative K removal was estimated to be 11.3 mg K/kg soil. The water soluble K was 4.5 mg K/kg soil and exchangeable K 25 mg/kg soil accounting for a total value of 29.5 mg K/soil. Here also the cumulative K removal by continuous leaching and flooding is only a very small fraction of the actual estimate indicating an apparent decrease under actual flooded conditions.

Total potassium supplying capacity of soil

The total potassium supplying capacity of the soil was computed by conducting exhaustion studies. The results presented in Tables 3 and 4 reveal that the crop continued to get a steady supply of potassium by replenishment from the fixed sources in Black cotton soil, whereas in Sandy Onattukara and lateritic alluvial soils, the K supply was almost exhausted by the end of the seventh crop. In black cotton soils the water soluble K was reduced from 8.5 ppm to 2.5 ppm and exchangeable K was reduced from 0.194 c mols kg^{-1} to 0.076 C mols kg^{-1}. As stated above, due to the high quantity of fixed K (0.021%) the exchangeable K was replenished to maintain the equilibrium. However in Sandy Onattukara soils the water soluble K was reduced from 6 ppm to traces while exchangeable K was reduced from 0.074 C mols kg^{-1} to 0.005 c mols kg^{-1}. In these soils, the fixed K as well as low (0.0052%) hence easily depleted. In the lateritic alluvium the water soluble K was depleted to 0.1 ppm from the initial level of 4.5 ppm and the exchangeable K from 0.064 c mols kg^{-1} to 0.003 c mols kg^{-1}. Here also the fixation of K is very low (0.0053 %) hence availability is more. The drop in the status of the exchangeable K in these soils which

