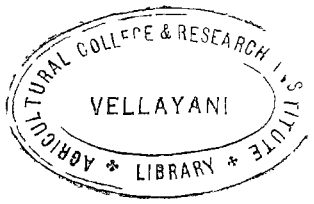
STUDIES ON THE EFFECT OF POTASSIUM ON THE GROWTH, YIELD AND NUTRIENT UPTAKE OF TWO NEWLY INTRODUCED RICE VARIETIES (*Tainan 3 and Taichung Native 1*)



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THESIS

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C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bona fide research work carried out by Shri. N.N. Ramankutty, under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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INTRODUCTION

INTRODUCTION

Rice is the staple food of more than half the world's population. With 76 million acres under this crop India contributes 32 per cent of the total area under rice in the world. Rice is grown on about 30 per cent of the cultivable area in India and it is by far the major crop in this country. Despite the vast area under this crop, it is common knowledge that the production of rice in India falls short of her requirements. The obvious reason for this deficit is that the average yield of rice in India is very low compared to most other countries of the world.

In Kerala, the food situation is worse than in any other State in India. The area under rice is approximately 2 million acres and the annual production is of the order of 10 to 11 million tons. This quantity is totally inadequate to meet even the bare minimum requirements of the population which is currently about 17 million. The deficit in food is as high as 50 per cent and Kerala has, therefore, to depend largely on other States to feed her people.

Food is thus the major problem in Kerala today and an all out effort is being made to bridge the wide gap between production and demand for rice in the State. In

this drive for maximising food production, every known method of stepping up rice yields is being tried including the introduction of new high yielding strains from other countries. Among the more promising of the varieties that have recently been introduced in Kerala, Tainan 3 and Taichung Native 1 are prominent. These strains which are from Taiwan are reputed for their heavy yields and they are currently under trial in various research stations and in cultivators' fields in different parts of the State.

It is a well known fact that high yielding varieties of rice generally make heavy demands on the soil for major plant nutrients. The data now available on the response of Tainan 3 and Taichung Native 1 to nitrogen, phosphorus and potassium application under conditions obtaining in Kerala are very meagre. This knowledge is of paramount importance in the formulation of suitable manurial schedules for these new strains that will ensure optimum yields. It was, therefore, considered worthwhile to undertake studies of a fundamental nature to determine the influence of each of the major nutrients on growth and yield characters of these two varieties of rice with a view to supplementing the data that field trials which are now underway in research stations and cultivators' fields may provide. Accordingly, a comprehensive investigation relating to the nitrogen,

phosphorus and potassium nutrition of Tainan 3 and Taichung Native 1 was carefully planned and carried out at the Agricultural College and Research Institute, Vellayani. Three post graduate students collaborated in this study and each of them had to deal with one of the major nutrients. The work assigned to the author related to potassium.

Like nitrogen and phosphorus, potassium plays a unique role in plant nutrition and is of critical importance in metabolic and photosynthetic activities in the plant. Nevertheless, relatively little attention has been paid so far in India to the potash requirements of a major crop like rice and, in fact, of most other crops as well. This is largely due to the general belief that Indian soils are well supplied with this plant nutrient and there is no potash problem in this country. The data now available on the response of rice to potash manuring in India is, consequently, very inadequate. As far as Kerala is concerned, it is an established fact that large areas growing rice are deficient in this nutrient. The positive response to the application of potash to these soils unmistakably indicates that to ensure better yields it is imperative that this nutrient be included in the manurial schedules for rice.

The present investigation was therefore undertaken with three main objectives, viz.,

(i) To determine the response of Tainan 3 and Taichung Native I to increasing doses of potassium;

(ii) To assess the effect of potassium at different levels on the uptake of major nutrients; and

(iii) To study the deficiency symptoms, if any, exhibited by these varieties due to lack of potassium.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The literature pertaining to the role of potassium in plant nutrition and crop production is voluminous. Most of it relates to crops other than paddy. An excellent review of the work done on various aspects of this problem is given by Lawton and Cook (1954).

The present investigation was confined to paddy. Consequently, the literature reviewed below is concerned mainly with this crop. However, relevant findings in respect of crops other than paddy are also cited where such references are helpful in the interpretation of the data obtained in the study reported here.

