DIFFERENTIAL RESPONSE OF RICE CULTIVARS TO POTASH APPLICATION IN THE RICE SOILS OF *ONATTUKARA*

By

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DECLARATION

I hereby declare that this thesis entitled **"DIFFERENTIAL RESPONSE OF RICE CULTIVARS TO POTASH APPLICATION IN THE RICE SOILS OF *ONATTUKARA*"** 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 of Society.

Vellayani,
25.07.1996.

SHAJI. K. V.

CERTIFICATE

Certified that this thesis entitled **"DIFFERENTIAL RESPONSE OF RICE CULTIVARS TO POTASH APPLICATION IN THE RICE SOILS OF *ONATTUKARA*"** is a record of research work done independently by Mr. SHAJI. K. V. 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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Shaji. K. V.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

INTRODUCTION

Rice (*Oryza sativa* L.) grown in 111 countries world over, provides staple food to more than 1.8 billion people. This crop is grown under different climatic and environmental conditions of the tropics and subtropics. To meet the growing food requirements of the teeming millions of the area, rice varieties with high yield potential and improved cultivation technologies have been evolved.

Attention is also been given to increase the area under rice cultivation by evolving varieties suitable for the marginal lands left uncultivated. These lands include those where soil conditions induce mineral stresses resulting in poor production potential. Ponnamperuma (1977) has summarised these mineral stresses. Efforts are going on in various research centres all over the globe for evolving varieties suitable for cultivation under nutrient deficient conditions.

Rice varieties differ markedly in their ability to absorb nutrients, or the amounts required to produce a unit yield and their relative tolerance to the deficiency of these nutrients in the soil.

There are many reports citing various rice cultivars which are tolerant to deficient conditions of various nutrients in soil. Such varietal characters should be exploited in formulating strategies for reducing the cost of cultivation of rice. The use of such tolerant varieties will enable farmers to obtain reasonable rice yields with the application of lower doses of nutrients even in strongly deficient soils. This is only suggestive of the need to identify rice genotypes which effectively utilise the resources on land and to develop low cost production technology for rice in an area where cost effectiveness has become the prime consideration.

Of the various nutrients required by rice potassium commands special attention being a macronutrient required in large quantities for its growth and higher productivity. It is estimated that a low land rice crop producing 9.8 tonnes of grains per hectare in about 115 days takes up 258 kg of K which is more than the requirement of any other single nutrient by the plant (Datta and Mikkelson, 1985). The recent increase in the prices of fertilizers has made potassic fertilizers costlier forcing the farmers to apply this fertilizer element judiciously according to the requirements of the varieties.

The sandy tracts of *Onattukara* region of Kerala is inherently low in potassium causing the application of potassic fertilizers over and above the recommended level (150%) for other regions. It is well known that there exists genetic variation in fertilizer use efficiency and nutrient deficiency tolerance of many rice cultivars (Lee, 1960; Foy, 1976). Thus the present project was undertaken to study the differential response of rice cultivars to potassium deficiency existing in the sandy tracts of

Onattukara under field situations. Thus it is an inexpensive remedy for controlling potassium deficiency in the field by exploiting genetic variability.

The objectives of the study were

1. To study the differential response of rice cultivars so as to identify cultivars which can perform normally at lower doses of potassium application.

2. To identify rice cultivars with low K requirement which could be used in breeding programmes for evolving varieties suited to the areas of low K status.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Potassium is an indispensable fertilizer element largely required in regulation of metabolic activities. Very little attention has been paid to varietal differences in relation to potassium utilisation by the rice crop, mainly because response to K was usually marginal as long as traditional fertilizer unresponsive varieties were grown (Von Uexkull, 1976). Under stress environment, K plays a vital role in adjustment of plants to adverse conditions. (Zaidi and Khan, 1994) without significantly affecting the yield.

An overall review of the literature on the physiological role of potassium in rice nutrition, its influence on various characters and yield and on the differential response of rice cultivars are presented in this chapter.

2.1 Role of potassium in rice nutrition

Potassium,being a macronutrient essential for plant growth, plays a key role in the growth and development of rice plants. Eventhough this macronutrient is not a constituent of organic compounds which form the building blocks of plants, it is a cofactor for 60 or more enzymes which catalyses the various metabolic processes in the plants for the production of these various organic compounds.

Kono and Takahashi (1961) reported a close relationship between the potassium content of the basal part of the culm and the breaking strength of the stem, implying that proper K nutrition is closely associated with lignification of sclerenchymatous cells which strengthens culms thereby increasing lodging resistance. They reasoned that potassium deficiency decreases the accumulation of starch and cell wall substances such as hollocellulose that influence the stem strength.

Fujiwara's (1965) research confirmed that potassium deficiency in rice plants increases respiration. The rice plant at low K level had higher respiration despite an adequate supply of other nutrient elements during various growth stages.

Noguchi and Sugawara (1966) studied the effects of potassium deficiency on growth morphology and physiological response of rice in a soil and nutrient culture. The most pronounced potassium deficiency symptoms, according to them, were dark green leaves on which brown spots developed along the main vein and spread to the entire leaf. They found that potassium increased culm wall thickness by accelerating lignification. Photosynthesis decreased with potassium deficiency and respiration rate was more. Transpiration was greater in potassium deficient plants. Enzyme activities particularly of catalase, peroxidase and cytochrome oxidase were also higher in potassium deficient plants. They also studied, through the nutrient culture experiment, the effects of different elements in the characteristics of various rice organs. They found that a deficiency of K decreased root elongation and root thickness. But K deficiency did not appear to affect the root: shoot ratio of the rice plants.

According to Haeder (1980), the grain filling rate ie., sink intensity of cereal grains can be enhanced by K nutrition of the plants as demonstrated in short term experiments in barley. No specific promotion of starch synthesis by K could be found. Accordingly K had a stimulating effect on sink intensity in general. An extension of sink duration ie., a prolonged grain filling period by increasing K nutrition was also observed in pot experiments with wheat. This could have been due to a retarded leaf senescence and consequently better supply with assimilates. But analysis of Abscissic acid (ABA) during grain development suggested an involvement of this phytohormone. Increasing K nutrition delayed the occurrence of 'ABA maximum' and also decreased its absolute level in grains. Similar results were observed by Yuan and Huang (1993).

De Datta and Mikkelson (1985) summarised the role of potassium in rice plants as (1) K favours tillering and increases the size and weight of the grains, (2) increases responses to other nutrients particularly N and P, (3) plays an important role in physiological processes in the plant including opening and closing of stomata and tolerance to unfavourable climatic conditions, (4) increases resistance to diseases such as blast, leaf spot and stem rot and (5) increases stem strength and reduces lodging susceptibility.

2.2 Differential response of rice varieties / cultivars to potassium nutrition

Field studies conducted upto 1950 on tall indica rice varieties have shown lack of response to potassium in almost all situations (Sethi *et al.*, 1952). But with the introduction of high yielding varieties, the experiments conducted provided evidence that in almost all types of soils the high yielding rice varieties were responsive to potassium application (Kanwar *et al.*, 1973). Reports of greater response of rice to K in *kharif* than in *rabi* season are also available (Mahapatra and Prasad, 1970).

Kalyanikutti (1969) demonstrated the response of rice to K supplements as a function of variety. She compared indica (Co33), japonica (Tainan 3), indica x indica (IR8) and indica x japonica (ADT 27) and concluded that Tainan 3 and IR8 needed nearly double the amount of K as required by ADT 27 and Co33.

According to Von Uexkull (1976) high yielding varieties like IR8, IR28 and IR29 are considerably more responsive to K than IR20 and IR 22.

Meelu *et al.* (1982) after reviewing the response of rice to K concluded that continuous reappraisal of K response is necessary in view of the heavy removal of K by rice, though the response of rice to K application is low. They reported that responses at research stations were low but at farmers' fields the grain yield response to 60 kg K_2O ha^{-1} ranged from 3-7.3 q ha^{-1}.

Nambiar and Ghosh (1984) compiled the results of the long term fertilizer experiments in India for 1971-82 and came to the conclusion that for every kilogram of K_2O applied, there was an increase of 5-10 kg grains. But Nanda and Sahoo (1984) in Orissa found that at K levels of 20-60 kg ha^{-1} the mean response of rice was 4.16 kg grain kg^{-1} K_2O. In view of the high uptake of K by the high yielding varieties of rice, Pande (1984) opined that a maintenance dose of 30 kg K_2O ha^{-1} should be recommended for low land rice.

In Tamil Nadu the average response of rice to K was worked out to 9.3 kg^{-1} to the first 40 kg K_2O ha^{-1} and 6.8 and 5.4 kg to subsequent 40 kg ha^{-1} increments of K (Mosi and Lakshminarayan 1987).

Qadar (1989) after a pot culture experiment pointed out that the variety CSR-1 having a tendency for more accumulation of potassium showed better response to higher levels of potassium supply in comparison to the variety Jaya.

Vijayaraghavan *et al.* (1992) in an experiment with varieties differing in their parental composition found that *'Kannaki'* which has

IR8 as female parent showed increased response to potassium application upto 80 kg ha^{-1} level whereas IET 3280 and 1089 showed response upto 60 kg ha^{-1} level.

In a field trial, Prasad (1993) showed that almost all crops responded significantly to K application in K deficient calcareous soil.

Ghosh (1994) reported significant increase in grain and straw yields and K uptake with increasing levels of K fertilisation (upto 90 kg ha^{-1}) in 3 different soils. In general a response of 8.9 kg paddy grain kg^{-1} of K_2O added was obtained.

2.3 Varietal screening for nutrient stress tolerance

2.3.1 P deficiency

The first varietal differences in susceptibility to P deficiency were observed in 1971, (IRRI, 1971). Of the 10 varieties screened, IR 8 was severely injured by P deficiency while IR5 and H4 grew well on a P deficient soil (Luisiana clay) in green house pots. The reason given for tolerance to P deficiency was that the rice varieties vary in their capacity to extract soil phosphorus and metabolise it efficiently (IRRI, 1971).

In the following year 52 varieties were screened on the same soil in outdoor concrete tanks. Their tolerance to phosphorus deficiency was assessed by comparing their grain yields with and without phosphate fertilizers (IRRI, 1972). It was found that their existed differential response in P application among the varieties tested.

A pot culture experiment at IRRI for screening P deficiency tolerance in 314 rice varieties revealed that 74 varieties were tolerant to P deficiency whereas 5 varieties were extremely susceptible (IRRI, 1975).

Ponnamperuma (1977) opined that screening rice varieties for tolerance to P deficiency might partially answer the problem of P deficiency.

IRRI report (1977) discussed a green house screening method for screening varieties for P deficiency tolerance in which mass field screening of more than 250 elite lines was done. Tolerance was scored according to the relative tiller count 4 weeks after transplanting.

Mahendran (1980) after analysing the phosphorus deficiency tolerance in rice cultivars reported four short duration rice varieties which are efficient P utilisers at lower doses of P.

George (1981) observed drastic differences in P utilisation by rice varieties of Kerala in a pot culture study conducted at Vellayani.

According to an IRRI report (1987) poor plant growth at early stages was observed in a screening experiment for tolerance to P deficiency in acid sulphate soils. The tolerant varieties were found to have bigger seedlings with higher dry weight and plant height and more vigorous plant growth in normal soils. These varieties possessed better absorption ability but not higher P content in the shoot.

Varietal screening experiment done in 1987 at the IRRI for screening 32 varieties for P deficiency tolerance revelaed that six varieties were P efficient and highly responsive to P application (IRRI, 1988).

2.3.2 Zinc deficiency

Zinc deficiency is the third most important nutritional factor after N and P limiting the growth of wet land rice. The disorder occurs on histosols, sodic, calcareous and sandy soils and on soils wet for prolonged periods (IRRI 1971, 1972).

Reports on screening rice varieties for zinc deficiency are few (IRRI 1972, 1973, 1974, 1975); they describe green house trials in soil cultures and replicated trials in the field. A number of varieties were found to be tolerant to zinc deficiency.

As a result of a screening trial for Zn deficiency tolerance involving 40 rice varieties in a farmer's field IR 20, IR 22, IR 38 and IR 2588-7-3-1 were found to be tolerant to zinc deficiency. It was concluded that use of a resistant variety is an inexpensive remedy for overcoming zinc deficiency (IRRI 1986).

Singh (1986) screened 19 semi dwarf indica rice varieties and reported that there existed deficiency tolerance in some varieties to zinc.

Mass screening trials conducted at IRRI in 1986 revealed that, of the 875 varieties screened, 289 were tolerant to zinc deficiency which included IR 20, IR 43, IR 48 and AC-1882 in addition to tissue culture derived rices (IRRI 1987).

Singh and Sakal (1987) screened rice varieties for zinc deficiency tolerance. Screening was based on the percentage of hills affected in a plot due to zinc deficiency. Zinc content of the third leaf from the top was determined with an AAS. Tolerant varieties were found to have higher zinc content than susceptible varieties.

Sakal *et al.* (1988) conducted a pot experiment to test the tolerance of rice varieties to zinc deficiency. Some varieties tested showed moderate tolerance and the variety UPR 238 was found to be tolerant to zinc deficiency and produced the maximum dry matter yield in the absence of zinc.

Performance of 40 promising rice cultures was evaluated for zinc deficiency tolerance at the IRRI in 1987. The results revealed that efficient cultures belonged to the intermediate plant type which mature in 130 days. Inefficient cultures were short and matured in 118 days (IRRI, 1988).

2.3.3 Iron toxicity

Iron toxicity, a nutritional disorder of wet land rice is associated with excess water soluble iron (Ponnamperuma *et al.* 1955). The disorder is characterised by purple reddish brown orange or yellow leaves which later dry and give the plant a scorched appearance (Ponnamperuma 1977).

Ponnamperuma and Castro (1972) in a pot culture experiment with 54 varieties under conditions of Fe toxicity reported that all plants exhibited signs of iron toxicity. But the degree and expression of the symptoms varied among varieties. IR 22, IR 506-1-89, H 105 and RD 17-1-3 were found to be least susceptible to Fe toxicity whereas RD 3, IR 20, IR 24 were found to be susceptible. IR 8, E 425 and IR 5 were very susceptible.

At IRRI in 1976, 288 rice cultures from several sources were screened for Fe toxicity tolerance in a green house and it was reported that 27 rice cultures were tolerant to Fe toxicity (IRRI, 1977).

A field mass screening at IRRI in 1985 for tolerance to Fe toxicity involving 89 rice cultures resulted in the finding that 7 of the rice cultures were tolerant (IRRI, 1986).

In acid sulphate soils Fe toxicity problem is common. Varietal difference in tolerance to Fe toxicity was observed during a screening test. The tolerant varieties had a higher ratio of shoot dry weight to plant height, dry weight ratio of root to shoot and vigorous roots (IRRI, 1987).

Mohanty (1987) after screening 14 cultures developed at CRRI, Cuttack for tolerance to Fe toxicity reported that varietal differences existed in tolerance to Fe toxic conditions.

Abraham and Pandey (1989) observed that varietal differences were significant for all the 4 varieties and 13 breeding lines tested for adaptability to Fe toxic soils.

2.3.4 Other nutrient stresses

Forteen rice varieties were screened at IRRI in 1970 for their reaction to Fe deficiency and to Mn and Al toxicities in 3 aerobic soils in the green house (IRRI, 1971) Preliminary work indicated that 4 dry land varieties in the group showed tolerance to Fe deficiency in all the 3 soils and for Mn and Al toxicities in acid soil, while wet land varieties showed varying degree of susceptibility in all the 3 soils.

Mamaril (1983) in a varietal screening experiment for studying the tolerance of 43 rice varieties to low sulphur reported that varieties differ in their reaction to low sulphur in terms of plant height, tiller number, days to maturity and grains per hill.

Fageria and Barbosa Fillio (1983) identified cultivars that produced well under high and less aluminium levels.

In a varietal trial at IRRI in 1986, it was amply proved that there exists varietal difference in the tolerance to Boron toxicity problem (IRRI, 1987).

2.4 Physiological and Biochemical reasoning for tolerance to mineral stresses

Various mechanisms have been proposed to explain the differential tolerance of plant species to mineral stresses.

Since the discovery by Weiss (1943) that differences in soybean varieties to Fe deficiencies are genetically controlled, considerable attention is being paid to work out the causes of varietal differences to deficiency of nutrient elements.

The differences in tolerance among varieties to the deficiency of an element may be owing to their differences in uptake, translocation or utilisation as proposed by Epstein (1972).

Clark and Brown (1974) reported that phosphatase activity of corn inbreds increased under P stress. The increase in phosphotase activity was greater in the inbreds that were more efficient under P stress.

Clark (1976) defined a mineral efficient plant as a plant that grows better, produces more dry matter and develops fewer deficiency symptoms than another plant when grown at low levels of mineral elements.