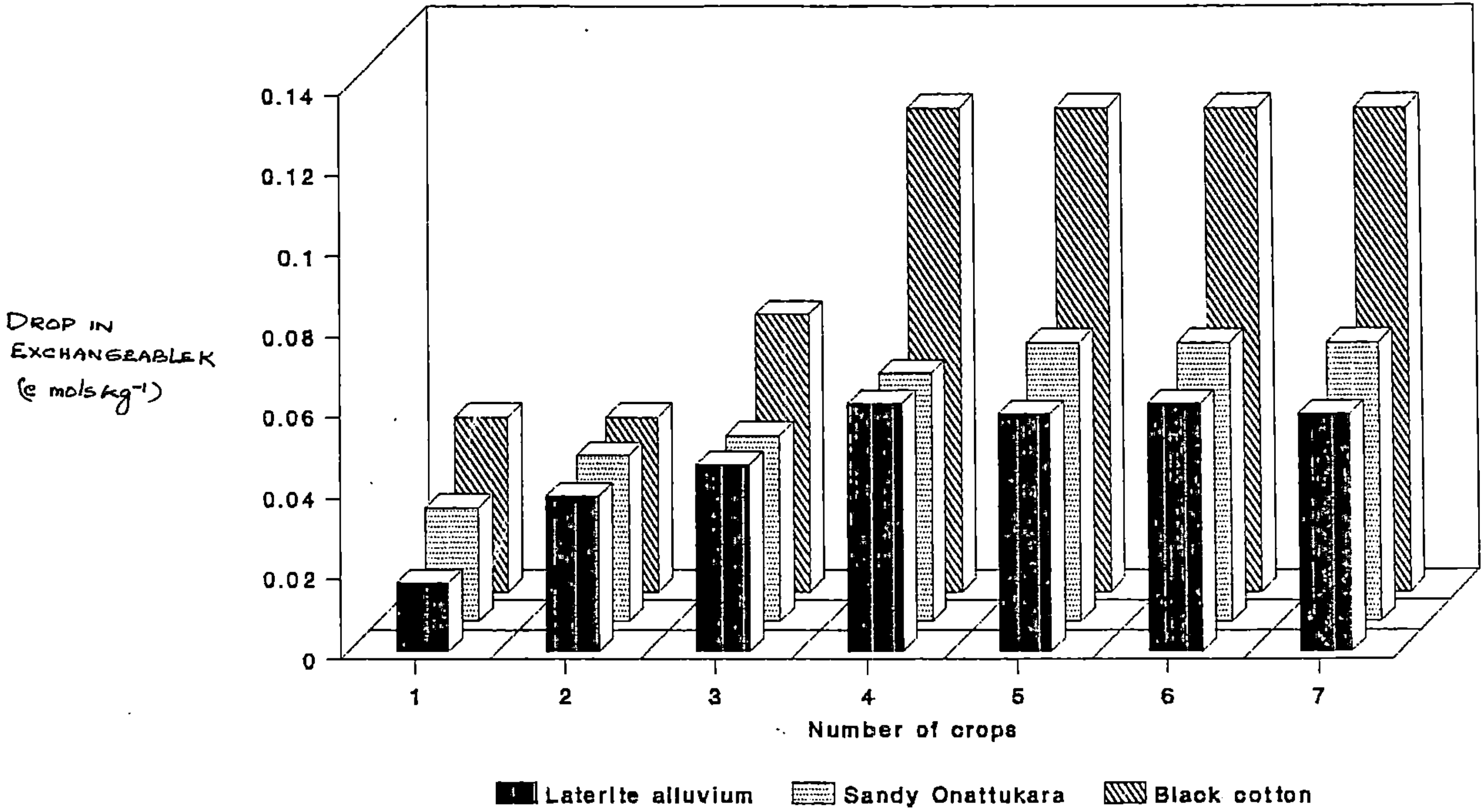


Fig. 2. Drop in the exchangeable K
content after each crop (cmols/kg)

became more prominent with progressive cropping is presented in Figure No.2.

The dry matter content (Fig. 3), percentage K in the plant (Fig. 4) and total K uptake (Fig. 5) decreased with progressive cropping in all these soil types, but the drop at the end of the seventh crop was most severe in the case of Sandy Onattukara. The potassium content also decreased in all these soils resulting in an increase in the total amount of K removed from the soils.

Seven successive croppings with rice has removed 306 mg K/kg from black cotton soil. This figure is about 3.5 times more than the estimated potential K supplying capacity of black soil 85.5 mg/kg as obtained by NH_4oAc extraction indicating the capacity of this soil to replenish the available K from the fixed form in the lattice. A reduction in the fixed K in these soils [Table 3(a)] supports the findings. The lateritic alluvium and sandy Onattukara on the other hand have only supplied 14.27 and 15.44 mg K/pot of one kg soil which is nearly half of the content of exchangeable plus water soluble K in these soils, which amounts to 29.5 and 35 mg K/kg soil. The lower K supplying capacity of these