A. Influence of potassium on growth characters and yield components of crops

(a) Paddy

Vaidyanathan (1933) reviewed the results of 52 experiments conducted up to 1930 to study the response of paddy to potash and reported that application of this nutrient gave an average negative response of 4.76 lb of paddy per pound of potash. Aiyar (1948) furnished data which showed a depressing effect when phosphorus and potassium were used together.

Sethi *et al* (1952) summarised the results of

experiments undertaken until 1949 and pointed out the paucity of relevant information on potash fertilisation of paddy.

Abdul Samad and Sahadevan (1952) examined the results of field experiments carried out at the Agricultural Research Station, Pattambi, and recorded an increased grain yield of 15 per cent when wood ash (4% K_2O) was applied at 4000 lb per acre along with groundnut cake at 400 lb per acre as basal dressing.

Noguchi and Sugawara (1952) investigated the effect of potassium on the growth, health and productivity of paddy. They observed lesser number of tillers in the plots that received no potash and a decrease in both grain and straw yield with incremental doses of this nutrient.

Singh (1953) obtained better stand and yield of paddy by the application of potash together with nitrogen and phosphorus and stressed the necessity for balanced fertilisation.

Mukerjee et al (1955) reported an average response of 1.96 to 2.6 maunds per acre for potash application at the rate of 40 lb K_2O per acre in cultivators' fields in Bihar and attributed this poor response to faulty experimental technique.

Ahamed Bavappa and Hanumantha Rao (1956) working

in Mysore on paddy recorded increase in the number and height of tillers, length and number of grains per panicle, length and thickness of grains and 1000 grain weight when potash was applied with lime.

Ghose et al (1956) pointed out the heavy demand for nitrogen and potash during the stage of primordia formation in paddy. Yamasaki (1957) emphasised the need for split application of potash for paddy in Japan.

Sathyanarayana (1957) obtained linear increases in grain yield with incremental doses of potash.

Tseng and Wang (1958) scrutinised the results of several field experiments conducted on different soil groups of Taiwan and reported varying responses of paddy to potash fertilisation. In these experiments potash was applied at 4 levels, viz., 0,40,80 and 120 kg/ha. Response to potash on red and yellow earths was higher than that on other soils. On slate alluvial and schist alluvial soils the higher doses of potash were found to depress the yield.

Govind and Chadha (1959) reported that maximum profit was obtained with increased doses of nitrogen along with higher doses of potash.

Increased grain yields of the order of 8 to 15 per cent were recorded by Abichandani (1959) when paddy seeds were soaked in nutrient solutions of potassium before sowing.

Basak et al (1960) and Digar (1960) reported poor response to potash applications along with nitrogen and phosphorus.

Cuthbertson (1960) in water culture studies on the nutrition of paddy obtained an increase in 1000 grain weight when potash was applied 35 to 45 days before flowering.

Raychaudhuri and Landy (1960) observed decrease of available potassium with decreasing pH in alluvial sandy soils of Rajasthan and laterite soils of Kerala, whereas in other soils the available potassium was maximum at a definite pH value.

Dubey and Das (1961) reported that potash at high levels depressed the yield of rice.

Water culture studies carried out at the International Rice Research Institute, Manila (1964) showed that Peta (indica) required more potassium than Tainan 3 (japonica).

Chin and Li (1965) obtained significant increases in yield when potassium was applied along with nitrogen and phosphorus.

Dutta and Khera (1965) obtained higher yields in Kalyan when potash was applied in split doses than when the same dose was applied basally.

Daji (1965) emphasised the need for potash

fertilisation in conjunction with nitrogen and phosphorus to obtain satisfactory yields of paddy. Srinivasulu and Pawar (1965), however, reported that two indica x japonica hybrids failed to respond to the combined application of phosphorus and potassium.

Donahue et al (1966) observed that grain and straw yields were highest when nitrogen, phosphorus and potash were applied to paddy at the maximum tillering stage. Top dressing with phosphorus and potassium was found to be more beneficial than basal application.

Usha (1965) recorded the beneficial influence of potash in promoting growth, tillering capacity and straw yield.

Fertility x variety x spacing trials conducted with Tainan 3 and Taichung Native 1 at the Paddy Breeding Station, Coimbatore, during 1966-'67 revealed that these varieties responded the maximum at a level of 160 kg nitrogen in conjunction with 80 kg K_2O and 80 kg P_2O_5 per hectare. Basal application of fertilisers was found to be significantly superior to top dressing for both the varieties.