Gerloff (1976) while reviewing the scientific literature available on the physiological mechanisms and plant structural features responsible for differential response in the efficiency of nutrient utilisation by plants, commented that relatively little work has been done on this line. He opined that several aspects of root structure and functions could be responsible for variations in N, P and K uptake from the low concentrations present in average soil solutions. Morphological features such as the number of roots, the degree of subdivision of the root system and the rate of growth and extension of the root system might regulate ion uptake by determining the amount of active surface exposed to the soil solution during root growth. Lindgreen (1976) while evaluating the differential response of snap beans to P absorption substantiated this theory.

According to Gerloff (1976) favourable root:shoot ratio ie., higher proportion of the total plant developed as roots also was found to be a major cause for the differential response. He further opined that differences in the reexport of mobile elements from deficient or senescing plant parts could be another basis for variations in the N, P and K efficiencies. Weak re-export would result in the retention of elements in old relatively inactive leaves rather than utilisation in active young terminal parts.

He suggested that intraspecies variations in K efficiency might be due to the recognised capacity of Na to substitute partially in the metabolic function of K. The differences in the nutrient utilisation by plants were also attributed to the differences in the efficiency of element utilisation in metabolic processes.

Aggarwala *et al.* (1991) ascribed the differential response of Barley to Mn deficiency to the better utilisation of Manganese as judged by the late appearance of the visible symptoms, production of higher biomass and seed yield, higher malic dehydrogenase activity and Hill activity in tolerant varieties than susceptible varieties.

2.5 Vegetative characters of rice as influenced by K levels

The ubiquitous occurrence of K in plants, its high mobility between organs and cells and its many physiological functions make it extremely difficult to describe the participation and the specific effects of this essential nutrient in morphogenesis comprehensively and casually (Beringer and Northdurft 1985). Even then a review of the various investigations done by the scientists gives an insight into the various morphological characters as influenced by K levels.

2.5.1 Shoot characters

Fageria (1976) after a field experiment came to a conclusion that potassium application did not show any influence on shoot yield at tillering stage of rice. Similar observations were made by Vijayalakshmi and Mathan (1991).

Effect of K on leaf area index (LAI) was studied by Smid and Peaslea (1976). According to them the enhanced uptake of nutrients due to potassic fertilizer use seemed to have promoted greater leaf area as well as increased chlorophyll content leading to higher roll of photosynthesis which finally resulted in more yield.

Senthilvel and Palaniappan (1985) observed an increased dry matter production of rice at flowering and maturity stage due to potassium top dressing.

Chakraborthy (1987) found as a result of a pot culture experiment with 7 successive rice crops that in the absence of K manuring, K contents in rice plants growing in different soils declined from the range of 0.7 to 1.3 per cent to 0.4 to 0.5 per cent at the third or fourth harvest when fairly steady state of dry matter production was reached.

Field trials with 4 rice varieties and 4 nutrient levels revealed that increase in nutrient levels of K significantly increased plant height and tiller number per plant in rainfed *kharif* crop (Deshmukh *et al.* (1988).

Sakeena and Salam (1988) reported that increasing rates of potassium fertilisation upto 35 kg K_2O ha^{-1} considerably improved the leaf area index of rice plants.

Qadar (1989) observed that application of potassium at 30 kg K_2O ha^{-1} significantly improved shoot dry weight of rice grown under pot culture conditions.

Sakeena and Salam (1989) observed considerable improvement in plant height and dry matter production in rice plants with potassium application upto 35 kg K_2O ha^{-1}. Similar observations were made by Singh *et al.* (1994).

According to Vijayalakshmi and Mathan (1991) when K level in a field experiment was increased from 50 kg K_2O ha^{-1} to 75 kg K_2O ha^{-1} there was significant depression of plant height.

Bansal *et al.* (1993) suggested that while N was required for early growth, K was required for later stages of growth as evidenced by the effect of K on dry matter production in a pot culture experiment. According to them dry matter production in rice crop responded moderately to K application.

2.5.2 Root characters

Literature regarding effect of K on root growth and root CEC in rice is rather meagre (Singha and Das, 1991).

In a nutrient culture experiment Noguchi and Sugawara (1966) studied the effects of different elements on the characteristics of various rice organs. They concluded that deficiency of K decreased root elongation and root thickness as did deficiencies of Ca and Mg. Potassium deficiency did not appear to affect the root/shoot ratio of rice although it did reduce rootlet number.

Vijayan and Sreedharan (1972) reported the beneficial effects of potassium in enhancing root development and thereby growth of rice plants.

In field culture experiment conducted by Singh and Singh (1981), it was concluded that root CEC was correlated significantly with the K content of grain and straw.

Singha and Das (1991) reported that total root length showed highest correlation with total K uptake and K content of grain and straw. Root weight was correlated significantly with straw K content and total K uptake and root volume with straw K content. Total length, weight and volume of roots increased significantly with increasing rate of K application. Root CEC was not affected by K application but there was an indication of positive effect. The variety IR 50 showed better root growth and higher root CEC.

Varietal differences in root parameters and rates of K application influenced K content, K uptake and yield in rice crop (Singha and Das 1991).

According to Vijayalakshmi and Mathan (1991) potassium application significantly increased the root yield of paddy at panicle initiation stage only. The highest root yield of 2.26 t ha^{-1} was obtained at 75 kg K_2O ha^{-1} which was 7.9% higher than control.

2.6 Yield attributes and yield of rice in relation to K nutrition

Kiuchi *et al.* (1962) reported that potassium significantly increased thousand grain weight and percentage of mature rice grains thereby increasing the yield. Similar results were obtained by Qadar (1989) who after a pot culture experiment found that application of potassium at 30 kg ha^{-1} significantly improved the thousand grain weight over the lower doses of K.

Kalicharan Das *et al.* (1970) found that high potassium application resulted in good favourable panicle size and increased fertility in rice grains.

Vig and Das (1977) found that potassium application increased the number of panicles m^{-2}. Similar observations were made by Pandey *et al.* (1993).

Roy *et al.* (1978) opined that application of potassium probably caused higher mobilisation of nutrients in soil and plant, enhanced enzymatic activities and translocation of photosynthates in plant system and ultimately increased the grain yield.

According to Aggarwal (1978) in a field trial conducted, the number of grains per panicle was highest at the highest level of K tried (30 kg K_2O ha^{-1}).

Beneficial effect of potassium on yield components, in particular on the number of panicles, number of filled grains and on filling percentage was observed by Sakeena and Salam (1988).

Tarafdar (1990) also observed in a field experiment to study the response of rice to potassium fertilisation that grain yield in rice generally increased with the increment of each level of potassium fertilization.

A research report of KAU (1991) discussed the response of rice to potassium during different seasons. It was observed that during *kharif* 89-90 the potassium application significantly increased the grain yield whereas in the subsequent rabi season no significant effect was seen.

Vijayalakshmi and Mathan (1991) observed that there was an increase in thousand grain weight due to the application of potassium at higher levels which in turn significantly increased the grain yield. But the length of panicle was not altered significantly by the addition of potassium at different levels.

Vijayaraghavan *et al.* (1992) after a pot culture experiment came to the conclusion that when K levels were increased from 0 to 80 kg K_2O ha^{-1}, number of grains per panicle increased from 94 to 119 in the variety *Kannaki*. Similar significant influence of K fertilisation on the number of grains per panicle and test weight of grain were also reported for a transplanted rice variety (Pankaj) by Ghosh *et al.* (1982).

Pandey *et al.* (1993) reported that application of 40 kg K_2O ha^{-1} in two equal splits as basal and at panicle initiation stage of rice significantly increased the yield attributes and grain yield.

From a pot culture experiment Yuan and Huang (1993) concluded that potassium application markedly reduced the number of unfilled grains due to its promoting effect on cytokinin synthesis which resulted in less zygote degeneration. They also opined that potassium enhanced grain weight because Abscissic Acid (ABA) peak was delayed by 4-5 days thereby delaying maturation and increasing carbohydrate translocation to the seeds.

Gosh *et al.* (1994) reported that number of filled grains per panicle and thousand grain weight increased significantly with the increase in the level of K fertilization. They came to the conclusion that K fertilization helped to meet the physiological demand of grains and enhanced the synthesis of carbohydrate relative to the demand of spikelets of the panicle.

After a pot culture experiment using the rice cv. Himalaya - 741, Sharma (1994) concluded that yield and yield components increased significantly by applying 9.25 ppm K.

2.7.2 Physiological Disorders

Sahu (1968) suggested the application of K among several other measures for reducing the bronzing disease of rice caused by Iron toxicity in water logged soils.

Low K content or K deficiency is often associated with Fe^{2+} toxicity which is common in acid latosolic and acid sulphate soils. Tanaka and

Yoshida (1970) opined that the physiologic disease of Akagare I is associated with K deficiency because of Fe toxicity. If the active Fe content is not high the soil redox potential falls quickly, the Fe^{2+} concentration in the soil solution rises sharply and Fe toxicity may develop.

Yoshida (1981) suggested that since there is a physiological interaction between Fe and K, a low K content in soil tends to aggravate Fe toxicity. He also reported that in Burma a physiological disease called Amiyi-Po was generally associated with K deficiency.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation used the varietal screening technique to evaluate the differential response of rice cultivars to potassium deficiency under field situations at the Rice Research Station, Kayamkulam. The methodologies employed in the present study are summarised here under.

3.1. Experimental site

Field screening was conducted during the *kharif* and *rabi* seasons in the paddy fields of Rice Research Station (R.R.S.) Kayamkulam which was selected to represent the sandy tracts of *Onattukara* region.

3.1.1. Location

R.R.S. Kayamkulam is situated at 9° 30'N latitude and 76° 20'E longitude at an altitude 3m above MSL.

3.1.2. Soil

The soil represents typical *Onattukara* type loamy sand with iron toxicity problem. According to Soil Taxonomy the soil is classified as isohyperthermic, *Ustic Quartzi Psamments*.

Table 3.1. Basic soil data

pH	5.00	
CEC	3.20	cmol (p+) kg^{-1}
Organic matter	1.19	%
Available N	179.00	kg ha^{-1}
Available P_2O_5	128.30	kg ha^{-1}
Available K_2O	99.80	kg ha^{-1}

3.2. Materials

3.2.1. Varieties selected

Rice varieties of tall *indica* and high yielding dwarf varieties and cultures which are popular in the sandy tracts of *Onattukara* region and the surrounding rice tracts were selected for the study. The varieties were grouped into the following groups.

1. High yielding dwarf varieties - Short duration (90-105 days)
2. High yielding dwarf varieties - Medium duration (110-120 days)
3. Tall indicas - Short duration (90-105 days)
4. Tall indicas - Long duration (130-180 days)

The list of varieties selected for the study is given in table 3.2 group wise.

Table 3.2. Classification of varieties selected for the study

Group I High yielding Dwarf varieties Short duration	Group II Tall Indicas Short duration Medium duration	Group III High yielding Dwarf varieties	Group IV Tall indicas Long duration
V1 MO7	V13 Ptb 10	V25 MO4	V37 Ptb 15
V2 MO8	V14 Ptb 22	V26 MO5	V38 Ptb 21
V3 MO9	V15 Ptb 23	V27 MO6	V39 Ptb 20
V4 Onam	V16 Ptb 28	V28 MO10	V40 Ptb 11
V5 Bhagya	V17 Ptb 29	V29 MO11	V41 Ptb 48
V6 Triveni	V18 Ptb 30	V30 Ptb46	V42 Ptb 44
V7 Ptb 45	V19 Karavalla	V31 Ptb49	V43 Ptb 8781
V8 Annapoorna	V20 Cul 7005-6-1	V32 Ptb51	V44 Ptb 1423-5
V9 Ptb 50	V21 Cul 7004-3-1	V33 Ptb52	V45 Dhanya
V10 Cul 8655-2	V22 Cul 7006-2-1	V34 Aswathi	V46 Lakshmi
V11 Ptb 36	V23 Cul 7005-6-1	V35 Jaya	V47 Sagara
V12 Ptb 43	V24 Cul 7006-2-1	V36 Jyothi	V48 Orumundakan tall

3.2.2. Treatments

Four levels of potassium at 0 (T_1), 50% (T_2), 75% (T_3) and 100% (T_4) levels of KAU recommendations as given in Table 3.3 were tried in the experiment. All the plots were uniformly treated with organic manure at the rate of 5 tons/ha. Nitrogen and phosphorus were applied as per the recommendation (KAU, 1989) as given below.

		N (kg/ha)	P_2O_5 (kg/ha)
1.	High yielding dwarf varieties Short duration	70	35
2.	Tall indicas - Short duration	40	20
3.	High yielding dwarf varieties Medium duration	90	45
4.	Tall indicas - Long duration	40	20

Table 3.3. Potassium levels

Group		kg K_2O ha^{-1}			
		T_1	T_2	T_3	T_4
G1	High yielding dwarf varieties Short duration	0	26.25	39.375	52.5
G2	Tall indicas - Short duration	0	15	22.50	30
G3	High yielding dwarf varieties Medium duration	0	33.75	50.625	67.5
G4	Tall indicas - Long duration	0	15	22.50	30

3.2.3. Design and layout

The design of the experiment was "Group Balanced Block in Split Plot Design". (Gomez and Gomez, 1992).

The layout of the experiment is presented in the figures (Fig. 1 and 2). There were four groups of the rice varieties viz., dwarf high yielding short duration, tall indicas short duration, dwarf high yielding medium duration and tall indicas long duration with 12 varieties in each group. The plots with respect to varieties were divided into 4 equal parts and four levels of K were applied. There were two replications.

G3

k3		k0		k1		k2	
V27	V30	V28	V32	V36	V26	V35	V27
V25	V33	V26	V33	V35	V30	V30	V34
V35	V29	V30	V25	V31	V27	V29	V32
V36	V28	V31	V35	V32	V28	V25	V33
V32	V26	V34	V27	V29	V34	V28	V31
V31	V34	V36	V28	V26	V33	V26	V36

G4

k2		k1		k0		k3	
V37	V43	V46	V40	V43	V47	V44	V39
V42	V39	V45	V44	V45	V38	V45	V41
V45	V44	V37	V42	V42	V40	V40	V48
V46	V48	V41	V43	V48	V41	V46	V43
V38	V41	V47	V39	V39	V46	V42	V38
V47	V40	V45	V38	V37	V44	V47	V37

G1

k3		k0		k1		k2	
V10	V4	V3	V4	V3	V8	V5	V12
V2	V5	V5	V12	V7	V1	V4	V1
V8	V3	V1	V11	V10	V5	V11	V8
V9	V12	V2	V10	V12	V2	V9	V3
V1	V6	V8	V9	V4	V6	V6	V7
V11	V7	V7	V6	V11	V9	V2	V10

G2

k2		k1		k0		k3	
V17	V21	V13	V22	V18	V20	V21	V16
V15	V18	V17	V20	V15	V21	V20	V22
V14	V20	V19	V16	V19	V14	V24	V14
V13	V16	V15	V18	V13	V22	V20	V17
V22	V24	V21	V14	V24	V17	V13	V19
V23	V19	V22	V23	V23	V17	V18	V15

Fig. 1. LAYOUT OF REPLICATION - 1

G4

k2		k1		k0		k3	
V45	V44	V38	V48	V46	V48	V39	V46
V42	V43	V43	V41	V37	V41	V43	V42
V39	V48	V39	V46	V40	V38	V45	V37
V40	V41	V37	V42	V44	V47	V48	V47
V38	V37	V47	V45	V42	V45	V38	V40
V47	V46	V40	V44	V43	V39	V44	V41

G1

k1		k3		k2		k0	
V7	V10	V6	V11	V5	V2	V11	V4
V2	V5	V1	V5	V7	V3	V5	V2
V6	V3	V3	V4	V4	V1	V9	V3
V4	V9	V9	V2	V10	V8	V5	V1
V8	V1	V12	V10	V11	V9	V7	V6
V12	V11	V7	V8	V12	V6	V8	V10

G2

k3		k1		k2		k0	
V17	V18	V15	V20	V18	V17	V16	V22
V21	V15	V22	V18	V20	V23	V21	V19
V14	V22	V21	V17	V15	V21	V15	V20
V16	V20	V24	V14	V14	V22	V22	V23
V24	V23	V13	V19	V13	V19	V17	V18
V19	V13	V16	V23	V22	V16	V13	V14

G3

k0		k2		k3		k1	
V36	V32	V27	V34	V30	V34	V33	V26
V26	V33	V32	V36	V32	V36	V36	V27
V30	V27	V29	V33	V27	V33	V34	V25
V34	V31	V26	V28	V25	V31	V32	V28
V28	V25	V35	V31	V29	V26	V29	V35
V35	V36	V25	V30	V35	V28	V31	V30

Fig. 2. LAYOUT OF REPLICATION - 2

3.2.4. Field culture

3.2.4.1. Land preparation

The experimental area was ploughed twice, weeds and stubbles removed and clods broken. The whole area was divided into 384 plots as mentioned above of size 1m x 1m each. The plots were separated with bunds of 30cm thickness and blocks with bunds of 50cm thickness. Individual plots were again dug and perfectly levelled.