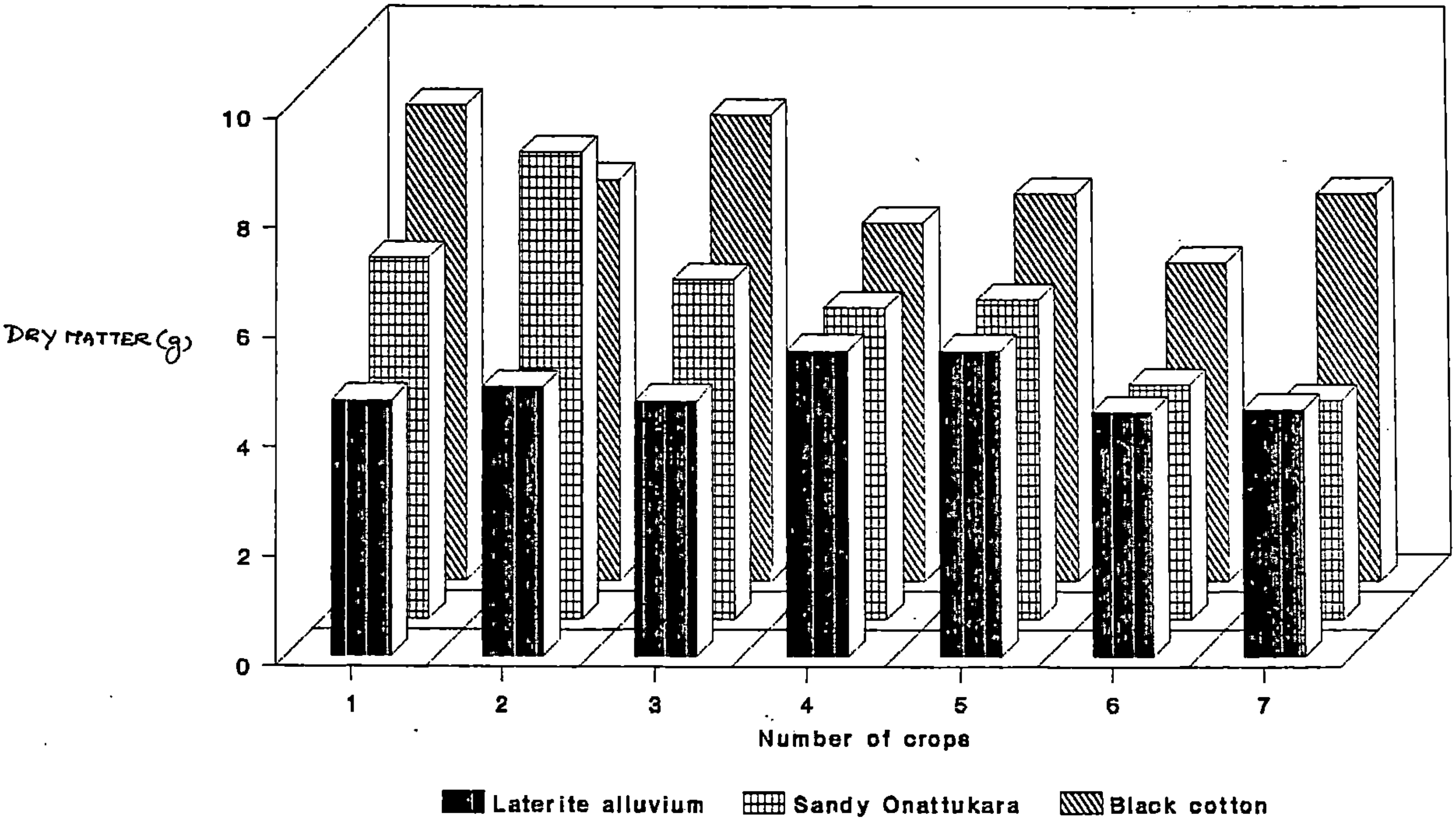


Fig. 3. Dry matter produced by each
crop of rice (g)

soils may be explained on the basis of the content of clay (25% and 15% respectively), CEC (8.21 meg/100 gm and 3.3 meq/100gm respectively), mineralogical pattern and the potential buffering capacity.

The black cotton soils have a high K fixing capacity (2.64 C mols kg^{-1}) compared to lateritic alluvium (0.81 C mols kg^{-1}) and Sandy Onattukara (0.27 C mols kg^{-1}). The soils with high K fixing capacity are naturally rich in fixed K and when these soils are flooded and in the presence of a standing rice crop release more K without causing the actual content of water soluble K and exchangeable K to become low.

Different soils having the same exchangeable K content may not have the same capacity for releasing and maintaining a constant level while K is being removed by plant roots (Le Roux, 1966). He noted that soils can have the same activity ratio values for K, but contain different amounts of labile K. The presence of ammonium ions resulting from added urea could displace more K from specific sites and make it available (Rich, 1964, Rich and Black, 1964) for the growing rice crop.