(b) Other crops

Wagnus (1848), as quoted by Reitemeier (1951), was probably the first to show the release of potassium from primary minerals. He did this by growing barley on an

artificial soil having ground feldspar as the only source of this nutrient and obtained mature grains.

Hollriegel (1898) and Wilfarth and Wimmor (1902) reported a close relationship between carbohydrate content and potassium level which was later endorsed by Gregory (1937) Sommer (1941) and Nightingale (1930).

Boynton and Burrel (1944) obtained an increased percentage of potash in the leaves of apple trees while Bear and Prince (1946) recommended application of potash at frequent intervals during the growth of alfalfa.

Nelson et al. (1946) found that increasing doses of potash increased the potassium content in a soybean variety. Similar results were obtained by Snider (1947) working on wheat and oats and Dunn and Rost (1948) on potato.

Middowson and Cooke (1958) reported significant responses of potatoes, peas, beans and kale to potash application. Middowson et al. (1961), however, observed that in barley, potash did not improve the strength of straw and had little effect upon the size of grain.

Sreedharan (1962), in studies on cotton at Coimbatore, showed that the application of potash at rates up to 80 lb per acre gave progressive economic yield, while the higher doses had a depressing effect. He also reported

that potash had little influence on ginning percentage, seed and lint indices, mean fibre length, mean fibre weight, maturity coefficient and bundle strength.

Jagate (1963) obtained significant increases in the quality and yield of lint in cotton by the addition of potash, the effect being more pronounced in long and medium staple varieties. The application of potash at the rate of 200 to 225 lb K_2O per acre to potato resulted in increased yield, larger size of tubers and increased mineral, carbohydrate and starch contents (Jagate 1964).

Patnaik and Farooqui (1964) working on Brinjal reported significantly earlier flowering and better fruit set, whereas Rajput and Yadava (1964) recorded a decrease in flower production in roses with incremental doses of potash.

B. Physiological role of potassium

Thomas and Hack (1941) observed that certain infections were associated with low level of potash nutrition and aggravated by high levels of nitrogen.

Nelson et al. (1945) and Brown and Potter (1949) obtained significant increases in the oil content of both soybeans and tung fruits with increased doses of potash and Mulder (1949) recorded an inverse relationship between potassium supply and free tyrosine content in potato tubers.

Govindarajan (1955) reported that the use of potash was beneficial as it improved grain setting and reduced the percentage of chaff in paddy. He also recommended the application of potassium as a NPK mixture for ragi, cotton, maize, jowar, tobacco, potatoes, chillies, onion, ginger and other vegetable and plantation crops in Mysore State.

Sircar and Datta (1957), in a study on the physiological role of potash in the nutrition of paddy, obtained higher nitrate and nitrite nitrogen in the leaves of low potassium plants. They also noted that potassium deficient plants dried up prematurely due to ammonium poisoning.

In water culture studies at the International Rice Research Institute, Manila (1964), Tainan 3 (japonica) recorded a remarkable increase in panicle weight with increase in potassium level from 0 to 20 ppm the increase above 20 ppm being gradual. The increase in the panicle weight of Peta (indica) was continuous up to 100 ppm of potassium solution and then slackened. While Tainan 3 appeared to control its nutrient content under low and high levels of nitrogen and potassium, Peta absorbed very large amounts of these nutrients under high levels at the same time showing low efficiency of the absorbed nutrients.

c. Symptoms of potassium deficiency

Eickstein et al. (1937) have reviewed comprehen-

sively symptoms of potash deficiency of common crops.

According to Nelson et al. (1945) the most striking symptom of potash deficiency in cotton is "cotton rust". Usually yellowing of tips and margins of leaves is followed by the appearance of necrotic spots. The leaves finally become reddish brown, curl up and fall off. The lint becomes twisted and is of poor quality.

Chapman et al. (1947) observed a low content of leaf potassium and reduced fruit size in oranges under low potassium levels.

In cereals, Wallace (1951) reported a bluish-green colour of young leaves, excessive tillering and shrivelled and immature grains in cases of potash deficiency.

Sircar and Datta (1957) studied the effects of potassium deficiency on the growth and nitrogen metabolism in paddy. Potash starved plants were slender, showed reduced height and increased succulence and withered in a few weeks. Brown streaks appeared on the slender stems, the phenomenon being known as "coppering". The leaves were dull green to yellow in colour, some of them showing red patches on the edge probably due to the development of anthocyanins. Older leaves were first affected by potassium deficiency, getting "scorched" and rolled up from tip downwards. Leaves at emergence were green but become chlorotic later.