3.2.4.2. Fertilizer application

Urea, Mussorie phosphate and MOP were applied to each plot as per the treatments and according to the duration of each variety and also according to split doses. Farm yard manure was applied @ 5 t ha^{-1} to all the plots.

3.2.4.3. Seeds and sowing

Seeds were sown by dibbling at the adequate spacing as per the "Package of Practices Recommendations" (KAU, 1989).

3.2.4.4. After cultivation

All the after cultivation operations were done as recommended in the "Package of Practices Recommendations" (KAU, 1989).

3.2.5. Observations

The biometric observations in the crop were recorded from the middle four hills from each plot which were tagged and then mean values computed. The observations were taken during the critical stages of crop ie., during active tillering, panicle initiation, flowering and harvest stages.

3.2.5.1. Observation on growth characters

3.2.5.1.1. Height of plant

Plant height was measured from the base to the tip of the topmost leaf. At harvest the height was recorded from the base of the plant to the tip of the longest panicle. Then mean height was computed and expressed in centimetres.

3.2.5.1.2. Tiller number

Tiller number was counted at the critical stages from the sample hills and the mean values worked out and expressed per hill.

3.2.5.1.3. Leaf Area Index (LAI)

LAI was calculated at the critical stages using the leaf area meter.

3.2.5.1.4. Dry matter production (DMP)

DMP was estimated during the critical stages of the crop growth by destructive sampling method. At each observation four hills were uprooted from each plot, washed, sundried, oven dried at 70-80°C to constant weight and mean DMP per plot computed and expressed in g $hill^{-1}$. At harvest the sum total of grain and straw yields were taken as total DMP.

3.2.5.2. Observations on yield attributes and yield

3.2.5.2.1. Number of productive tillers

At the harvest stage the number of productive tillers were counted from sample hills and the mean number per hill worked out.

3.2.5.2.2. Length of panicle

The panicles from the sample hills were harvested and their lengths were measured from the neck to the tip and average expressed in centimeters.

3.2.5.2.3. Weight of panicle

All the panicles from the sample hills were separately weighed from each plot and the mean worked out and expressed in grams.

3.2.5.2.4. Thousand grain weight

One thousand grains were counted from the samples drawn from the cleaned produce from each plot and the weights recorded in grams after adjusting to 14% moisture using the formula suggested by Gomez (1972).

3.2.5.2.5. Grain yield

The grain yields per plot were recorded from the net plots and the weights adjusted to 14% moisture and expressed in g $plot^{-1}$.

3.2.5.3. Root studies

3.2.5.3.1. Root length

After harvest, the roots of each sample hill was removed carefully, washed and maximum length measured and mean length expressed in centimetres.

3.2.5.3.2. Root spread

Roots of each hill after washing were placed as such on a plain paper and maximum width of the root system measured and expressed in centimetres.

3.2.5.3.3. Thin root : Thick root ratio

The roots of each hill after washing were separated into thin roots and thick roots, weighed separately and the mean ratios found out and expressed in grams.

3.2.5.3.4. Root CEC

The CEC of the fresh roots was found out by hydrogen saturation method (Crook *et al.*, 1960).

3.2.5.4. Chemical analyses

3.2.5.4.1. Soil analyses

Soil samples were collected before the start of the experiments from each plot at two depths of 0-15 and 15-30cm and were analysed to determine available nitrogen by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus by Bray's (No. 1) colorimetric method and available potassium by ammonium acetate method (Jackson, 1973).

The soil analyses were repeated during all critical stages of crop growth and also at harvest.

3.2.5.4.2. Plant analyses

Sample plants collected from each plot at critical stages of crop growth and at harvest were sundried, oven dried to constant weight, ground, digested and nutrient contents estimated. The total nitrogen contents of the plants by the modified microkjeldahl method, phosphorus content by vanadomolybdo phosphoric yellow colour method and potassium content by Flame photometric method (Jackson, 1973) were estimated.

The grains were also analysed for protein content (Simpson *et al.*, 1965) and starch content. (Chopra and Kanwar, 1976).

3.2.5.5. Statistical analysis

The data of the field culture study were analysed by the analysis of variance for Group Balanced Block in Split Plot Design. The analysis of variance table is given as follows (Replication (r); Groups (a); Varieties (b); levels of K (c)).

Analysis of variance	
Source	**DF**
Replication	(r-1) = 1
Groups (A)	(a-1) = 3
Error (1)	(r-1) (a-1) = 3
Varieties within	
Group 1 (G1)	(b-1) = 11
Group 2 (G2)	(b-1) = 11
Group 3 (G3)	(b-1) = 11
Group 4 (G4)	(b-1) = 11
Error 2	a(b-1) (r-1) = 44
Between varieties in	
Group (1)	
Levels of K	(c-1) = 3
Variety of K	(b-1 (c-1) = 33
Group (2)	
Levels of K	(c-1) = 3
Variety of K	(b-1 (c-1) = 33

Group (3)	
Levels of K	(c-1) = 3
Variety of K	(b-1 (c-1) = 33
Group (4)	
Levels of K	(c-1) = 3
Variety of K	(b-1 (c-1) = 33
Error (3)	ab(c-1) (r-1) = 144

Important correlations were also worked out (Snedecor and Cochran, 1967).

RESULTS

RESULTS

A field experiment was conducted at the Rice Research Station, Kayamkulam to investigate the differential response of 48 rice varieties belonging to high yielding dwarf and tall indica groups to potassium in the soils of *Onattukara* region. The results obtained are presented below.

4.1 Effect of K on vegetative characters

The data are presented in tables 4.1 to 4.6.

4.1.1 Plant height

4.1.1.a Maximum tillering stage

The height of plants at maximum tillering stage in all the groups showed a similar increasing trend with increase in K levels (Table 4.1). In all the groups, except in dwarf high yielding short duration group all the varieties showed similar response to different K levels whereas in dwarf high yielding short duration group the varieties showed no interaction effect with respect to the different levels of K. Cul 8655-2 registered highest plant height at this stage (36.13 cm) whereas Annapoorna registered the lowest (29.38 cm) among dwarf short duration high yielding varietal group (Table 4.2).

Table 4.1. Effect of K on vegetative characters at critical stages of crop growth

		Plant height (cm)				Tiller No. (hill^{-1})				LAI (cm^2 hill^{-1})		
		MT	PI	F	H	MT	PI	F	H	MT	PI	F
	K0	29.885	54.771	74.146	89.271	4.698	9.000	8.938	8.396	1.555	4.821	5.258
	K1	31.573	63.290	85.480	100.188	4.906	9.719	9.536	8.958	1.501	4.794	5.240
G1	K2	31.917	63.417	87.344	102.250	4.990	9.906	9.946	9.104	1.467	4.825	5.236
	K3	32.063	66.292	88.135	103.510	4.844	9.646	9.594	9.094	1.530	4.857	5.240
	F	5.73**	13.01**	80.21**	24.04**	1.85**	7.02**	5.14**	6.77**	1.21	0.32	0.04
	K0	48.469	69.325	88.875	102.792	5.333	8.698	8.677	8.010	1.105	4.963	5.325
	K1	51.729	71.281	92.021	108.438	5.750	9.313	9.188	8.531	1.216	4.871	5.301
G2	K2	54.260	74.813	96.021	101.894	5.729	9.552	9.438	8.917	1.169	4.881	5.375
	K3	54.152	74.781	93.719	112.917	5.917	9.646	9.479	9.042	1.172	4.925	5.308
	F	42.08**	3.87**	17.09**	11.86**	7.46**	8.22**	6.28**	13.00**	1.73**	0.84	0.46
	K0	47.844	62.073	80.771	93.521	5.583	9.177	9.302	8.865	1.175	5.278	5.676
	K1	49.740	66.583	82.948	97.219	5.885	10.021	10.083	9.406	1.226	5.301	5.753
G3	K2	49.635	66.958	84.531	100.177	6.156	10.583	10.698	10.229	1.246	5.325	5.702
	K3	55.250	72.750	89.656	104.385	6.240	10.688	10.708	10.104	1.209	5.354	5.791
	F	58.57**	10.00**	27.01**	12.03**	10.74**	21.62**	20.43**	24.54**	0.75	0.52	1.00
	K0	49.219	106.740	136.504	155.156	3.865	9.135	8.656	8.094	1.339	4.436	4.997
	K1	50.073	115.510	114.792	160.177	3.854	9.155	8.708	8.240	1.419	4.382	5.098
G4	K2	51.250	119.573	149.473	167.688	3.885	8.896	8.604	8.083	1.520	4.212	5.075
	K3	52.604	119.730	150.156	171.229	3.979	9.010	8.771	8.188	1.391	4.419	5.135
	F	12.30**	18.92**	74.6**	29.94**	0.4	0.55	0.24	0.34	4.81**	4.98**	1.36
	SE	0.2905	0.957	0.5043	0.9198	0.0626	0.1031	0.1019	0.0862	0.0240	0.0319	0.0347
	CD	0.58107	1.913	1.0085	1.8377	0.1252	0.2062	0.2039	0.1783	0.0481	0.0638	0.0693

Table 4.2. Varietal effects on growth characters

Group 1

	Pl.ht MT	Pl.ht PI	Pl.ht F	Pl.ht H	Till.No. MT	Till.No. PT	Till.No. F	Till.No. H	LAI MT	LAI PI	LAI F
V1	30.84	48.03	69.69	85.50	4.16	9.938	10.156	9.406	1.430	4.303	4.993
V2	33.63	61.62	76.78	90.31	4.00	9.156	8.906	8.344	1.501	4.498	5.076
V3	32.22	56.56	78.94	92.19	4.06	9.906	9.375	8.781	1.447	4.168	4.894
V4	30.91	65.91	86.75	100.69	4.84	10.750	10.500	10.031	1.191	5.062	5.555
V5	31.13	64.84	89.44	105.44	4.81	9.875	10.031	9.313	1.700	4.754	5.075
V6	29.75	65.78	88.25	104.03	4.47	9.563	9.500	8.844	1.406	5.075	5.394
V7	29.94	56.56	79.69	94.66	5.28	9.250	9.469	8.750	1.638	4.950	5.235
V8	29.38	59.06	79.97	96.72	4.88	8.781	9.000	8.469	1.543	4.980	5.250
V9	30.22	52.94	77.19	94.69	5.16	8.438	8.313	7.969	1.672	4.959	5.215
V10	36.13	80.16	105.31	124.63	5.75	10.188	9.406	9.125	1.824	5.392	5.742
V11	31.06	68.56	87.28	102.44	5.50	9.656	9.594	9.000	1.475	5.091	5.387
V12	31.13	63.28	86.06	94.38	5.34	9.313	8.969	8.625	1.330	4.660	5.108
F	4.79**	10.99**	45.82**	15.43**	12.97**	4.71**	4.99**	4.43**	5.47**	19.26**	0.36
SE	0.609	1.769	0.939	1.805	0.116	0.2052	0.1905	0.1212	0.0527	0.0577	0.0648
CD	1.231	3.576	1.89	3.648	0.234	0.4147	0.385	0.2448	0.1066	0.1167	0.1309

Among tall indica short duration varieties Ptb 22 showed highest plant height (56.59 cm) with Ptb 30 showing the least (45.88 cm) (Table 4.3). In dwarf high yielding medium duration varietal group (Table 4.4) Mo 10 and Mo 4 registered highest and lowest plant heights (56.16 and 43.34 cm) respectively while in tall indica long duration varietal group (Table 4.5), Orumundakan tall and Ptb 21 showed highest and lowest plant heights respectively. (53.44 cm and 48.81 cm).

4.1.1.b At panicle initiation stage

All the varietal groups responded similarly to the varying K levels with respect to the plant height at this stage except the tall long duration group where variety x K interaction was significant (Table 4.1). In dwarf high yielding short duration group at this stage also Cul 8655-2 (80.16 cm) showed the maximum plant height with respect to all other varieties in the group whereas Mo 7 (48.03 cm) recorded the lowest plant height (Table 4.2). Among tall short duration varieties (Table 4.3) as in earlier stage Ptb 22 recorded maximum plant height (76.31 cm) and Ptb 30 the lowest plant height (65.63 cm). In the dwarf high yielding medium duration group also (Table 4.4) as in the earlier stage Mo 10 registered maximum plant height (73.44 cm) whereas unlike in the earlier stage Mo 5 registered the lowest plant height (58.44 cm). Similarly in tall indica long duration group (Table 4.5) Orumundakan tall and Cul 8781 registered the highest and lowest plant heights (142.06 cm and 93.53 cm) respectively.

Table 4.3. Varietal effects on growth characters

Group 2

	P1.ht MT	P1.ht PI	P1.ht F	P1.ht H	Till.No. MT	Till.No. PT	Till.No. F	Till.No. H	LAI MT	LAI PI	LAI F
V13	53.91	76.50	97.72	115.90	4.875	8.750	8.656	8.125	1.098	4.796	5.271
V14	56.59	76.31	99.78	120.90	5.656	9.063	8.844	8.469	1.249	5.172	5.453
V15	53.06	73.84	90.50	106.47	5.719	9.438	9.281	8.969	1.206	4.951	5.395
V16	52.52	70.09	89.19	107.75	5.500	8.656	8.656	8.125	1.192	4.952	5.344
V17	50.53	69.38	89.94	105.34	5.250	8.656	8.938	8.313	1.171	5.056	5.451
V18	45.88	65.63	89.97	105.75	5.813	9.406	9.563	8.813	1.179	4.870	5.259
V19	51.81	71.56	91.34	105.50	6.000	9.438	9.344	8.844	1.309	5.320	5.635
V20	52.31	73.78	93.31	109.88	6.150	9.438	9.063	8.719	1.005	4.529	5.044
V21	53.63	72.88	91.16	104.09	5.969	9.469	9.625	8.969	1.197	4.931	5.264
V22	52.72	73.47	94.34	110.94	5.906	9.875	9.594	9.188	1.159	4.891	5.331
V23	50.09	73.06	90.84	108.34	5.469	9.719	9.531	8.563	1.109	4.654	5.177
V24	52.78	74.09	93.81	107.25	5.875	9.719	9.250	8.406	1.109	4.801	5.302
F	8.95	1.48	6.17**	3.71**	4.87**	2.12	1.77	1.80	1.11	6.81**	2.67**
SE	0.609	1.769	0.939	1.805	0.116	0.2052	0.1905	0.1212	0.0527	0.0577	0.0648
CD	1.231	3.576	1.890	3.648	0.234	0.4147	0.3850	0.2448	0.1066	0.1167	0.1309

Table 4.4. Varietal effects on growth characters

Group 3

	P1.ht MT	P1.ht PI	P1.ht F	P1.ht H	Till.No. MT	Till.No. PT	Till.No. F	Till.No. H	LAI MT	LAI PI	LAI F
V25	43.34	63.72	78.59	92.31	5.344	9.250	9.406	9.000	1.022	5.427	5.811
V26	47.59	58.44	79.84	93.56	5.219	9.094	9.125	8.438	1.248	5.283	5.705
V27	52.16	68.69	78.94	94.13	6.219	10.875	10.688	9.563	1.229	5.258	5.752
V28	56.16	73.44	90.75	108.41	6.344	10.969	10.750	10.188	1.117	5.250	5.742
V29	51.66	68.16	84.03	99.88	6.344	10.469	10.406	9.938	1.173	5.375	5.757
V30	52.97	69.69	85.97	98.25	6.031	10.313	10.563	10.313	1.432	5.438	5.762
V31	45.88	67.41	86.03	97.88	5.625	9.688	9.906	9.469	1.225	5.473	5.775
V32	55.25	72.94	89.69	105.41	6.150	10.344	10.406	9.938	1.152	5.156	5.667
V33	51.153	67.66	87.41	102.69	5.969	9.938	9.938	9.656	1.173	5.240	5.699
V34	47.59	64.38	82.53	95.00	6.344	10.781	10.500	9.875	1.166	5.298	5.709
V35	51.28	66.03	85.31	100.63	6.094	10.406	10.563	9.969	1.333	5.238	5.626
V36	50.00	64.56	84.63	97.78	5.906	9.781	10.125	9.469	1.294	5.338	5.763
F	16.10**	2.71**	8.84**	3.68**	5.49**	4.05**	3.66**	4.11**	2.04*	1.40	0.31
SE	0.609	1.769	0.939	1.805	0.116	0.2052	0.1905	0.1212	0.0527	0.0577	0.0648
CD	1.231	3.576	1.89	3.648	0.234	0.4147	0.385	0.2448	0.1066	0.1167	0.1309

Table 4.5 Varietal effects on growth characters

Group 4

	P1.ht MT	P1.ht PI	P1.ht F	P1.ht H	Till.No. MT	Till.No. PT	Till.No. F	Till.No. H	LAI MT	LAI PI	LAI F
V37	50.19	124.75	144.41	164.31	3.156	7.688	7.781	7.094	1.665	4.603	5.727
V38	48.81	105.03	133.75	151.94	3.781	8.406	8.406	7.688	1.778	4.826	5.662
V39	50.75	115.88	143.91	161.97	3.125	8.563	8.344	7.719	1.585	4.627	5.471
V40	49.38	106.84	136.31	155.38	2.813	8.250	7.625	7.344	1.475	4.776	5.487
V41	51.03	106.28	134.94	153.50	3.060	8.188	7.438	7.281	1.374	4.582	5.195
V42	51.53	111.09	140.50	154.09	3.250	8.969	8.406	7.906	1.358	4.712	5.202
V43	49.78	93.53	137.14	156.44	3.160	8.781	8.250	7.906	1.369	4.270	4.469
V44	51.50	115.09	147.73	166.38	3.906	9.500	9.000	8.469	1.203	3.993	4.447
V45	50.31	112.09	140.84	147.47	5.156	9.656	9.500	9.000	1.277	3.882	4.314
V46	50.31	127.56	161.19	185.16	4.969	10.000	9.656	8.844	1.304	3.941	4.488
V47	52.41	123.38	153.88	177.03	5.250	10.406	10.156	9.438	1.354	4.072	4.720
V48	53.44	142.06	168.19	184.09	5.125	10.063	9.656	9.125	1.316	4.066	4.736
F	2.27*	25.86**	66.55**	23.90**	34.28**	8.97**	10.98**	9.49**	5.55**	19.23**	30.79**
SE	0.609	1.769	0.939	1.805	0.116	0.2052	0.1905	0.1212	0.0527	0.0577	0.0648
CD	1.231	3.576	1.89	3.648	0.234	0.4147	0.385	0.2448	0.1066	0.1167	0.1309

4.1.1.c Flowering stage

All the four groups behaved more or less similarly with respect to the response to different K levels (Table 4.1) whereas with in the groups of dwarf high yielding short duration and tall short duration, the varieties behaved differently to the varying K levels. Within the other two groups the interaction effect between varieties and K levels was significant. Within the group dwarf high yielding short duration, as in the earlier stages Cul 8655-2 recorded highest plant height (105.31 cm) and Mo 7 registered lowest plant height (69.69 cm) (Table 4.2). In the group tall indicas short duration (Table 4.3) also as in the earlier stages Ptb 22 recorded maximum plant height (99.78 cm) among the group whereas Ptb 28 registered lowest plant height (89.19 cm). Within the dwarf high yielding medium duration group (Table 4.4) Mo 10 recorded highest plant height (90.75 cm) whereas Mo 4 recorded the lowest (78.59). For the group tall indica long duration (Table 4.5) the varieties Orumundakan tall and Ptb 21 recorded the highest and lowest plant heights at this stage (168.19 cm and 133.75 cm) respectively.