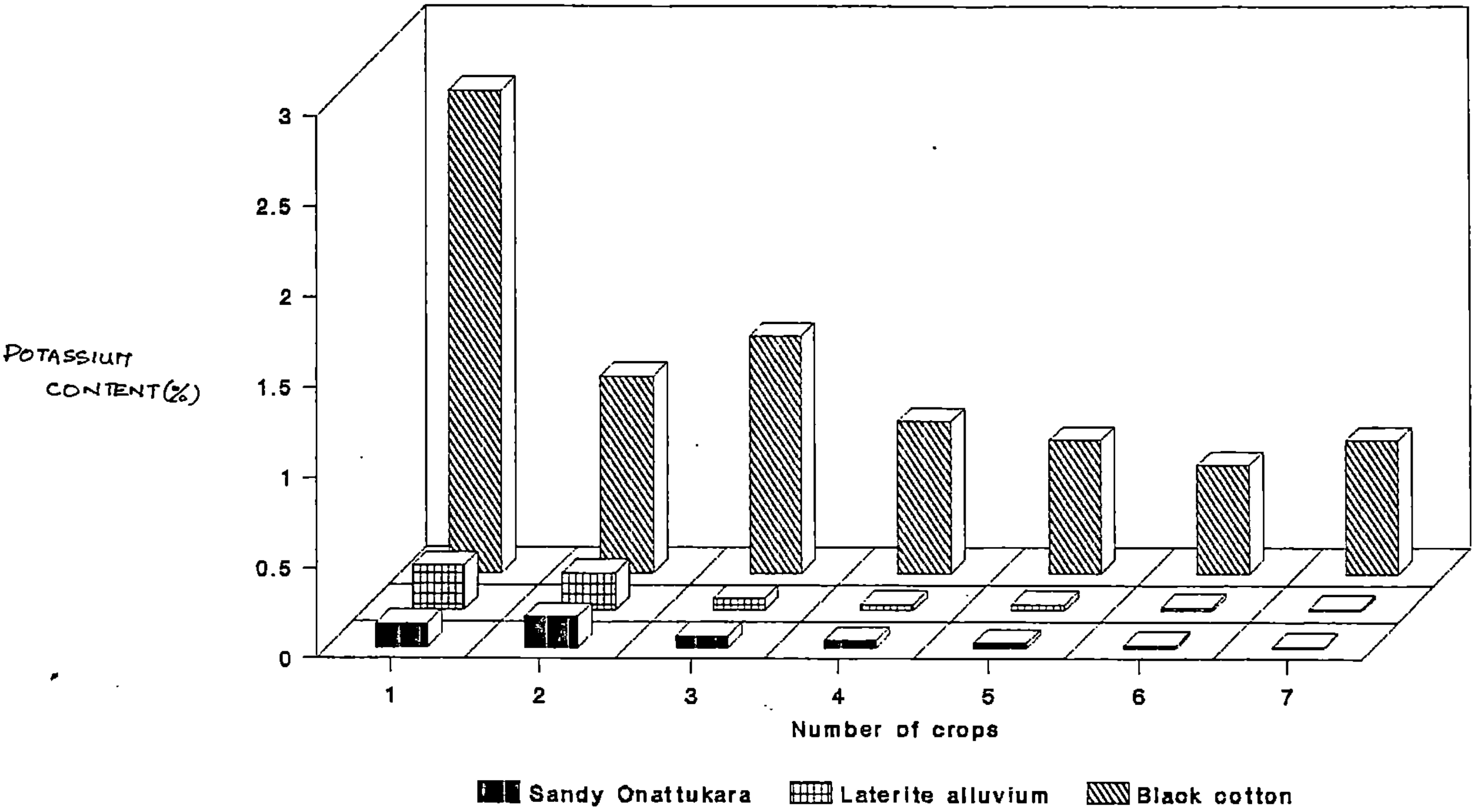


Fig. 4. Potassium content in the plant (%)

The variation in the potential buffering capacity of a particular soil can also decide the potassium supplying capacity. It is known to increase with increase in the CEC (Lee, 1973). The black cotton soil with a high clay content (35%) and high CEC (47.5) has an ability to release more K into the soil over a long period. The sandy Onattukara and lateritic alluvium with low clay content, low CEC as well as low potential buffering capacity are incapable of releasing more K and suggests the need for frequent fertilization. Sparks and liebhardt (1981) found that soils with low potential buffering capacity did not respond to applied K. The lack of response was ascribed to the large quantity of potassium bearing minerals in these soil that with time could release K to exchangeable and soluble forms.

After the seventh crop the cumulative K removed by black cotton, Sandy Onattukara and lateritic alluvium accounted to 306, 15.5 and 14.27 mg of K/kg soil respectively. In leaching studies the cumulative K removed by ammonium acetate extraction accounted to only 12.8, 2.8 and 11.22 mg K/kg soil in black cotton, sandy onattukara and lateritic alluvium. An under estimated value only is obtained by ammonium acetate extraction and this might be due