Takahashi (1961) observed faulty carbohydrate and protein metabolism for potash deficient paddy along with malfunctioning of physiological processes and scorching of leaves.

According to Srivasthava (1963) banana leaves became necrotic from margins leading to the yellowing of leaves in a very short time followed by the production of stunted suckers when the potash supply was inadequate. The same worker (1963) also noted a tendency of irregular emergence of leaves and early necrosis leading to premature death of plants in pineapple due to potash deficiency.

At the International Rice Research Institute, Manila (1964) water culture studies revealed significant differences in potassium deficiency symptoms which were characterised by dark brown spots, more in Tainan 3 (japonica) than in Peta (indica).

D. Influence of major nutrients on the uptake of potassium.

(a) Nitrogen

Richard (1938), as quoted by Sircar and Datta (1957), observed the failure of plants to reach maturity when grown in high ammonium salt solutions with low potassium due to ammonium toxicity. In cereals full utilisation of nitrogen was reported in the presence of potassium. According to

Sircar and Datta (1957), when potassium is applied with ammonium salts, ammonium accumulation occur which might result in toxicity. The role of potassium in the synthesis of amino acids and proteins has also been stressed.

Von Contard (1959) pointed out the antagonistic role of potassium to nitrogen and emphasised the importance of balanced fertilisation. The physiological disorders caused by excess of nitrogen can often be corrected if the plant received sufficient potash.

Maximum economic return was reported by Govind and Chadha (1959) when incremental doses of nitrogen were applied in conjunction with higher doses of potassium.

(b) Phosphorus

Cowie (1942) observed enhanced potassium deficiency in potatoes when only phosphorus and nitrogen were applied.

A reduction in the potassium percentage in legume hay was noted by Lawton et al.(1952) when superphosphate was applied to soils containing added potash.

A combination of 30 lb of nitrogen and 60 lb of P_2O_5 was reported to be the optimum for the maximisation of paddy yields by Digar (1960).

Chin and Li (1966) failed to obtain any response to phosphorus alone but when applied with potassium there was an increase in yield of 76 per cent in paddy. It was also observed that the application of phosphoric acid increased the content of this nutrient in the plant.

(c) Potassium

Increase in the potassium content of plant parts has been reported by several investigators working on different crops, viz., Boynton and Burrel (1944) in apple leaves, Bear and Prince (1945) in alfalfa, Nelson et al. (1945) in soybean, Snider (1947) in wheat and oat straw, Dunn and Rost (1948) in potatoes, Russel (1950) in grass hay and Tucker and Smith (1952) in red clover.

Daji (1965) observed 2-9 per cent increased grain yield in paddy due to the application of nitrogen and phosphorus and 12-22 per cent increase due to nitrogen, phosphorus and potassium, thus indicating the necessity of applying balanced fertilisers for obtaining the maximum benefit.

Chin and Li (1966) found a positive correlation between the added potassium and the number of grains per earhead. Higher potassium content was obtained only in the straw which was attributed to the incremental doses of potassium.

MATERIALS AND METHODS

MATERIALS AND METHODS

As stated earlier, this investigation was carried out at the Agricultural College and Research Institute, Vellayani. It was a pot culture study and it was conducted in the open on a site adjoining the Agricultural Chemistry Laboratory.

A. Pot culture study

(1) Growth medium

Cement concrete pots of dimensions 100 cm x 100 cm x 15 cm were used. The growth medium was river sand collected from the Thiruvallum river bed. The pots were filled with sand to a height of 10 cm.

(2) Seeds and sowing

Two high yielding, non-lodging strains of paddy, viz., Tainan 3 (Japonica) and Taichung Native I (Indica), were used in this study. Both these are hybrid strains obtained from the International Rice Research Institute, Manila. Tainan 3 is a cross between Kwan Fu 401 x Cjunk 38 and Taichung Native I is a cross between a spontaneous dwarf mutant in Dee-Geo-Woo-Gen and Tsai-yuan-chung.