4.1.1.d Harvest stage

In all the four groups (Table 4.1) the response to different K levels was in similar lines with the tall indica long duration group showing significant interaction effect between the varieties and different K levels.

In dwarf high yielding short duration group (Table 4.2), as in the earlier critical stages of crop growth, Mo 7 recorded the lowest plant height even at the harvest stage (85.50 cm) while Cul 8655-2 maintained its superiority over all other varieties in the group recording the highest plant height (124.63 cm). In the tall indica short duration group (Table 4.3) while Ptb 22 maintained its superiority in plant height (120.90 cm) over all the other varieties in this group, the lowest plant height in the group was recorded by Cul 7004-3-1 (104.09 cm). In the case of dwarf high yielding medium duration group (Table 4.4) the highest and lowest plant heights were recorded as in the earlier stages by Mo 10 (108.41 cm) and Mo 4 (92.31 cm) respectively, while in the case of tall indica long duration group (Table 4.5) Orumundakan tall maintained its superiority with respect to plant height (184.09 cm) over all the other varieties in the group as in the earlier stages whereas the lowest plant height was recorded by Dhanya (147.47 cm).

4.1.2 Tiller number per hill

4.1.2.a Maximum tillering stage

Except in the case of tall indica long duration group where there was no significant effect for different levels of K, all other groups showed significant difference in their response to K levels (Table 4.1). Within the dwarf high yielding short duration group, (Table 4.2) Cul 8655-2 recorded the maximum number of tillers (5.75) while Mo 8 recorded the least (4.00). Among the tall indica short duration group, (Table 4.3) Cul 7005-6-1 and Ptb 10 registered the highest (6.156) and the least (4.875) tiller number hill^{-1} at this stage while in the dwarf high yielding medium duration group (Table 4.4) both Mo 10 amd Mo 11 showed the highest number of tillers (6.344) whereas Mo 5 recorded the least number of tillers (5.219). In the case of tall indica long duration group (Table 4.5), Sagara and Ptb 4 recorded the highest and least number of tiller hill^{-1} (5.25 and 2.313) respectively.

4.1.2.b Panicle initiation stage

Generally similar trends were observed at this stage also compared to the earlier critical stage of maximum tillering phase (Table 4.1) with the group tall indica long duration group showing no significant effect with respect to the different K levels. In the group dwarf high yielding short duration (Table 4.2), Onam and Ptb 50 registered the maximum and minimum number of tillers hill^{-1} (10.75 and 8.438) respectively among the 12 varieties. But in the group tall indica short duration both Cul 7005-6-1 and Cul 7006-2-1 recorded the highest number of tillers hill^{-1} (9.719) with Ptb 28 and Ptb 29 (8.656) registering the least number of tillers hill^{-1} (Table 4.3). In the group dwarf high yielding medium duration (Table 4.4) Mo 10 maintained its superiority over all other varieties in the group with respect to this character (10.969) with Mo 5 recording the least number of tillers hill^{-1} (9.094). In the group tall indica long duration Orumundakan tall was superior (10.406) with reference to this character among the varieties in the group (Table 4.5).

4.1.2.c Flowering stage

Similar trends continued in the flowering stage also (Table 4.1). In the group dwarf high yielding short duration (Table 4.2) Onam (10.50) and Ptb 50 (8.313) recorded the highest and lowest number of tiller $hill^{-1}$ respectively while in the group tall indica short duration (Table 4.3) the highest and least number of tillers were recorded by Cul 7004-3-1 (9.625) and Ptb 10 (8.656) respectively. In the case of the group dwarf high yielding medium duration (Table 4.4) maintaining the earlier positions Mo 10 (10.75) and Mo 5 (9.125) recorded the highest and least number of tillers $hill^{-1}$. In tall indica long duration group (Table 4.5) Sagara (10.156) maintained its superiority over all other varieties in the group with respect to the tiller number $hill^{-1}$ and Ptb 48 (7.438) registered the least number of tillers $hill^{-1}$.

4.1.2.d Harvest stage

At this stage also the group tall indica long duration showed no significant effect with respect to response to K levels while all the other groups showed significant differences with respect to K levels (Table 4.1). Onam (10.031) and Ptb 50 (7.969) as in all other critical stages registered the maximum and minimum number of tillers $hill^{-1}$ respectively in the group of dwarf high yielding short duration varieties (Table 4.2). But in the group of tall short duration varieties (Table 4.3) unlike in the earlier stages Cul 7006-2-1 recorded the highest number of tiller $hill^{-1}$

(9.188) with both Ptb 10 and Ptb 28 registering the least number of tillers $hill^{-1}$ (8.125). Among the dwarf high yielding medium duration varieties (Table 4.4) also unlike in the earlier stages Ptb 46 registered maximum number of tillers $hill^{-1}$ (10.313) in the group with Mo 5 (8.438) recording the least number of tillers $hill^{-1}$. But in the group of tall indica long duration, the variety (Table 4.5) Sagara maintained its superiority over the other varieties with respect to this character (9.438) while Ptb 15 registered the least number of tillers $hill^{-1}$ (7.094).

4.1.3. Leaf area index (LAI)

In general LAI at maximum tillering, panicle initiation and flowering stage did not show any significant difference with respect to varying K levels (Table 4.1).

4.1.4 Dry weight at critical stages

4.1.4.a Maximum tillering stage

All the varietal groups except that of tall indica short duration varieties showed significant effects with respect to different K levels (Table 4.6). In the group of dwarf high yielding short duration varieties Ptb 36 and Ptb 25 recorded the highest (2.885 g) and least (2.278 g) dry weight $hill^{-1}$ respectively (Table 4.7) whereas in the group of tall indica short duration the highest and least dry weights were recorded by Cul 7005-6-1 (3.339 g) and Ptb 23 (2.413 g) respectively (Table 4.8).

Table 4.6. Effect of K on dry weight at critical stages of crop growth (dry weight in g $hill^{-1}$)

		Maximum tillering	Panicle initiation	Flowering	Harvest
G1	K0	2.358	7.547	11.488	14.471
	K1	2.823	8.382	12.875	16.829
	K2	2.559	8.211	12.834	16.332
	K3	2.655	8.477	13.010	16.833
	F	1.93**	4.59**	7.04**	10.41**
G2	K0	2.714	8.254	10.580	15.049
	K1	2.950	8.853	11.291	15.995
	K2	2.759	8.812	11.316	16.551
	K3	2.915	8.848	11.608	16.554
	F	0.69	2.23**	2.64**	4.25**
G3	K0	2.844	8.635	13.449	18.212
	K1	3.187	9.997	15.445	19.533
	K2	3.158	9.478	15.070	19.590
	K3	3.365	9.863	15.210	19.748
	F	2.41**	9.80**	11.35**	4.19**
G4	K0	2.844	16.117	21.265	23.978
	K1	3.318	16.620	22.923	25.051
	K2	3.407	16.960	23.497	25.710
	K3	3.161	16.829	23.272	25.428
	F	3.15**	3.58**	14.15**	4.77**
	SE	0.0967	0.1357	0.1862	0.2409
	CD	0.1933	0.2713	0.3724	0.4818

Table 4.7. Varietal effects on dry matter

Group 1 (g hill^{-1})

	MT	PI	F	H
V1	2.694	8.506	12.698	16.844
V2	2.508	8.577	12.934	15.897
V3	2.553	7.666	13.080	16.140
V4	2.821	5.524	13.264	16.653
V5	2.554	8.408	12.967	16.400
V6	2.512	7.740	12.473	17.224
V7	2.278	7.230	11.880	15.191
V8	2.678	8.317	12.760	16.916
V9	2.577	8.394	12.324	15.996
V10	2.416	7.915	11.746	15.326
V11	2.885	8.233	12.041	15.429
V12	2.709	7.848	12.453	15.379

Table 4.8. Varietal effects on dry matter

Group 2 (g hill^{-1})

	MT	PI	F	H
V13	2.806	8.383	9.809	14.676
V14	2.705	8.135	10.045	14.725
V15	2.413	7.771	8.813	12.595
V16	2.614	8.346	9.905	15.171
V17	3.198	8.994	11.094	16.618
V18	2.933	8.854	11.148	16.399
V19	3.051	8.980	11.454	17.065
V20	3.339	8.790	11.448	15.581
V21	2.793	9.089	12.194	16.445
V22	2.660	8.936	12.659	17.381
V23	2.683	8.904	12.573	17.146
V24	2.821	9.118	13.263	17.735

In the group of dwarf high yielding medium duration varieties (Table 4.9) Mo 4 (3.671 g) and Ptb 51 (2.877 g) recorded the highest and least dry weights hill^{-1} respectively whereas in the group of tall indica long duration (Table 4.10) Sagara (3.664 g) and Ptb 11 (2.876 g) recorded the highest and least dry weights.

4.1.4.b Panicle intiation stage

All the varietal groups behaved similarly with respect to K levels at this stage with reference to dry weight hill^{-1}. In the case of dwarf high yielding short duration varieties (Table 4.7) Ptb 45 continued to produce the least dry weight (7.230 g) whereas Mo 8 produced the highest dry weight hill^{-1} (8.577 g). In the group of tall indica short duration (Table 4.8) Ptb 23 (7.771 g) continued to be inferior to all other varieties in the group whereas Cul 7006-2-1 was the superior one (9.118 g). Within the high yielding dwarf varieties of medium duration (Table 4.9), while Mo 4 was the inferior variety (8.378 g) in the group Jaya recorded the highest dry weight hill^{-1} (11.734 g). Among the group of tall indica long duration varieties (Table 4.10) Ptb 20 (16.040 g) and Orumundakan tall (18.033 g) produced the least and highest dry weights hill^{-1} respectively.

4.1.4.c Flowering stage

With respect to the K levels all the varietal groups showed similar trends with significant effects for K levels (Table 4.6).

Table 4.9. Varietal effects on dry matter

Group 3

(g hill^{-1})

	MT	PI	F	H
V25	3.671	8.378	13.316	18.366
V26	2.888	9.308	14.474	18.958
V27	3.269	8.925	14.500	18.356
V28	3.170	9.065	14.574	18.732
V29	2.885	9.585	15.250	18.717
V30	2.946	9.105	14.634	20.100
V31	2.924	8.875	14.130	18.111
V32	2.877	9.625	14.777	19.086
V33	2.901	8.975	14.431	20.278
V34	3.615	9.895	15.434	19.760
V35	3.238	11.734	16.748	21.103
V36	32.19	10.755	15.124	19.659

Table 4.10. Varietal effects on dry matter

Group 4

(g hill^{-1})

	MT	PI	F	H
V37	3.075	16.838	21.026	23.733
V38	3.065	16.313	21.916	24.724
V39	3.038	16.040	22.488	23.835
V40	2.876	16.379	22.953	25.196
V41	3.096	16.485	23.034	24.141
V42	3.159	16.354	22.764	25.186
V43	3.490	16.779	22.711	25.016
V44	3.100	16.403	22.458	24.259
V45	3.091	16.459	22.529	26.648
V46	3.356	16.823	23.760	26.089
V47	3.664	16.674	23.513	24.313
V48	3.180	18.033	23.720	27.318

Among the dwarf high yielding short duration varieties (Table 4.7), Cul 8655-2 and Onam produced the least (11.746 g) and highest (13.264 g) dry weights hill^{-1} respectively whereas in the group of tall indica short duration varieties (Table 4.8) Ptb 23 (8.813 g) continued to be the most inferior variety while Cul 7006-2-1 (13.263 g) emerged superior at this stage. In the dwarf high yielding medium duration varietal group (Table 4.9), Jaya (16.748 g) and Mo 4 (13.316 g) continued to produce maximum and least dry weights hill^{-1} while in the tall indica long duration varietal group Lakshmi (23.760 g) and Ptb 15 (21.026 g) produced highest and least dry weights hill^{-1} (Table 4.10).

4.1.4.b Harvest stage

The trends shown in the earlier stages continued at this stage also among all varietal groups (Table 4.6). In the group of high yielding short duration varieties (Table 4.7), while Triveni emerged superior to all the other varieties in the group (17.224 g), Ptb 45 produced the least dry weight hill^{-1} (15.191 g). Among the varieties of tall indica short duration group (Table 4.8) Cul 7006-2-1 (17.735 g) continued to maintain its superiority over all other varieties in the group while Ptb 23 (12.595 g) continued to be inferior. In the case of dwarf high yielding medium duration varieties (Table 4.9) Jaya (21.103 g) continued to be superior to all other varieties in the group while Ptb 49 (18.111 g) produced the least dry weight hill^{-1}. Among the tall indica long duration varietie (Table 4.10), Ptb 15 (23.733 g) continued to be the most inferior variety with reference to dry matter production while Orumundakan tall produced the highest dry matter hill^{-1} (27.318 g).

4.2. Effect of K on root characters

The results are presented in tables 4.11 to 4.13.

4.2.1. Root spread

All the varietal groups showed significant effects of K on root spread while among the dwarf high yielding medium duration varieties, significant variety x K interaction effect was also prominent (Table 4.11).

Among the dwarf high yielding short duration varieties (Table 4.12), the variety Ptb 43 registered maximum root spread of 18.4 cm whereas the variety Annapoorna registered the least root spread (15.725 cm) among the group (Table 4.12). For tall indica short duration varieties Ptb 22 (19.788 cm) and Ptb 10 (17.513 cm) registered the highest and lowest root spreads respectively. Among the dwarf high yielding medium duration varieties (Table 4.13) Mo 10 (22.463 cm) and Jaya (17.650 cm) recorded the highest and lowest root spreads respectively among the tall indica long duration varieties the maximum and minimum root spreads were recorded by the varieties Cul 1423-5 (21.625 cm) and Orumundakan tall (20 cm) respectively (Table 4.13).