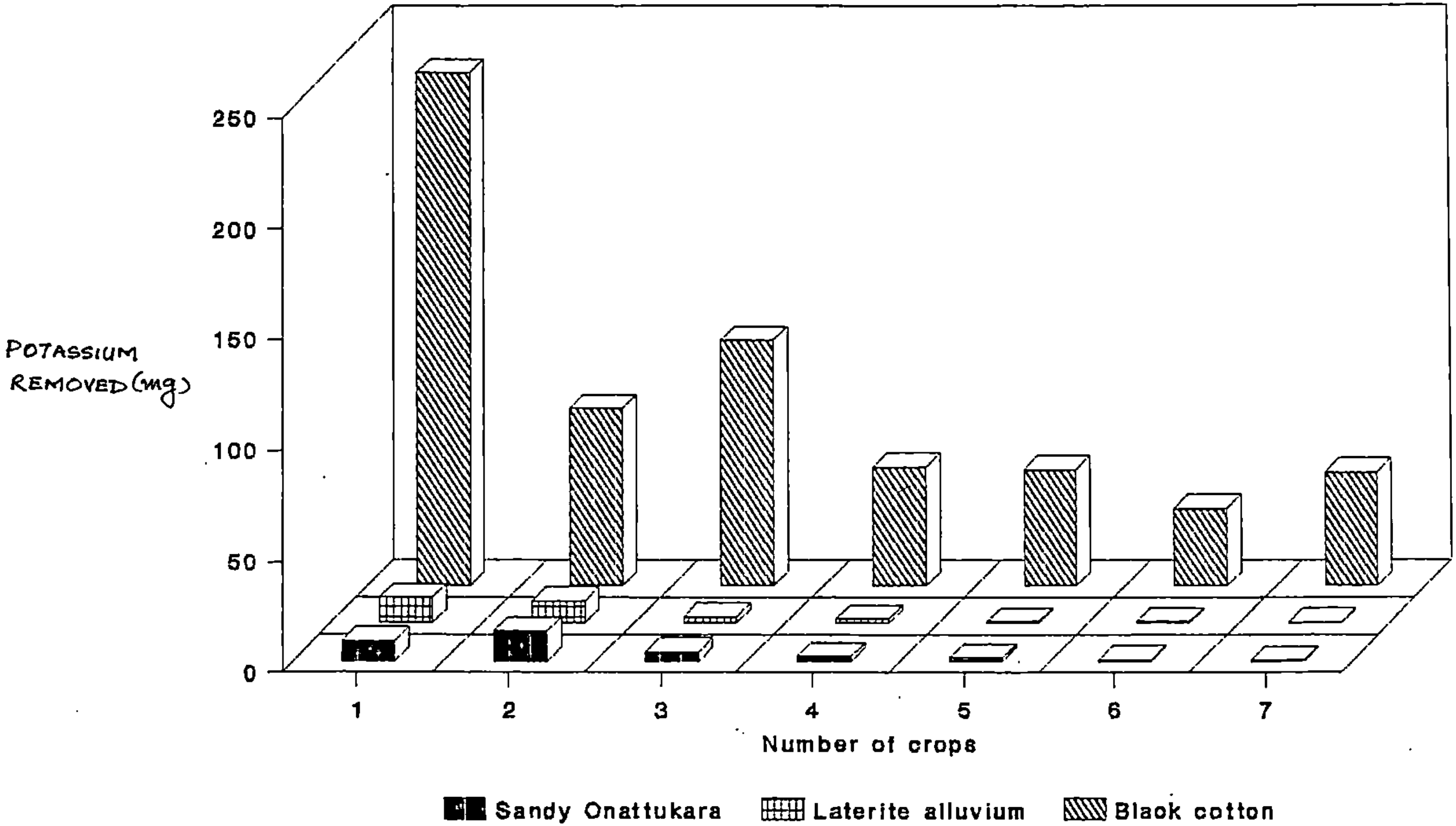


Fig. 5. Amount of K removed by each crop of rice (mg)

to the reversible equilibrium between soil K and that extracted by ammonium acetate during leaching whereas under exhaustive rice cropping the plant could continuously remove K from the system there by creating a concentration gradient between soil and solution K rendering no chance for such an equilibrium. The results indicate the possible limitation of using NH_4oAc in determining the K supplying capacity of soils for growing rice (Padmaja et al. 1988).

Response studies in the two soils - sandy Onattukara and lateritic alluvium

Response of rice to graded levels of added K conducted with the above two soils that reached the depletion stage due to continuous cropping, revealed a linear pattern. The positive effect of increasing levels of K was reflected in the biometric characters as well as in the yield of straw and grain and in the content and uptake of nutrients.

(1) Height of the plant

In both the sandy Onattukara soil and lateritic alluvial soil there was progressive increase in the height of the plant with increase in the level of applied K and the maximum plant height at each level was attained at the time of harvest. Baroh et al. (1964) reported that the application of potash helped to increase the growth of the plant in the later stage with not much effect in the earlier stages. Same results were reported by Bawappa and Rao (1950). Tisdale and Nelson (1965) however reported that potash is not considered essential for vegetative growth but it might have an influence in increasing the uptake of N_2 which in turn result in increasing the height of the plant.

The maximum height was obtained in sandy soil compared to lateritic alluvium. This is because of the less adsorption and high availability in the former compared to the latter. In lateritic alluvium the applied K would go into the exchange complex and very low quantity of K will be available for plant uptake.