Twentyfive holes were made in each pot with a spacing of 20 cm either way and 4 seeds dibbled per hole. The seedlings were thinned to two per hole after 10 days. The remaining seedlings were cut into bits and incorporated into the sand in the respective pots. Thus each pot had 25 hills with 2 seedlings per hole. Basal dressing of fertilisers for all the treatments was applied on the day previous to sowing and the pots were irrigated so as to maintain adequate moisture in the growth medium for the germination of seeds.

(3) Layout and treatments

Eight treatments with 2 varieties and 4 levels of potassium were arranged in a randomised block design with 3 replications. Details are furnished below.

Treatments	Variety and levels
1	V_1 $N_{100}P_{80}K_0$
2	V_1 $N_{100}P_{80}K_{40}$
3	V_1 $N_{100}P_{80}K_{80}$
4	V_1 $N_{100}P_{80}K_{120}$
5	V_2 $N_{100}P_{80}K_0$
6	V_2 $N_{100}P_{80}K_{40}$
7	V_2 $N_{100}P_{80}K_{80}$
8	V_2 $N_{100}P_{80}K_{120}$

V_1 - Tainan 3 V_2 - Taichung Native 1

(4) Application of fertilisers

No organic manures were used in this investigation. Ammonium sulphate (21% N), Superphosphate (16% P_2O_5) and muriate of potash (60% K_2O) were applied in five split doses as per the schedule given below. All the treatments included a uniform basal dose of a commercial product known as 'Spartan' at 25 g per pot to supply all the necessary micronutrients.

	$N_{100}P_{80}K_0$	$N_{100}P_{80}K_{40}$	$N_{100}P_{80}K_{80}$	$N_{100}P_{80}K_{120}$
Basal dose	$N_{10}P_{20}K_0$	$N_{10}P_{20}K_{10}$	$N_{10}P_{20}K_{10}$	$N_{10}P_{20}K_{10}$
Top dressing 15th day	$N_{30}P_{30}K_0$	$N_{30}P_{30}K_{20}$	$N_{30}P_{30}K_{30}$	$N_{30}P_{30}K_{30}$
30th day	$N_{30}P_{20}K_0$	$N_{30}P_{20}K_{10}$	$N_{30}P_{20}K_{20}$	$N_{30}P_{20}K_{30}$
45th day	$N_{20}P_{10}K_0$	$N_{20}P_{10}K_0$	$N_{20}P_{10}K_{10}$	$N_{20}P_{10}K_{20}$
60th day	$N_{10}P_0K_0$	$N_{10}P_0K_0$	$N_{10}P_0K_{10}$	$N_{10}P_0K_{30}$

(5) Irrigation

The crop was irrigated with tap water. A constant level of 3 cm of water was maintained above the surface of the sand throughout the growth period.

(6) Crop protection

The experimental area was enclosed by bird proof coir netting. Spraying with Endrin and dusting with BHC 10% were done whenever required.

(7) Observations

The following observations were recorded to determine the influence of the different treatments on the growth and yield characters of the two varieties of rice under study.

i. Plant height

Measurements of plant height were recorded regularly at fortnightly intervals from the date of sowing until harvest. The length of shoot from the surface of the soil to the tip of the longest leaf was taken as the height.

ii. Vegetative tillers

Tiller counts were also made at fortnightly intervals.

iii. Productive tillers

The number of productive tillers was recorded on the day of harvest.

iv. Yield

The crop was harvested on 9-4-1967, 33 days after flowering. The weights of grain and straw were noted separately after cleaning and drying.

Measurements of other ancillary yield characters, viz., length of panicle, weight of panicle, 1000 grain weight and chaff percentage were also recorded. The roots left in each pot were carefully removed, washed thoroughly to remove sand particles, dried and weighed.

B. Laboratory Studies

The laboratory studies comprised analysis of (i) growth medium (sand), and (ii) grain and straw. Standard methods as outlined by Piper (1950) and Jackson (1962) were adopted.

The growth medium was analysed to determine both its mechanical and chemical composition. Mechanical analysis was done by the International pipette method. Nitrogen was estimated by Kjeldahl method. Total P_2O_5 and K_2O, CaO, MgO, Fe_2O_3 and R_2O_3 were determined in the HCl extract. Al_2O_3 was obtained by difference. pH was determined with a Beckman pH meter.