Table 4.11. Effect of K on root characters

		Root spread (cm)	Root length (cm)	Thin root : Thick root	Root CEC (meq/100g)
G1	K0	15.667	18.358	2.535	9.433
	K1	16.654	21.433	2.614	11.225
	K2	18.466	22.621	2.733	12.292
	K3	18.338	22.554	2.607	12.483
	F	50.995**	68.08**	0.71	19.03**
G2	K0	16.308	19.262	2.175	10.617
	K1	18.658	21.938	2.486	11.325
	K2	18.950	23.054	2.375	12.108
	K3	19.425	23.675	2.585	12.658
	F	53.85**	64.89**	3.25**	7.79**
G3	K0	18.033	19.275	1.930	10.133
	K1	19.971	22.275	2.147	11.375
	K2	20.792	24.221	2.420	11.933
	K3	20.662	24.725	2.529	12.458
	F	45.31**	104.05**	8.72**	9.70**
G4	K0	19.917	21.596	2.276	10.875
	K1	20.658	22.854	2.160	11.708
	K2	21.383	23.629	2.163	11.929
	K3	21.425	24.417	2.205	12.625
	F	14.20**	24.64**	0.31	5.07**
	SE	0.1311	0.0288	0.0676	0.2220
	CD	0.2621	0.0575	0.1351	0.44403

Table 4.12. Varietal effects on Root characters

Groups 1 & 2

	Root spread cm	Root length cm	Thin root : Thick root	Root CEC
V1	16.862	18.700	3.243	10.775
V2	18.263	20.538	1.797	10.112
V3	17.888	18.275	2.833	10.987
V4	16.600	22.388	3.159	9.425
V5	17.575	24.238	2.816	11.575
V6	17.112	21.013	2.188	11.625
V7	17.850	25.463	2.637	12.525
V8	15.725	20.325	2.310	12.550
V9	17.737	21.688	3.025	10.325
V10	17.025	21.688	2.133	11.625
V11	16.275	19.225	2.909	13.275
V12	18.400	21.162	2.420	11.500
F	27.00**	2.93**	1.45	11.75**
V13	17.513	20.800	2.410	11.275
V14	19.788	20.063	2.103	12.250
V15	17.763	25.825	1.973	9.475
V16	18.050	20.150	2.293	13.750
V17	17.788	22.300	2.114	9.650
V18	18.325	23.162	2.070	12.100
V19	18.150	22.037	2.646	13.975
V20	19.700	22.650	2.179	9.250
V21	18.075	21.188	2.124	13.650
V22	18.375	22.488	2.100	12.375
V23	18.725	21.913	2.205	10.725
V24	17.75	21.213	2.166	11.650
F	3.66**	5.98**	6.840**	9.19**
SE	0.1952	0.3961	0.3195	0.3061
CD	0.3944	0.8005	0.6458	0.6187

Table 4.13. Varietal effects on root characters

Groups 3 & 4

	Root spread cm	Root length cm	Thin root : Thick root	Root CEC
V25	21.037	22.775	2.166	8.950
V26	18.088	22.438	2.138	12.075
V27	19.912	23.275	2.235	9.575
V28	22.463	23.875	2.150	10.525
V29	18.938	22.775	2.353	10.375
V30	18.538	22.475	2.161	11.975
V31	20.975	22.125	2.284	14.400
V32	21.113	20.487	2.334	12.625
V33	19.063	22.938	2.011	11.100
V34	17.650	21.388	2.199	11.750
V35	20.325	23.188	2.260	11.700
V36	20.428	20.900	2.121	10.250
F	8.79**	14.33**	2.05**	6.55**
V37	20.428	20.900	2.100	10.250
V38	21.088	22.063	2.034	13.050
V39	20.650	22.713	2.205	11.950
V40	20.287	22.138	2.191	10.575
V41	20.900	24.550	2.240	12.263
V42	20.650	24.338	2.327	9.800
V43	21.113	22.750	1.973	10.975
V44	21.625	23.063	2.247	11.800
V45	21.463	21.363	2.041	10.675
V46	21.538	24.888	2.247	13.350
V47	20.400	23.863	2.300	13.475
V48	20.000	24.863	2.216	13.250
F	7.07**	7.72**	0.32	14.74**
SE	0.1952	0.3961	0.3195	0.3061
CD	0.3944	0.8005	0.6458	0.6187

4.2.2 Root length

All the four varietal groups showed significant differential response to K levels (Table 4.11). Also all the varieties behaved similarly to the different levels of K producing longer roots with increasing doses of K.

Among the high yielding dwarf short duration varieties (Table 4.12), the varieties Ptb 45 (25.463 cm) and Mo 9 (17.888 cm) registered maximum and minimum root length respectively whereas in the tall indica short duration varietal group the maximum and minimum root lengths were recorded by Ptb 23 (25.825 cm) and Ptb 22 (20.063 cm) respectively. Among the dwarf high yielding medium duration varieties (Table 4.13) the longest and shortest root lengths were recorded by the varieties Mo 10 (23.875 cm) and Ptb 51 (20.487 cm) respectively (Table 4.13). The varieties Lakshmi (22.488 cm) and Ptb 15 (17.513 cm) registered maximum and minimum root lengths respectively among the tall indica long duration varietal group (Table 4.13).

4.2.3 Thin root - thick root ratio

With respect to the different K levels there was significant response in thin root - thick root ratio in all the groups except tall indica long duration group and dwarf short duration (Table 4.11). The varieties Mo 7 (3.243) and Mo 8 (1.797) had the maximum and minimum thin root - thick root ratios respectively among the dwarf high yielding short duration varieties (Table 4.12). Among the tall indica short duration varieties (Table 4.12), Karavalla emerged superior with maximum thin root - thick root ratio (2.646) even though the ratio for the variety was on par with all the other varieties except that for Ptb 23 which registered the least value of the ratio (1.973). For the group of dwarf high yielding medium duration varieties the value of the ratio for all the varieties were on par with that of Mo 11 (2.353) and Ptb 52 (2.011) recording maximum and minimum values respectively among the varieties. Similar was the case with the tall indica long duration varieties with Ptb 44 (2.327) and Cul 8781 (1.973) recording the highest and least values respectively for the ratio (Table 4.13).

4.2.4 Root CEC

Generally all the groups behaved in a similar manner in their response to differing K levels with respect to root CEC thus exhibiting significant difference in root CEC values among the K levels (Table 4.11). Among the dwarf high yielding short duration varieties (Table 4.12) the variety Ptb 36 (13.275) recorded the highest root CEC with the variety Onam (9.425) registering the lowest root CEC. Among the tall indica short duration varieties the varieties Karavalla, Ptb 28 and Cul 7004-3-1 recorded the highest root CECs with Karavalla proving superior (13.975) but the Cul 7005-6-1 recorded the least root CEC (9.250). In the group of dwarf high yielding medium duration varieties (Table 4.13) the variety Ptb 49 (14.4) registered the highest root CEC with Mo 4 (8.95) recording the least. Within the tall indica long duration varietal group the varieties Sagara (13.475) and Ptb 44 (9.8) recorded the highest and least root CECs respectively.

4.3 Effect of K on nutrient contents in the plants

The results are tabulated in Tables 4.14 to 4.18 and Appendices 1 to 6.

4.3.1 Plant nitrogen content

During the maximum tillering phase there was no significant difference in N contents of the plants with the K levels in all the varietal groups except tall indica short duration and dwarf high yielding medium duration groups whereas during panicle initiation and flowering stages dwarf high yielding short duration varietal groups showed significant responses to differing K levels (Appendices 1-6). However at the harvest stage, none of the groups except that of tall indica long duration varieties showed significant response to different K levels.

4.3.2 Plant phosphorus content

During all the four critical stages of crop growth tall indica long duration varieties showed significant response to differing K levels whereas dwarf high yielding medium duration varietal group showed response to different K levels only during maximum tillering and harvest stages

(Appendices 1-6). Dwarf high yielding short duration group showed significant response to K levels during maximum tillering stage only. But between varieties within a group no significant response was found in any of the groups.

4.3.3. Plant potassium content

K content in plants at all critical stages for all the four groups significantly increased with increasing K levels (Table 4.14). During later stages of the crop growth ie., during flowering and harvest stages, all the varieties within all the groups showed significant interaction effects with varying K levels. Among dwarf high yielding short duration varieties, Onam had the minimum K content during all stages of crop growth (Table 4.15). During maximum tillering and panicle initiation stages Annapoorna had the maximum K content over all the other 11 varieties. But during harvest stage Ptb 45 had the maximum plant K content.

Among the tall indica short duration varieties irrespective of the stage of growth, the varieties Karavalla and Cul 7004-3-1 had the maximum and minimum plant K contents respectively (Table 4.16). As far as dwarf high yielding medium duration varieties were concerned, during all the critical stages of crop growth the variety Mo 4 was found to have the least K content (Table 4.17). Except during the flowering stage the variety Aswathi was found to have the maximum K content whereas during the flowering stage it was the variety Mo 6 which had the maximum K content.

Table 4.14. Effect of K levels on plant K content at critical stages of crop growth

(Potassium content in %)

		MT	PI	F	H
G1	K0	2.837	2.607	2.327	2.193
	K1	3.135	2.763	2.485	2.283
	K2	3.362	2.832	2.545	2.343
	K3	3.357	2.788	2.480	2.337
	F	28.34**	11.05**	14.75**	8.28**
G2	K0	2.747	2.428	2.130	1.895
	K1	2.940	2.620	2.233	2.001
	K2	3.100	2.698	2.330	2.053
	K3	2.958	2.652	2.320	2.005
	F	9.74**	16.18**	14.70**	7.45**
G3	K0	2.787	2.457	2.188	1.997
	K1	2.960	2.645	2.372	2.073
	K2	3.240	2.902	2.535	2.223
	K3	3.188	2.752	2.383	2.144
	F	17.86**	40.29**	34.23**	15.44**
G4	K0	2.770	2.332	2.062	1.840
	K1	2.938	2.517	2.140	1.897
	K2	3.072	2.653	2.230	1.955
	K3	3.030	2.563	2.187	1.962
	F	8.27**	21.12**	8.82**	5.61**
	SE	0.0323	0.0205	0.0168	0.0167
	CD	0.0645	0.0409	0.0336	0.0333

Table 4.15. Varietal effects on nutrient contents (K)

Group 1

	K% MT	K% PI	K% F	K% H
V1	3.175	2.745	2.535	2.340
V2	3.195	2.800	2.530	2.365
V3	3.065	2.735	2.515	2.450
V4	3.115	2.540	2.325	2.155
V5	3.210	2.815	2.535	2.295
V6	3.165	2.170	2.310	2.185
V7	3.215	2.720	2.560	2.340
V8	3.315	2.845	2.450	2.265
V9	3.051	2.775	2.515	2.340
V10	3.205	2.780	2.405	2.280
V11	3.180	2.700	2.335	2.200
V12	3.180	2.805	2.495	2.285
F	0.79	2.75**	3.63**	4.04**
SE	0.0561	0.0339	0.0341	0.0294
CD	0.1134	0.0685	0.0689	0.0594

Table 4.16. Varietal effects on nutrient contents (K)

Group 2

	K% MT	K% PI	K% F	K% H
V13	2.975	2.580	2.190	1.884
V14	2.940	2.585	2.240	1.930
V15	2.725	2.345	2.140	1.825
V16	2.785	2.385	1.990	1.775
V17	2.970	2.635	2.260	1.995
V18	2.935	2.635	2.335	2.080
V19	3.335	2.990	2.640	2.460
V20	2.920	2.700	2.225	1.969
V21	2.585	2.275	1.970	1.730
V22	3.065	2.785	2.370	2.095
V23	2.940	2.630	2.320	2.040
V24	3.060	2.650	2.360	2.080
F	5.56**	16.59**	13.81**	21.40**
SE	0.0561	0.0339	0.0341	0.0294
CD	0.1134	0.0685	0.0689	0.0594

Table 4.17. Varietal effects on nutrient contents (K)

Group 3

	K% MT	K% PI	K% F	K% H
V25	2.715	2.310	1.970	1.670
V26	3.055	2.840	2.595	2.355
V27	3.130	2.905	2.630	2.303
V28	2.825	2.370	2.153	1.920
V29	2.805	2.355	1.995	1.665
V30	2.805	2.415	2.115	1.810
V31	3.210	2.875	2.420	2.215
V32	3.100	2.765	2.470	2.270
V33	3.250	2.840	2.400	2.145
V34	3.265	2.950	2.595	2.370
V35	3.105	2.775	2.480	2.235
V36	3.050	2.865	2.610	2.265
F	5.78^{**}	26.01^{**}	39.91^{**}	22.62^{**}
SE	0.0561	0.0339	0.0341	0.0294
CD	0.1134	0.0685	0.0689	0.0594

The varieties Ptb 15 and Lakshmi were found to have the minimum and maximum K content respectively among the 12 tall indica long duration varieties during all the critical stages of crop growth (Table 4.18).

Table 4.18. Varietal effects on nutrient contents (K)

Group 4

	K% MT	K% PI	K% F	K% H
V37	2.715	2.155	1.795	1.560
V38	2.745	2.320	1.925	1.650
V39	2.805	2.400	1.970	1.780
V40	2.940	2.375	2.035	1.800
V41	2.825	2.395	2.135	1.835
V42	2.950	2.620	2.295	2.065
V43	3.035	2.595	2.235	1.985
V44	3.070	2.495	2.185	1.995
V45	3.010	2.545	2.265	1.990
V46	3.220	2.895	2.435	2.230
V47	2.885	2.605	2.195	1.915
V48	3.180	2.795	2.385	2.155
F	4.61**	18.36**	15.78**	22.62**
SE	0.0561	0.0339	0.0341	0.0294
CD	0.1134	0.0685	0.0689	0.0594

4.4 Effect of K on yield attributes

The results are presented in Tables 19 to 21.

4.4.1 Panicle length

Panicle length differed significantly between all the varieties within all varietal groups except tall indica short duration varietal group (Tables 4.20 and 4.21). With respect to the K levels in all the varietal groups response was there for higher K levels (Table 4.19). All the high yielding varieties irrespective of their duration showed interaction effects with the K levels.

Among the high yielding short duration varieties (Table 4.20) Bhagya recorded lowest panicle length (17.536 cm) and Mo 8 had the longest panicle (19.271 cm).

The varieties Karavalla and Ptb 30 recorded the longest (20.921 cm) and shortest (19.578 cm) panicles among the tall indica short duration varieties (Table 4.20). Among the medium duration varieties (Table 4.21) Jaya and Mo 4 recorded the longest (21.094 cm) and shortest (17.732 cm) panicles respectively whereas in the tall indica long duration group (Table 4.21) the longest and shortest panicles were produced by Lakshmi (23.513 cm) and Ptb 15 (19.246 cm) respectively.

Table 4.19. Effect of K on yield and yield attributes

		Panicle length (cm)	Panicle weight (g)	1000 grain weight (g)	Productive tillers (hill^{-1})	Yield (gplot^{-1})
	K0	15.739	2.065	25.242	6.823	563.54
	K1	18.063	2.176	27.442	7.177	637.50
G1	K2	19.603	2.212	28.592	7.740	685.21
	K3	20.094	2.206	29.375	7.833	718.17
	F	247.92**	71.99**	292.98**	23.58**	55.30**
	K0	17.208	2.101	23.983	7.083	470.63
	K1	20.048	2.168	26.333	7.625	559.17
G2	K2	21.398	2.192	28.017	8.167	619.38
	K3	21.428	2.216	28.683	8.323	665.21
	F	253.96**	37.73**	397.66**	32.75**	54.83**
	K0	16.965	2.167	27.433	8.042	467.92
	K1	19.350	2.269	28.200	8.438	520.42
G3	K2	20.528	2.296	28.650	8.563	571.88
	K3	21.335	2.317	28.871	8.823	602.92
	F	233.96**	68.81**	36.50**	10.92**	27.29**
	K0	19.850	2.120	27.600	6.844	514.58
	K1	21.640	2.176	28.767	6.990	557.08
G4	K2	22.179	2.198	29.421	6.938	557.29
	K3	22.262	2.222	29.742	7.083	578.13
	F	81.39**	29.34**	81.14**	1.03	5.53**
	SE	0.1	0.0056	0.0728	0.0682	7.8662
	CD	0.2000	0.0111	0.1456	0.136	15.7334

Table 4.20. Varietal effects on yield attributes and yield

Groups 1 & 2

		Productive tillers per hill	Panicle length (cm)	Panicle weight (g)	1000 grain weight (g)	Yield (g/plot)
G1	V1	5.97	18.455	2.154	27.675	460.63
	V2	6.31	19.271	2.085	27.325	630.00
	V3	6.34	18.229	2.206	22.250	633.13
	V4	7.81	18.244	2.213	29.125	631.25
	V5	7.93	17.536	2.106	29.225	650.00
	V6	7.53	18.565	2.260	25.650	773.75
	V7	7.31	18.103	2.139	25.325	661.25
	V8	7.75	18.853	2.169	25.750	711.88
	V9	7.34	18.205	2.168	28.425	650.00
	V10	8.34	19.102	2.139	32.150	734.38
	V11	8.34	18.186	2.210	29.275	643.38
	V12	7.72	17.746	2.133	29.775	645.65
	F	19.24**	2.13**	3.22**	68.70**	15.51**
G2	V13	7.38	19.646	2.106	24.850	551.88
	V14	7.75	20.476	2.229	26.925	664.38
	V15	8.06	19.699	2.149	26.475	581.88
	V16	7.59	20.636	2.193	30.500	636.88
	V17	7.63	20.103	2.140	29.325	487.50
	V18	8.13	19.578	2.168	26.025	730.63
	V19	7.72	20.921	2.280	26.200	746.25
	V20	7.78	19.699	2.156	27.650	545.00
	V21	7.91	19.733	2.094	25.150	421.25
	V22	8.06	19.849	2.183	25.675	519.38
	V23	7.84	19.720	2.158	26.950	634.38
	V24	7.75	20.182	2.179	25.300	423.75
	F	1.47	1.61	4.22**	29.29**	31.12**
	SE	0.127	0.2487	0.0159	0.227	13.647
	CD	0.257	0.5026	0.0321	0.4500	27.580