Mean tiller number/hill

Tiller count is found to vary significantly between the various levels of K. This is because K affects the uptake of nitrogen (Tisdale and Nelson, 1965) and hence it indirectly affects the tiller number. So at 2K level, maximum tiller production occurred. Since same level of nutrients were applied to the two soils, no significant difference was observed between the two soils.

Number of productive tillers/hill

Potassium is found to have a direct influence in the formation of productive tillers. In Sandy Onattukara soils the number of productive tillers were found to be more than lateritic alluvium because of the low adsorption and high availability of nutrients.

Grain yield

The mean grain yield increased from 0 level K up to 2K levels in both soils and it varied significantly between soils. From the data presented in Table 6 it can be seen that K nutrition enhanced the yield in both soils. Samad and Sahadevan (1952) could get an increase of 15% in grain yield by the application of potash in the form of wood ash at 4000 lb/acre.

Straw yield

The straw yield was found to increase from zero level K up to 2K level. Sandy Onattukara soils produced maximum straw yield because of the high K availability. The positive influence of K in increasing the straw yield in rice has been reported by many workers (Singh et al., 1976). Increase in the dry matter production with increase in the level of K upto 50 kg K_2O/ha was observed by Misra (1980).

Percentage filled grains

Potash is found to affect the filling of grain significantly with the increase in the level of K. The percentage filled grains were high in sandy soils (24.35%) compared to lateritic alluvium (17.72%). This is due to high nutrient availability.

Govindarajan (1955) reported that potash was beneficial as it improved grain setting and reduced the percentage of chaff in paddy. Kiuchi and Ishizuka (1961) reported that adequate potash supply was essential for increasing the seed setting rate.

Percentage potassium in straw

It was found to increase from 0 level K to 2K level and the potassium percentage was high in Sandy Onattukara soil compared to lateritic alluvium. Similar results were presented by Ishizuka (1965) in rice soils. It is seen that in light textured soils with predominance of kaolinitic clay showed a fair level of available K and plant absorb all the K that is available in the growing medium. This finding is in confirmation with that of Bandyopadhyay and Gowsami (1988) who observed that concentration of potassium in the soil solution increased much in Kaolinitic soil with higher levels of K application as compared to alluvial and black soils.

Nitrogen content in straw

Nitrogen content in straw was found to increase with increase in the level of potash applied for both soils. However, the nitrogen content was found to be high in lateritic alluvial soils compared to Sandy Onattukara at all levels. This may be attributed to a lesser loss of nitrogen.

Phosphorous content in straw

The phosphorous content was found to high in Sandy Onattukara compared to lateritic alluvium and it was found that the phosphorous content was found to increase with increase in the level of K in Sandy Onattukara but it was fluctuating in the case of lateritic alluvium. This is because in the lateritic alluvium soils the phosphorus availability is low due to the fixation of phosphates by iron and aluminium oxides and also at the broken edges of the clay minerals.

Percentage potassium in grain

The potassium content in the grain was found to be high in Sandy Onattukara soils compared to lateritic alluvium and it was found that the potassium content increased with increase in the level of applied potash. The content in Sandy Onattukara soils is found to be high due to the high availability.

Percentage nitrogen in grain

The nitrogen content in the grain was found to be almost similar in the two soils at the different levels of applied potash. The nitrogen content was found to increase with the level of applied potash. Potassium is known to help in the translocation of nitrogen to the grain.

From the experiment on the response of rice to the various levels of applied K, it was found that even at the 2K level the yield characters show an increasing trend suggesting that the level of potash applied at 2K level (in sandy Onattukara - 112 mg and lateritic alluvium 120 mg of KCl/pot) was insufficient for maximum yield.

SUMMARY

SUMMARY AND CONCLUSION

A study was conducted in the three typical wet land soils of Kerala - Black cotton, Sandy Onattukara and lateritic alluvium, to investigate their potassium exchange and release pattern so as to enable a deeper insight into the potassium supplying capacity and the level of K at which maximum response may be obtained. The following three experiment were conducted to achieve the objectives -

1. Cumulative potassium removal by continuous flooding and leaching

2. Total potassium supplying capacity of soil by crop exhaustion

3. Potassium response studies

The important conclusions derived from this investigation are summarised below.

1. The black cotton soils are alkaline in reaction with a pH of 8.2, high in clay and potassium content while

sandy Onattukara is acidic, low in clay and potassium content and lateritic alluvial soils have moderate clay content and are low in potassium.