Table 4.21. Varietal effects on yield attributes and yield

Groups 3 & 4

		Productive tillers per hill	Panicle length (cm)	Panicle weight (g)	1000 grain weight (g)	Yield (g/plot)
G3	V25	8.16	17.732	2.180	21.875	441.25
	V26	7.50	19.526	2.221	32.512	556.25
	V27	8.60	18.246	2.179	24.275	531.25
	V28	8.60	20.159	2.141	31.725	446.88
	V29	8.70	19.641	2.136	27.850	418.13
	V30	8.84	18.752	2.119	23.250	464.38
	V31	8.41	19.678	2.349	24.875	697.50
	V32	8.63	20.270	2.281	28.525	605.63
	V33	8.53	19.663	2.452	30.775	651.25
	V34	8.75	20.354	2.414	30.825	533.13
	V35	8.38	21.094	2.365	31.400	570.00
	V36	8.31	19.440	2.309	31.575	573.75
	F	4.16**	7.08**	8.12**	144.18**	20.24**
G4	V37	5.94	19.246	2.176	24.850	533.13
	V38	6.69	21.254	2.089	27.775	608.75
	V39	6.69	20.230	2.116	27.000	548.75
	V40	6.41	20.424	2.105	24.800	490.63
	V41	6.31	20.669	2.166	30.675	567.50
	V42	6.84	20.216	2.125	28.950	621.25
	V43	7.03	20.666	2.146	30.150	675.63
	V44	7.50	23.115	2.205	30.910	562.50
	V45	7.50	22.210	2.275	28.325	605.00
	V46	7.28	23.513	2.239	31.450	510.00
	V47	7.81	22.844	2.258	30.425	528.75
	V48	7.56	23.404	2.248	31.275	569.38
	F	10.45**	17.40**	5.23**	56.52**	5.80**
	SE	0.127	0.2487	0.0159	0.2227	13.647
	CD	0.257	0.5026	0.0321	0.4500	27.580

4.4.2 Panicle weight

All the varieties irrespective of their groups behaved more or less similarly with respect to K levels (Tables 4.20 and 4.21). The varieties Triveni (2.26 g) and Mo 8 (2.085 g) in high yielding short duration group and Karavalla (2.28 g) and Cul 7004-3-1 (2.094 g) in tall indica short duration group respectively produced heaviest and lightest panicles (Table 4.20). In the group of high yielding medium duration varieties (Table 4.21) the heaviest panicle was produced by Ptb 52 and Aswathi (2.414 g) while Ptb 46 (2.119 g) was found to produce panicles with least weight. Dhanya (2.275 g) and Ptb 21 (2.089 g) respectively produced heaviest and lightest panicles among the tall indica long duration varieties (Table 4.21).

4.4.3 Thousand grain weight

All the varietal groups except dwarf high yielding medium duration group behaved similarly showing significant response to K levels while this group showed significant interaction effect between varieties and different K levels also (Table 4.19).

The varieties Cul 8655-2 (32.15 g) and Mo 9 (22.25 g) in short duration high yielding group and Ptb 28 (30.5 g) and Ptb 10 (24.85 g) among tall indica short duration varieties produced grains with maximum and minimum thousand grain weights respectively in their group (Table 4.20).

Among the high yielding medium duration varieties the varieties Mo 5 (32.512 g) and Mo 4 (21.875 g) produced grains with maximum and minimum weights whereas the varieties Lakshmi and Ptb 11 recorded the highest (31.45 g) and lowest (24.8 g) thousand grain weights respectively among tall long duration varieties (Table 4.21).

4.4.4 Productive tillers

There was no within group variation between varieties with reference to this parameter in tall short duration varietal group whereas all the other groups recorded significant response between varieties within their groups (Tables 4.20 and 4.21). With reference to the different K levels except tall long duration varieties all the other varieties showed significant response to K levels (Table 4.19). In dwarf high yielding short duration group significant interaction between varieties and K levels was also recorded.

4.5 Effect of varieties and different K levels on yield

In all the varietal groups the trend in grain yield was more or less the same except in tall long duration group where no significant difference was observed between the lowest levels of K (Table 4.19).

There was an increase by 27.4% in yield when K level was increased to K_3 from K_0 level in dwarf high yielding short duration group whereas the increase in tall short duration group was 41.3%. But in the dwarf high yielding medium duration group and in the tall long duration group the increases were only by 28.9% and 11% respectively.

Among the dwarf high yielding short duration varieties (Table 4.20) Triveni recorded the highest yield (773.75 g plot^{-1}) while Mo 7 recorded the least (460.63 g plot^{-1}). Among the tall short duration varieties Karavalla (746.25 g plot^{-1}) and Cul 7004-3-1 (421.25 g plot^{-1} which recorded the highest and lowest yields respectively. Ptb 49 (697.50 g plot^{-1} and Mo 11 (418.13 g plot^{-1} recorded respectively the highest and lowest grain yields among the medium duration varieties (Table 4.21). Grain yields were highest in Ptb 48 (621.25 g plot^{-1}) and lowest in Cul 8781 (475.63 g plot^{-1}) among the long duration varieties (Table 4.21).

4.6 Effect of K on the quality of grains

4.6.1 Starch content

Significant varietal influence was observed in all the groups except tall short duration groups (Table 4.23 and 4.24). Potassium doses had shown profound positive influence on starch content of the grains in all the groups tested (Table 4.22). Among dwarf short duration varieties, Bhagya recorded the maximum starch content in grains (62.7%) while Annapoorna recorded least starch content (55.7%) (Table 4.23).

Table 4.22. Effect of K on grain quality

		Starch (%)	Protein (%)
G1	K0	52.51	8.25
	K1	58.44	8.29
	K2	60.76	8.50
	K3	63.57	8.52
	F	50.73**	5.95**
G2	K0	62.22	8.23
	K1	65.16	8.44
	K2	69.81	8.78
	K3	70.67	8.87
	F	36.41**	26.04**
G3	K0	62.38	8.47
	K1	64.66	8.45
	K2	65.66	8.50
	K3	68.02	8.48
	F	12.57**	0.16
G4	K0	60.79	8.62
	K1	64.07	8.69
	K2	65.68	8.72
	K3	66.71	8.74
	F	15.39**	0.73
	SE	0.457	0.040
	CD	0.914	0.081

Table 4.23. Varietal effects on quality of grains

	Group 1			Group 2	
	Starch (%)	Protein (%)		Starch (%)	Protein (%)
V1	59.32	8.48	V13	67.01	8.19
V2	57.98	8.59	V14	67.20	8.25
V3	58.86	8.66	V15	66.71	8.27
V4	57.12	8.49	V16	67.47	8.45
V5	62.66	8.43	V17	66.02	8.60
V6	60.09	8.23	V18	68.65	8.82
V7	59.28	8.32	V19	67.85	8.63
V8	55.70	8.25	V20	66.48	8.60
V9	56.03	8.20	V21	67.31	8.65
V10	59.33	8.35	V22	66.83	8.77
V11	58.86	8.42	V23	65.00	8.72
V12	60.64	8.20	V24	67.04	9.01
F	27.36**	3.41**	F	0.600	8.98**
SE	0.830	0.059	SE	0.830	0.059
CD	1.677	0.119	CD	1.677	0.119

Table 4.24. Varietal effects on quality of grains

Group 3			Group 4		
	Starch (%)	Protein (%)		Starch (%)	Protein (%)
V25	62.24	8.52	V37	59.31	8.15
V26	63.73	8.24	V38	61.51	8.20
V27	63.46	8.10	V39	61.68	8.27
V28	68.95	8.29	V40	65.40	8.16
V29	65.05	8.17	V41	64.95	8.50
V30	65.21	8.17	V42	64.82	9.03
V31	66.16	8.66	V43	65.44	9.11
V32	64.20	8.74	V44	65.26	8.88
V33	67.09	8.61	V45	68.19	9.12
V34	64.01	8.72	V46	65.07	9.17
V35	64.40	8.81	V47	65.78	8.77
V36	67.68	8.68	V48	64.26	8.96
F	2.75**	9.93**	F	4.05**	24.08**
SE	0.830	0.059	SE	0.830	0.059
CD	1.677	0.119	CD	1.677	0.119

Mo 10 and Mo 11 produced grains with highest and lowest starch contents (68.9% and 62.2%) respectively among medium duration varieties (Table 4.24) while Dhanya and Ptb 15 had grains with highest and least starch contents (68.2% and 59.3%) respectively among tall long duration varieties (Table 4.24).

4.6.2. Protein content

Varietal influence was significant in all the groups. In both the short duration varietal groups potash doses had profound positive influence (Table 4.23). Among dwarf short duration varieties (Table 4.23) Mo 9 (8.661 %) had the maximum protein content with Ptb 43 (8.2 %) having minimum protein content. As far as tall short duration varieties (Table 4.23) were concerned Cul 7006-2-1 (9.01 %) had the highest protein content with Ptb 10 (8.19 %) posting least protein content. Ptb 51 (8.74 %) and Mo 6 (8.10 %) respectively registered highest and least protein content among high yielding medium duration varieties (Table 4.24). Among tall indica long duration varieties Lakshmi (9.17 %) and Ptb 15 (8.15 %) registered the highest and least protein content (Table 4.24).

DISCUSSION

DISCUSSION

A field experiment was conducted at the R.R.S. Kayamkulam to investigate differential response of rice cultivars selecting a cafeteria of 48 rice varieties belonging to high yielding dwarf and tall indica of distinct growth durations to potassium nutrition in the coastal sandy alluvium locally known as the Onattukara region. Rice cultivation in this region is typically the wet land rice culture followed in other parts of the state. The results obtained from this investigation are discussed here under taking into consideration the special rice farming situations of the locality.

5.1 Effect of K on vegetative characters

5.1.1 Plant height

As the study was proposed to investigate the differential response due to strain variation and hence to evaluate the relative efficacy of different cultivars for potassium utilisation, plant height was taken as one of the primary indices of growth. A close scrutiny of the data revealed an increasing trend in plant height with higher doses of K in almost all groups tested at the maximum tillering stage except in dwarf high yielding short duration group which showed no interaction effects with respect to the different levels of K.

At the panicle initiation stage, all the varietal groups except the tall long duration group showed similar trends and responded positively to the varying levels of K. With respect to tall long duration group all the varieties recorded highest plant height at the highest dose of K. This clearly indicates the effects of K nutrition in plant growth masking the varietal effects and hence no differential response in plant height could be observed due to K application.

At the flowering stage differential response in plant height due to K application was shown by dwarf high yielding short duration varieties and tall indica long duration varieties. In the other two groups a linear response of plant height to K levels could be observed.

During the harvest stage the positive interaction effect between the plant height and K levels observed in the case of tall indica long duration varieties might be due to the prolonged utilisation of K by the crop taking into account the longer active vegetative phase. In all the other groups response to K application in relation to plant height was inconsistent and considerable varietal variations were observed. This might be due to the inherent variation in the utilisation of K by these cultivars. However all the varieties performed well at higher dose of K owing to the very low native K status.

5.1.2 Number of tillers per hill

As the response to application of potassium was not significant for long duration varieties at any critical stage of crop growth with respect to the number of tillers per hill, these varieties showed no effect for added potassium. This clearly indicated the efficiency of long duration varieties either in utilising native potassium or the capacity to perform at low K concentration due to to its long vegetative and reproductive phases. This is further evident from the low number of tillers compared to the varieties in other groups. Thus these varieties can perform with little potassium without affecting tiller production, one of the indirect yield attributes.

In all the other groups tiller production was influenced by the levels of K thus producing more tillers with the increasing levels of K. This is in conformity with the observation made by Vijayalakshmi and Mathan (1991).

5.1.3 Leaf area index

Significant effect of K nutrition on LAI observed with respect to long duration varieties at maximum tillering and panicle initiation stages might be due to the effective utilisation of K for vegetative stages. After these two stages effect of K on leaf growth was stagnant. This might be due to the better diversion or partition of K for other metabolic activities related to osmotic regulation, water use efficiency and reproductive phases. This observation was in conformity with that of Smith and Peaslea (1976).

In the case of tall indica short duration varieties the above effect was restricted to maximum tillering only thus indicating the modification of K flux in the plant system for other metabolic activities right from the initial vegetative phase. This appears to be a general character of tall indica since the effect of potassium on leaf growth and leaf spread was restricted to early vegetative phase.

But as far as high yielding varieties were concerned LAI at no stage was significantly influenced by potassium nutrition.

5.1.4 Dry weight

Dry weight at critical stages of plant growth showed significant increase with K levels except in short duration tall indica group at maximum tillering stage, thus showing the positive effect of K nutrition on biomass production. Similar observation was earlier made by Senthivel and Palaniappan (1981) while studying the effect of potassium top dressing in rice.

This positive effect of K nutrition on biomass production is supposedly due to the nutritional effect of K subdueing the varietal effect in deciding the biomass production. Hence differential response to K application was not observed in any of the groups tested. This might be due to the inherent low K status of the soil and increased K uptake commensurate with the total biomass produced. More or less a linear relationship was observed with respect to K doses and dry weight in the present study. Similar observation was made by Qadar (1989).

Inclusion of a higher dose above the K_3 level probably would have given more information about the differential response of these varieties. As this proposition is not economical and is not envisaged in the study such a treatment has not been included in the investigation.

5.2 Effect of K on root characters

Differential response of varieties with respect to K with reference to root spread was observed only in dwarf medium duration varieties. All the groups showed significant effect of K on root spread and all the varieties with in each group registered significant difference. As the total root yield is decided by root spread and root length it is clear from the observation that in all the four groups higher levels of potassium positively and significantly influenced the total root mass. This was in consonance with the observation made by Vijayalakshmi and Mathan (1991).

Thus it is evident that root spread is more or less a dependent character on K in all groups where as in dwarf medium duration group there was significant variety and potassium interaction.

Root length proved to be more or less a varietal character as the interaction is found to be significant. Varieties within a group over all levels of K also showed significant variations. Similar observations were earlier made by Singha and Das (1991).

This morphological feature is presumed to regulate uptake of K and other nutrients by controlling the amount of active surface area exposed to the soil solution during plant growth. Similar results have been observed by Andrew, (1966) Epstein, (1972) and Clarkson, (1974). Measurement of Km and Vmax values for the roots of different species by the above workers suggested that the effectiveness of the uptake mechanism varied among species with respect to mineral nutrients.

Thin root - thick root ratio was influenced by K application only in tall short duration and dwarf medium duration varieties. As this ratio tended to be higher in the order dwarf short duration > tall short duration > dwarf medium > tall long duration, it was evident that number of thin roots were more in high yielding short duration and medium duration varieties compared to long duration varieties. As the adsorptive surface per unit mass of root is more in the case of thin roots, it is obvious that an effective absorption of potassium from the soil solution is achieved by high yielding short and medium duration varieties. These results were in conformity with the reports of Lindgran (1976) who studied the effect of root diameter and size in relation to the exposed root surface and uptake mechanisms. He also observed that the highest nutrient uptake rate per unit weight was with the smallest individual roots as compared to the lowest absorption rate with the heaviest roots. This effect is reflected more or less in a uniform pattern in the total grain yield with short duration dwarf varieties producing the maximum yield followed by dwarf medium duration, tall short duration and long duration varieties.

Data on root CEC clearly indicated verietal variations and variations due to K doses. However their combined effect was not significant. Increase in root CEC consequent to K application has been reported by Singh and Singh (1981) and Singha and Das (1991).

This increase in root CEC consequent to K application might be due to the production of pectic substances and creation of greater density of exchange sites arising from protein amino groups. In most of the plant species pectin groups along with protein amino groups accounts to a substantial amount of charge sites at the growing root tips. Varietal differences with respect to root CEC has also been reported by Singh and Das (1991). This could be attributed to genetic variations between varieties which controls the factors involved in the production of charge contributing biomolecules in the roots such as protein, pectins and various carbohydrates.

5.3 Effect of K on plant nutrient composition

5.3.1 Nitrogen content of plants

Nitrogen content of rice plants at all the critical stages of growth was influenced by potassium levels though the groups differed considerably in their response to K applications. At panicle initiation and flowering stages nitrogen contents in short and medium duration varieties were greatly influenced by K levels where as at the harvest stage only long duration varieties showed significant variations with respect to nitrogen content.

The variations in nitrogen content at varying levels of K application appeared to be a varietal character since at harvest the plant nitrogen content levelled off considerably to a lower value, consequent to the mobilisation of K from shoot to grain.

5.3.2 Phosphorus content of plants

Only in long duration varieties there were significant variation in phosphorus content of plants at various K levels during the critical stages of crop growth. This can be attributed to the accumulation of phosphorus over a long growth period owing to its photosensitive nature and long duration. As the mobility of phosphorus in plant system is much less, translocation of phosphorus to grains also is limited as compared to mobile elements.

Non significant differences among varieties within a group with respect to phosphorus clearly indicated similar trends in phosphorus absorption and utilisation and also its dependence mostly on duration of the crop.

5.3.3 Potassium content of plants

Potassium content of plants significantly increased at all levels of K addition in all the four groups at all critical stages of crop growth. Considerable varietal variations and significant interaction effects also have been observed at flowering and harvest stages. Thus both genetic variability and variations in concentration of K in soil solution were equally important in deciding the K content of plants. As the soil was inherently poor in potassium, response to added K, as expected, was very high. This effect was to a greater extent expressed by varietal influence.

5.4 Effect of K on yield attributes and yield

5.4.1 Productive tillers per hill

In the case of productive tillers per hill, one of the important yield attributes, significant effect due to varietal influence was observed in all but, tall short duration group. As most of the tall short duration group varieties were selections of local cultivars, establishment of their superiority over hybridised medium and short duration varieties was not achieved in the case of genetic purity. Hence their response to the addition of any input, as expected, will be more or less uniform for a particular agroclimatic situation. On the other hand dwarf varieties, being hybrids and cultures mostly obtained though hybridisation and selection, had the innate desirable qualities combined with respect to the utilisation of nutrient inputs. These groups have shown varietal influence in deciding the number of productive tillers.

Tall long duration varieties which have shown significant varietal influence unlike tall short duration varieties, appeared to be more versatile and less sensitive to higher levels of fertilizer K. These varieties have shown relatively poor tiller count and behaved more or less independently with respect to number of productive tillers produced per hill.

Influence of K doses was very highly significant for all short duration and medium duration varieties, thus indicating their high K requirement to produce a substantial yield increase over the long duration group. Similar observation were made earlier by Vig and Das (1977) and Panday *et al.* (1993). However differential response accrued to K doses and varietal influence could be observed in the case of dwarf short duration varieties only. Hence all the other 3 groups have shown independent responses with respect to varieties and K doses.

Dwarf short duration group with high yielding characters have responded favourably to potassium application partially due to its high K requirement for higher yield potentials and mainly through the differences in the genetic variability in K utilisation. Thus varieties Bhagya and Sabari at K_3 levels produced higher number of productive tillers (9.25) while Mo 7 at K_2 and K_3 levels (5.75) and Mo 7, Mo 8, and Mo 9 at K_3 levels (6.125) and Mo 9 at K_0 level (6) produced less number of productive tillers.

5.4.2 Length of panicle

In the case of length of panicle individual effect of K doses and variety were both significant for all the groups except tall short duration group. This clearly indicated the influence of varietal characters and fertilizer inputs in deciding their yield parameters. Differential response of varieties to K doses was noticed only in short duration varieties. This must be due to the variety - K interaction effects in expressing yield differences. The variety Mo 7 at K_3 level produced distinctly long panicles (22.15cm). The same variety at K_2 level produced the next longer panicle (21.315) among dwarf short duration varieties where as in the case of varieties Mo9, ptb45, ptb50 and Cul 8655-2 there were longer panicles produced at K_2 levels than at K_3 levels.

In the case of dwarf medium duration varieties Jyothi (23.43 cm) and Ptb49 (22.44 cm) produced longer panicles at K_3 level whereas Ptb 49 (15.98 cm), Mo 4 (15.8) and Mo 6 (14.95 cm) at K_0 levels produced shortest panicles. The varieties Mo 10, Ptb 51, Aswathi and Jyothi produced longer panicles at K_2 level than at K_3 level.

Tall indica varieties did not show any differential response indicating a strong varietal effect independent of K doses.

5.4.3 Panicle weight

All the varieties tested showed significant differences in their panicle weights in relation to the varying levels of K. In general an increasing trend with the increase in the levels of K was found in all the groups.

The application of higher levels of K might have caused higher mobilisation of nutrients in soil and plants, enhanced enzymatic activities and better translocation of photosynthates to the panicles thereby increasing their weight.

The character panicle weight appeared to be dependent on variety and fertilizer doses and no interaction effects were observed. This clearly revealed that these two effects were acting independently.

Among the dwarf short duration varieties Triveni recorded heavier panicles (2.26g $panicle^{-1}$) where as Bhagya and Mo 8 produced lighter panicles (2.106 and 2.085g $panicle^{-1}$ respectively).

Ptb 22 and Karavalla produced distinctly heavier panicles among tall short duration group (2.29 and 2.28 g $panicle^{-1}$ respectively) while Cul 7004-3-1 produced lightest panicles (2.094 g $panicle^{-1}$).

Among the dwarf medium duration varieties Ptb 52 and Ptb 46 produced heaviest and lightest panicles (2.452 and 2.116g $panicle^{-1}$) respectively while Dhanya and Ptb 21 among long duration varieties produced heaviest and lightest panicles (2.275 and 2.089g $panicle^{-1}$) respectively.

5.4.4 Thousand grain weight

In all the groups with the increase in K levels there was a general increase in the thousand grain weight. This is in conformity with the observations made earlier by many workers (Kiuchi *et al.* 1962, Qadar 1989, Vijayalekshmi and Mathan, 1991).

As a result of application of K which is a mobile element catalytically active in various enzymatic processes involved in translocation of photosynthates from source to sink, heavier grains resulted though high translocation efficiency. Further there are reports (Haeder 1980, Yuan and Huang, 1993) suggesting that delay in attainment of peak abscissic acid content due to increased K nutrition increased maturity period which resulted in more translocation of carbohydrates and proteins to seeds there by producing heavier grains.

Among the dwarf short duration varieties Mo8, Bhagya, Triveni, Ptb45 Annapoorna and Ptb50 produced heavier grains at K_2 levels than at K_3 levels thus showing deficiency tolerance with respect to their character. Cul 8755-2 at K_3 level produced grains with highest test weight (33.8g) at K_2 level whereas Mo 9 at K_0 level produced lightest grains (20.5g).

Ptb22, Ptb23, Ptb28 and Ptb29 produced heavier grains at K_2 levels than at K_3 levels among tall short duration varieties. Ptb28 produced the heaviest grains thousand grain weights of 31.6g at K_3 level and 31.5g at K_2 level whereas Cul 7006.2-1 (22.4g) and Ptb 10 (22g) at K_0 levels produced grains with least thousand grain weight.

The long duration varieties which showed deficiency tolerance to K with respect to thousand grain weight were Ptb15, Ptb20, Ptb48 Cul 8781 and Cul 1423-5.

5.4.5 Yield

Yield response to potassium application was more among the tall short duration varieties which recorded an increase of 41.34% at K_3 level over the K_0 level whereas for the tall long duration group the increase was by 28.85% and in dwarf short duration and medium duration groups, the increases were by 27.44% and 10.98% respectively.

In the tall short duration group there was significant interaction effect of variety and K levels. This showed that there was differential response to K among varieties in this group. The variety Karavalla produced the maximum yield in this group (872.5 g $plot^{-1}$ at K_3 level)

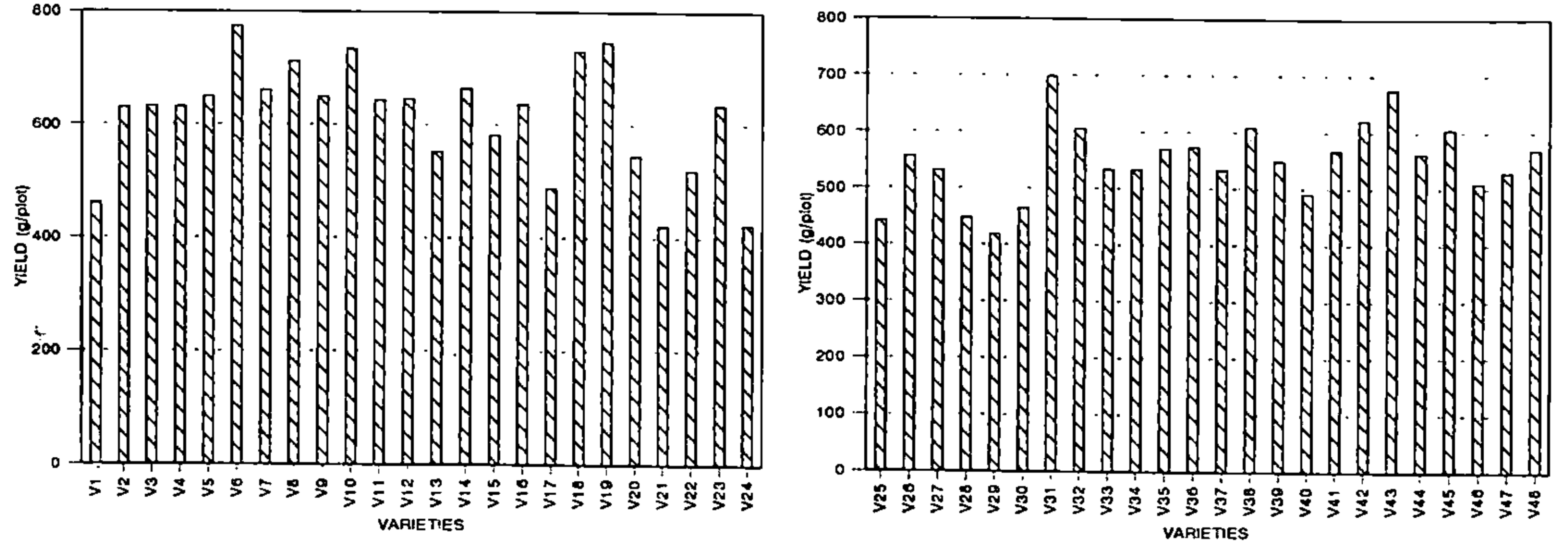

Fig. 3. Varietal effect on yield

which incidentally was the highest yield from any of the plots in the experiment. In the case of Ptb 30 which produced a high yield of 812.5 kg plot^{-1} at K_3 level there was no significant difference from its yield at K_2 level. (782.5 g plot^{-1}) Thus it can be shown that for Ptb 30 K_3 level and K_2 level produced yields which were on a par.

Similarly Ptb 23 showed more or less equal performance at K_2 and K_3 levels giving the same yield of 662.5g plot^{-1}. Also the Pattambi variety Ptb 29 did not show significant difference in yields between K_2 and K_3 levels - 547.5g plot^{-1} at K_2 and 565g plot^{-1} at K_3. Further low yielders in this group, Cul 7005-6-1, Cul 7004-3-1 and Cul 7006-2-1 also showed the same trend at potassium levels K_2 and K_3 thus showing less requirement of K for comparable yields. Thus these varieties could be grown with a lower K doses than the package of practices (POP) recommendations without affecting their yield potentials. However all the varieties performed significantly superior over control at higher levels of K. Hence the varieties Ptb 30, Ptb 23 and Ptb 29 could be grown economically at lower doses without affecting the yield that could be obtained at K doses as per the POP recommendation. In this particular case the recommendation can be reduced to 22.5kg K_2O ha^{-1} from the present POP recommendation of 30kg K_2O ha^{-1} for the above varieties in the *kharif* season.

Karavalla coming in this group has given the highest yield among the varieties tested at K_3 level and the performance at K_2 level (800 g

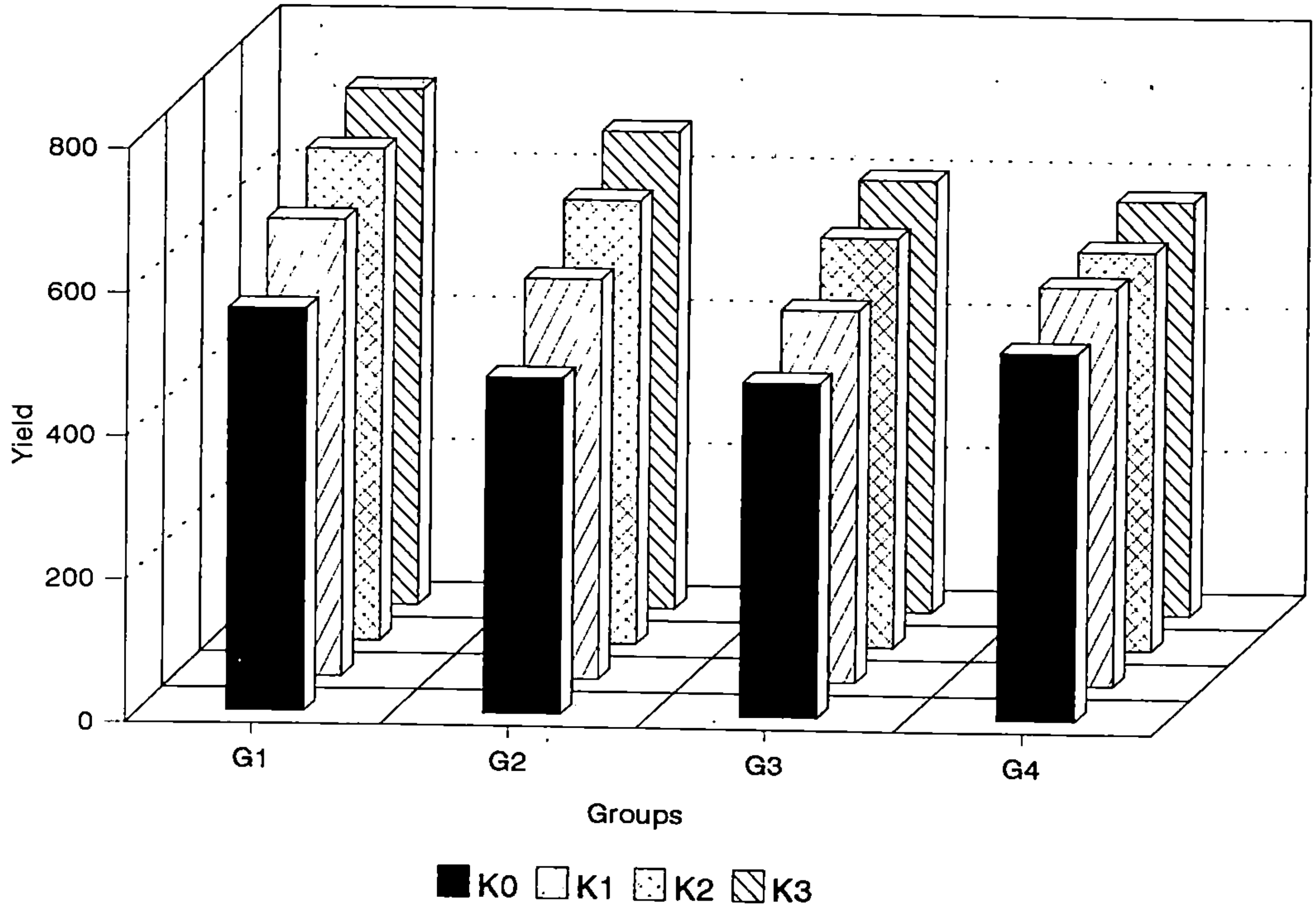

Fig. 4. Effect of K on yield

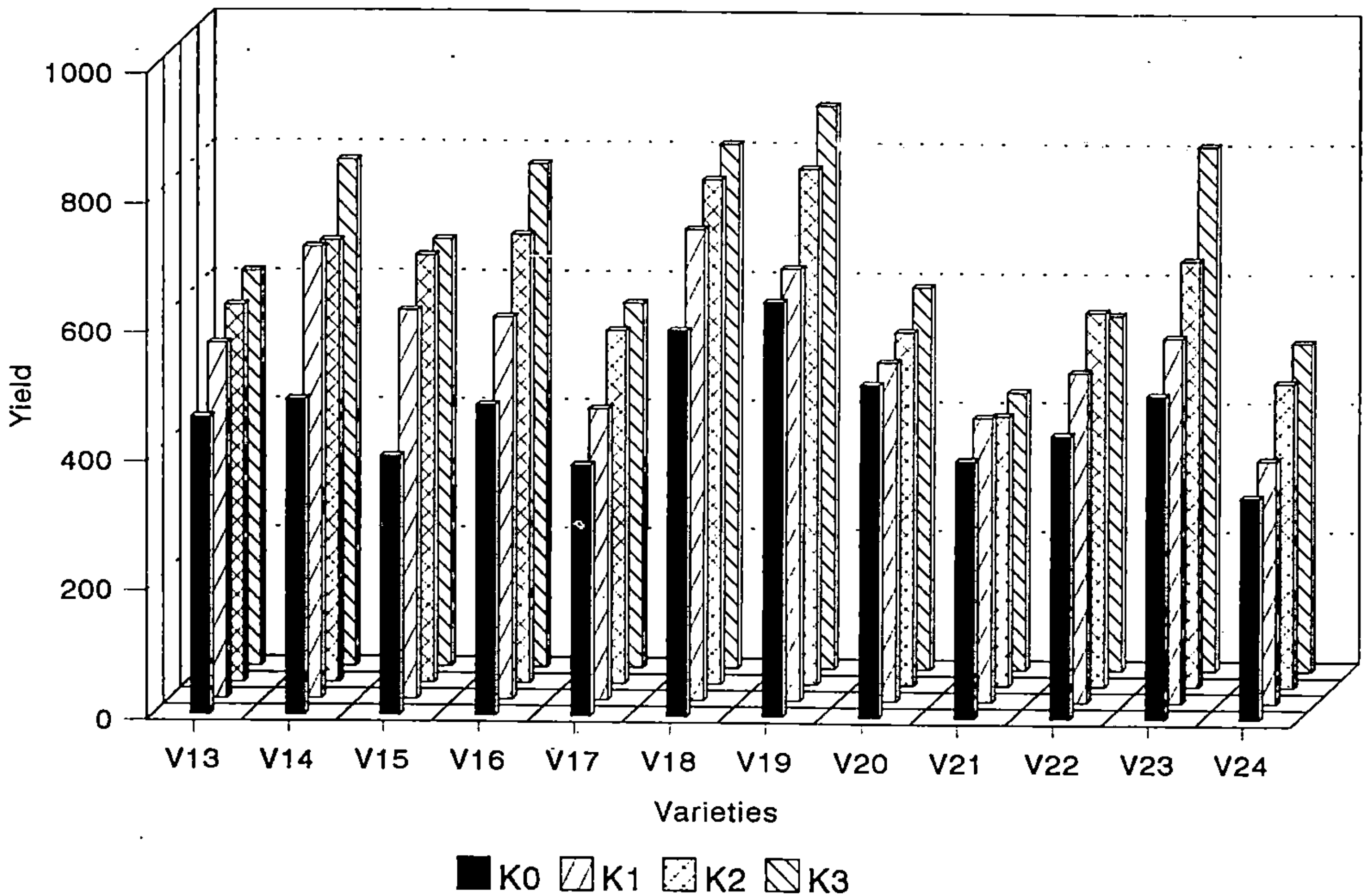

Fig. 5. Variety - Potassium interaction in the yield of Tall short duration varieties

plot^{-1}) was far above satisfactory than the other varieties with differential response.