2. The cumulative potassium removal after seven successive leachings of 1 kg soil was found to be 12.8 mg in black cotton, 2.98 mg in Sandy Onattukara and 11.4 mg in lateritic alluvium. However the potential capacity of these soils were estimated to be 85.5, 35.0 and 29.5 mg K per Kg soil respectively.

3. Leaching and crop exhausition studies carried out to compute potassium supplying capacity of soils showed that -

   a. In black cotton soils the water soluble K was only depleted upto 2.5 ppm from 8.5 ppm and the exchangeable K to 0.076 c mols kg^{-1} from 0.194 c mols kg^{-1} even after seven successive cropping with rice.

   b. In Sandy Onattukara soil the potassium was depleted after seven crops of rice. The water soluble K was reduced to traces and exchangeable K was reduced from 0.074 c mols kg^{-1} to 0.005 c mols kg^{-1}.

c. In the lateritic alluvium the water soluble K was depleted to 0.1 ppm from the initial level of 4.5 ppm and exchangeable K from 0.064 c mols kg^{-1} to 0.003 c mols kg^{-1}.

d. The total K removed from black cotton, Sandy Onattukara and lateritic alluvium after seven successive croppings with rice amounts to 306, 15.44 and 14.27 mg K per one kg soil.

4. Response study was carried out on depleted soils with different levels of applied K (0 K, 1/4 K, 1/2 K, 1K, 1 1/2 K and 2 K. Where K represents cumulative k removal) showed that the biometric characters like height of the plant, mean tiller number/pot, number of productive tillers/plant, yield attributes - grain yield, straw yield, percentage filled grains (fertility %), NPK content in straw and NK content in grain, were found to increase with increasing levels of potash and it was found to be maximum at 2 k level in both soils.

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ABSTRACT

Being in the humid tropics, the pedogenic environment prevailing in Kerala keeps the soil inherently deficient in the status of potassium. The exchange and release patterns of potassium was studied using typical wet land soils viz.Black cotton soils of Chittoor, sandy Onattukara of Kayamkulam and laterite alluvium of pattambi. This investigation gives a deeper insight into the potassium supplying capacity of these soil types of Kerala.

From the basic chemical analysis of the soils, it was revealed that the black cotton soils are high in clay content (%) and potassium fixation and supplying capacity are also high. In sandy Onattukara the clay content is very low (15%) and hence the fixation and potassium content were found to be low while in lateritic alluvium eventhough the clay content is high (25%) the potassium content and fixation is low due to the kaolinitic nature of the clays.

A study on the cumulative potassium removal by continuous flooding with water and leaching with neutral

normal ammonium acetate revealed that the total potassium removed by seven successive leachings to be 12,8 mg, 2.28 mg and 11.4 mg K in black cotton, sandy Onattukara and lateritic alluvium soil respectively. But the potential capacity of supplying K in these soils as estimated by chemical analysis was found to be 85.5, 31.0 and 29.5 mg k/kg soil indicating a situation where the analytical procedures give much higher estimate than that is actually available under field conditions.

From another experiment to find the total potassium supplying capacity of these soils by crop exhaustion studies, it was found that the total potassium supplied by these soils amounted to 306, 15.44 and 14.27 mg k/kg soil. However the black cotton soil alone remained undepleted even after seven successive cropping with rice. The high amount of potassium supplied by Black cotton soil was due to the high content of fixed K, while in sandy Onattukara and lateritic alluvium the low content of fixed potassium, low clay content and low CEC explains the low availability of potassium.

When we compare the amounts of potassium obtained by crop exhaustion with the amount of K removed by leaching it may be noted that leaching studies provided an under estimated value. This might be due to the reversible equilibrium possible between soils K and that extracted by ammonium acetate during leaching, where as under exhaustive cropping the plant root continuously removed K from the system there by creating a concentration gradient between soil K and solution K rendering no chance for such an equilibrium.

The response studies carried out in the above depleted two soils - Sandy Onattukara and Lateritic alluvium with different levels of applied K (0 K, 1/4 K, 1/2 K, 1 K, 1 1/2 K, and 2 K. Where K represents cumulative K removal by crop exhaustion) showed that biometric characters, yield attributes and nutrient content showed an increasing trend with increase in the levels of applied K. The response was maximum at 2 K levels. The response applied K showed a linear pattern.