5.5. Effect of K on the quality of grains

5.5.1. Starch content

It was observed that potassium doses had profound positive influence on the starch content of the grains in all the groups. It is well known that many starch producing plant species respond to usually high application of K^+ fertilizers and that K deficiency in many species result in deceased starch contents (Evans and Sorger, 1966). Further K has a direct role in the starch synthetase reaction stimulating its activities in many cereal crops (Akatsuka and Nelson, 1966) In many cases K uptake increased starch synthetase activity and better protection of the inactivation of this enzyme.

5.5.2 Protein content

Varietal influence was very much significant in all the groups. Hence it is evident from the data that the utilisation of nitrogen and bioconversion to proteins were influenced significantly by potassium levels and genetic variability. This observation was in conformity with the findings of Sakeena and Salam (1988).

The role of potassium as an important cofactor in the enzymes associated with protein synthesis and translocation is well documented. Further accumulation of amino acids in plant systems also have been reduced considerably by higher K uptake.

Although the above statement is applicable to all cultivars, significant response to potassium application has been shown by short duration groups only. This might be due to the inherent utilisation efficiency and high requirement for K with respect to protein synthesis. Further long duration varieties owing to their longer vegetative span could derive sufficient potassium from native sources thus compensating a high requirement.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

A study was made to investigate differential response of rice cultivars of dwarf and tall types of varying durations in the coastal sandy alluvium of *Onattukara* region to potassium. The important observations and conclusions drawn from the field experiment conducted at the R.R.S. Kayamkulam are summarised below.

Potassium increased plant height in all the varieties of all the four groups at all critical stages of crop growth.

In all the high yielding varieties tested, potassium had no effect on the LAI while in the tall indicas influence of K on LAI was prominent during the earlier stages of crop growth.

Dry matter production at all critical stages of crop growth increased significantly with the increasing K levels thus showing positive effect of K nutrition on biomass production. No differential response was observed. Effect of K nutrition was independent of varietal characters.

In all the four groups, higher levels of potassium positively and significantly influenced the total root mass production. Root spread was more or less a dependent character on K nutrition for all the varieties.

As far as root length is concerned significant varietal and K interaction was observed in all the four groups.

The number of thin roots appeared to be more in the case of high yielding varieties when compared to long duration varieties. Thin root - thick root ratio appeared to be more of a varietal character in short duration varieties.

Root CEC was found to be affected by both varietal nature and K levels independently. In general there was an increase in root CEC with increase in K levels.

The variation in nitrogen content at varying levels of K appeared to be a varietal character since at harvest the plant nitrogen content levelled off considerably to a lower value consequent to the mobilisation of N from the shoot to the grains.

Only long duration varieties showed significant variation in P content with differing K levels at all critical stages of crop growth because of the accumulation of phosphorus over a long growth period owing to its photosensitive nature and longer duration.

Both genetic variability and variation in concentration of K in soil solution were equally important in deciding the K content in the plant. Also as the soil was inherently poor in K content response to added K was very high.

Long duration varieties did not show any significant variation in productive tiller formation with respect to the different K levels and also the relative number of productive tillers were low among them. All the other varieties showed significant variations in productive tiller formation with respect to K levels.

Generally tall indicas produced longer panicles than dwarf varieties. Among tall short duration varieties the panicle length did not show any significant variation.

Panicle weight and thousand grain weight of all the varieties tested showed more or less a linear response to the increasing levels of K. Varietal differences were also significant in all the groups.

Yield increase over control was more in tall short duration varieties than in any other varietal groups for higher levels of K. Among the tall short duration varieties varietal effects and potassium level interacted significantly to produce higher yields. Karavalla produced higher yields among all the varieties tested. Ptb23 and Ptb29 produced more or less comparable yields at 22.5kg K_2O ha^{-1} level when compared to 30kg K_2O ha^{-1}. Low yielders like Cul 7005-6-1, Cul 7004-3-1 and Cul 7006-2-1 also registered higher yields at K_2 level. Thus these varieties can be grown with a lower K dose than the POP recommendations without affecting the yield potential. All the other varieties showed a more or less linear trend in yield with increasing K levels.

As this experiment was done in microplots and to locate varieties which can perform at lower K levels no conclusions could be drawn for field level adoption unless it is repeated during different seasons in cultivators' fields incorporating more varieties in each group.

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APPENDICES

Appendix - 1

Effect of K levels on plant N content at critical stages of crop growth

(Nitrogen content in %)

		MT	PI	F	H
G1	K0	2.171	1.941	1.714	1.357
	K1	2.165	1.940	1.787	1.368
	K2	2.180	1.976	1.846	1.366
	K3	2.190	2.014	1.849	1.352
	F	0.31	4.41**	13.51**	0.16
G2	K0	2.461	2.390	2.222	1.400
	K1	2.485	2.388	2.268	1.407
	K2	2.522	2.409	2.262	1.384
	K3	2.522	2.475	2.348	1.404
	F	2.12**	5.90**	9.38**	0.29
G3	K0	2.592	2.522	2.412	1.323
	K1	2.632	2.554	2.462	1.359
	K2	2.643	2.571	2.465	1.381
	K3	2.648	2.569	2.470	1.358
	F	1.45**	1.86**	2.53**	1.61
G4	K0	2.472	2.416	2.347	1.335
	K1	2.511	2.431	2.364	1.391
	K2	2.506	2.425	2.364	1.412
	K3	2.525	2.441	2.378	1.412
	F	1.15	0.41	0.56	3.75**
	SE	0.0145	0.0116	0.0120	0.0130
	CD	0.0290	0.0232	0.0239	0.0260

Appendix - 2

Effect of K levels on plant P content at critical stages of crop growth

(Phosphorus content in %)

		MT	PI	F	H
G1	K0	0.489	0.413	0.346	0.282
	K1	0.543	0.435	0.349	0.288
	K2	0.538	0.422	0.355	0.287
	K3	0.562	0.424	0.340	0.295
	F	4.58**	0.81	0.38	0.62
G2	K0	0.426	0.362	0.341	0.265
	K1	0.426	0.362	0.341	0.265
	K2	0.434	0.370	0.349	0.260
	K3	0.443	0.373	0.348	0.247
	F	0.45	0.60	0.18	0.19
G3	K0	0.526	0.430	0.370	0.297
	K1	0.562	0.421	0.350	0.269
	K2	0.578	0.422	0.362	0.278
	K3	0.581	0.415	0.364	0.270
	F	2.95**	0.36**	0.65	2.98**
G4	K0	0.397	0.412	0.396	0.280
	K1	0.432	0.434	0.411	0.294
	K2	0.428	0.416	0.370	0.272
	K3	0.450	0.395	0.353	0.267
	F	2.23**	2.44**	6.46**	2.68**
	SE	0.0101	0.0071	0.007	0.00497
	CD	0.0202	0.0142	0.0140	0.00995

Appendix - 3

Varietal effects on Nutrients contents (N and P)

Group 1

	N% (MT)	N% (PI)	N% (F)	N% (H)	P% (MT)	P% (PI)	P% F	P% H
V1	2.100	1.722	1.565	1.404	0.553	0.432	0.357	0.285
V2	2.034	1.803	1.680	1.362	0.506	0.416	0.336	0.308
V3	2.205	1.789	1.617	1.372	0.543	0.435	0.326	0.264
V4	2.191	2.051	1.957	1.299	0.555	0.441	0.345	0.267
V5	2.240	1.838	1.670	1.376	0.506	0.419	0.330	0.311
V6	2.327	2.267	2.111	1.397	0.543	0.409	0.354	0.266
V7	1.973	1.810	1.677	1.379	0.476	0.426	0.348	0.308
V8	2.247	2.117	1.478	1.372	0.530	0.409	0.354	0.273
V9	2.041	1.841	1.680	1.351	0.555	0.418	0.337	0.284
V10	2.247	1.978	1.858	1.386	0.556	0.440	0.364	0.311
V11	2.300	2.184	2.006	1.375	0.520	0.406	0.332	0.267
V12	2.216	2.216	1.792	1.260	0.553	0.428	0.385	0.314
F	6.36**	32.79**	25.96**	2.09*	1.00	0.43	1.25	2.33*
SE	0.0317	0.0237	0.0247	0.0202	0.156	0.0133	0.0107	0.0095
CD	0.0641	0.0479	0.0498	0.0409	0.0316	0.0269	0.0218	0.0193

Appendix - 4

Varietal effects on nutrient contents (N and P)

Group 2

	N% (MT)	N% (PI)	N% (F)	N% (H)	P% (MT)	P% (PI)	P% F	P% H
V13	2.569	2.492	2.30	1.390	0.413	0.356	0.341	0.275
V14	2.531	2.496	2.392	1.404	0.485	0.389	0.358	0.274
V15	2.541	2.464	2.324	1.393	0.484	0.370	0.341	0.241
V16	2.555	2.450	2.387	1.400	0.426	0.380	0.371	0.293
V17	2.391	2.363	2.191	1.382	0.398	0.355	0.336	0.261
V18	2.555	2.394	2.319	1.410	0.385	0.355	0.346	0.251
V19	2.573	2.527	2.412	1.400	0.443	0.404	0.375	0.263
V20	2.457	2.408	2.216	1.383	0.429	0.369	0.354	0.245
V21	2.492	2.303	2.118	1.339	0.429	0.383	0.316	0.250
V22	2.450	2.337	2.198	1.355	0.395	0.324	0.334	0.248
V23	2.461	2.429	2.261	1.400	0.445	0.369	0.344	0.248
V24	2.398	2.324	2.188	1.428	0.439	0.327	0.323	0.246
F	2.13*	4.78**	7.38**	0.58	1.51	1.55	1.35	1.34
SE	0.0317	0.0237	0.0247	0.0202	0.156	0.0133	0.0107	0.0095
CD	0.0641	0.0479	0.0498	0.0409	0.0316	0.0269	0.0218	0.0193

Appendix - 5

Varietal effects on nutrient contents (N and P)

Group 3

	N% (MT)	N% (PI)	N% (F)	N% (H)	P% (MT)	P% (PI)	P% F	P% H
V25	2.608	2.545	2.422	1.397	0.660	0.505	0.413	0.308
V26	2.562	2.541	2.429	1.297	0.563	0.420	0.355	0.263
V27	2.597	2.531	2.433	1.355	0.615	0.428	0.334	0.295
V28	2.552	2.510	2.422	1.355	0.539	0.421	0.365	0.279
V29	2.653	2.548	2.429	1.344	0.671	0.453	0.358	0.271
V30	2.597	2.524	2.426	1.335	0.685	0.461	0.340	0.288
V31	2.510	2.475	2.380	1.358	0.430	0.390	0.364	0.280
V32	2.629	2.566	2.468	1.341	0.521	0.392	0.354	0.276
V33	2.573	2.538	2.436	1.351	0.483	0.378	0.362	0.266
V34	2.695	2.604	2.499	1.369	0.548	0.404	0.364	0.274
V35	2.835	2.646	2.543	1.400	0.541	0.414	0.370	0.267
V36	2.737	2.625	2.541	1.365	0.486	0.395	0.360	0.266
F	4.04**	2.15*	2.09*	0.91	9.88**	4.99**	1.61	0.96
SE	0.0317	0.0237	0.0247	0.0202	0.156	0.0133	0.0107	0.0095
CD	0.0641	0.0479	0.0498	0.0409	0.0316	0.0269	0.0218	0.0193

Appendix - 6

Varietal effects on nutrient contents (N and P)

Group 4

	N% (MT)	N% (PI)	N% (F)	N% (H)	P% (MT)	P% (PI)	P% F	P% H
V37	2.335	2.275	2.209	1.337	0.416	0.355	0.357	0.240
V38	2.391	2.334	2.272	1.376	0.468	0.385	0.353	0.238
V39	2.506	2.439	2.359	1.341	0.443	0.353	0.357	0.276
V40	2.436	2.342	2.323	1.397	0.394	0.453	0.389	0.290
V41	2.408	2.317	2.254	1.376	0.416	0.426	0.415	0.281
V42	2.566	2.475	2.439	1.414	0.428	0.448	0.396	0.289
V43	2.597	2.510	2.443	1.383	0.397	0.420	0.381	0.250
V44	2.567	2.476	2.387	1.348	0.421	0.408	0.370	0.298
V45	2.580	2.524	2.429	1.418	0.414	0.435	0.374	0.301
V46	2.569	2.482	2.419	1.400	0.451	0.445	0.403	0.265
V47	2.555	2.489	2.398	1.425	0.423	0.405	0.401	0.298
V48	2.531	2.478	2.426	1.435	0.449	0.438	0.396	0.311
F	3.84**	6.59**	5.31**	1.34	0.74	3.33**	1.83	0.34
SE	0.0317	0.0237	0.0247	0.0202	0.156	0.0133	0.0107	0.0095
CD	0.0641	0.0479	0.0498	0.0409	0.0316	0.0269	0.0218	0.0193

DIFFERENTIAL RESPONSE OF RICE CULTIVARS TO POTASH APPLICATION IN THE RICE SOILS OF *ONATTUKARA*

By

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ABSTRACT OF A THESIS
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ABSTRACT

It is known that there exists varietal differences in tolerance to nutrient deficiency conditions among rice cultivars. The sandy soils of *Onattukara* region is inherently deficient in K which resulted in a higher POP recommendation for rice in terms of K application. So to exploit the varietal differences of rice in deficiency tolerance of K, a field experiment was undertaken to screen 48 rice cultivars belonging to tall indicas and dwarf high yielding groups of varying growth durations. The experiment was laid in 384 microplots in "Group Balanced Block in Split Plot Design" with four K levels and two replications. The various growth and yield attributes and yield were studied with a view to locate varieties which could produce similar yields even at lower levels of K.

The results indicated that in general the varietal influences on most of the growth characters in all the four groups were profound. Moreover positive and significant effect of K doses were observed. However LAI showed no variation with differing levels of K. Differential response of varieties to varying K doses as manifested by root spread was considerable only in medium duration varieties while

an appreciable difference was noticed in the root spread in all the groups. Root length, thin root-thick root ratio and root CEC appeared to be varietal characters which increased with increasing levels of K.

The plant nitrogen content at varying levels of K was more of a varietal character. On the contrary, long duration varieties exhibited significant variation in P content with differing K levels at all critical stages of crop growth. Both K levels and genetic variability of the varieties were equally important in deciding the K content in plants and the response to added K was of a higher magnitude.

All but long duration varieties responded positively and significantly to K in terms of productive tiller formation and generally tall indicas produced relatively longer panicles than dwarf varieties. Higher levels of K also led to the production of heavier grains. Yield increases over control was comparatively higher in tall short duration varieties than any other varieties for higher levels of K. Differential response of K was highly pronounced in tall short duration varieties with Ptb23, Ptb29, Cul 7005-6-1, Cul 7004-3-1, and Cul 7006-2-1 giving comparable yields at 22.5kg K_2O ha^{-1} as that of the POP recommendation. However as this experiment was done in microplots the final recommendation of varieties tolerant to K deficiency could be done only after extensive studies in large plots and in farmers' fields during various seasons.