Grain and straw were analysed separately for nitrogen, P_2O_5 and K_2O content with a view to assessing

the amounts of each of these nutrients assimilated by the two varieties of rice under different treatments. Nitrogen was estimated by Kjeldahl method. P_2O_5 and K_2O were determined in the extract of the material with triple acid mixture made up of nitric, perchloric and sulphuric acid in the ratio of 4 : 1 : 1. P_2O_5 was estimated colorimetrically using a Klett Summerson colorimeter to measure the intensity of the molybdic blue colour developed. K_2O was determined by the sodium cobaltinitrite method.

C. Statistical analysis

The data obtained were statistically analysed using the analysis of variance method.

RESULTS

RESULTS

The results of the investigation that was carried out are presented below:

1. Analysis of the growth medium

The mechanical and chemical composition of the growth medium is given in Table 1.

It will be observed that the coarse and fine sand fractions together comprised 94.0 per cent of the growth medium. The silt and clay contents were negligible, the values being 1.0 per cent and 3.5 per cent respectively.

The growth medium had a pH of 6.2. The acid insolubles were very high amounting to 69.65 per cent. The sesquioxide content was 0.67 per cent. The levels of all the major plant nutrients were low, the values for nitrogen, P_2O_5 and K_2O being 0.06 per cent, 0.008 per cent and 0.0006 per cent respectively. Calcium and magnesium oxides together amounted to 0.113 per cent.

2. Influence of variety and level of potassium on growth characters

Data relating to certain plant characters, viz., height and tiller number, recorded at fortnightly intervals, are presented in Table 2.

TABLE 1

Mechanical and chemical composition of the sand used in the pot culture experiment

Mechanical analysis	%	Chemical analysis	%
Coarse sand	90.6	Nitrogen	0.0600
Fine sand	3.4	Phosphorus(P_2O_5)	0.0080
Silt	1.0	Potassium (K_2O)	0.0006
Clay	3.5	Calcium (CaO)	0.0080
		Magnesium (MgO)	0.1060
		Aluminium(Al_2O_3)	0.6000
		Iron (Fe_2O_3)	0.0700
		Total sesqui-oxides (R_2O_3)	0.6700
		Acid insolubles	97.5500

TABLE 2

Height of plants at four stages of growth

Treatment	Mean - height (cm)			
	15th day	30th day	45th day	60th day
V_1K_0	17.5	32.8	52.2	62.4
V_1K_1	18.9	34.9	56.3	64.2
V_1K_2	19.5	35.8	57.4	65.5
V_1K_3	21.7	37.6	58.7	66.9
Mean	19.4	35.3	56.1	64.8
V_2K_0	24.2	36.0	45.7	50.9
V_2K_1	26.7	38.3	48.4	51.4
V_2K_2	25.6	38.2	48.2	50.4
V_2K_3	25.9	36.5	47.0	52.4
Mean	25.6	37.3	47.3	51.3
Mean for levels K_0	..	..	..	..
K_1	..	..	..	..
K_2	..	..	..	..
K_3	..	..	..	..
C D (0.01) Varieties	2.95	1.08 (0.05)	..	2.3
C D Levels	..	..	..	..

(a) Plant height

Plant height ranged from 79.7 cm to 83.9 cm in Tainan 3. There was practically no variation in height in Taichung Native 1, the values lying between 65.3 cm and 65.8 cm. The maximum height was recorded by Tainan 3 for potassium application at 120 kg K_2O/ha.

Taichung Native 1 was significantly superior to Tainan 3 in plant height in the early stages of growth. However, from the 45th day onwards Tainan 3 recorded significantly greater height and this superiority was maintained until harvest.

The results revealed a progressive increase in plant height with increasing supply of potassium only in the case of Tainan 3. But this increase was not significant for the different levels of this nutrient applied.

(b) Tiller counts

Taichung Native 1 maintained superiority over Tainan 3 in the production of tillers throughout the growing period. On the 60th day the mean number of tillers in Taichung Native 1 varied from 21.3 to 22.4 and in Tainan 3 from 16.7 to 22.0 . . At harvest the values ranged between 14.6 and 15.3 in the former variety and 10.7 and

TABLE 8

Tiller counts at four stages of growth

Treatment	Mean number of tillers			
	15th day	30th day	45th day	60th day
V_1K_0	2.0	8.4	16.6	16.7
V_1K_1	2.0	9.3	16.2	17.2
V_1K_2	2.0	9.4	16.9	22.0
V_1K_3	2.0	10,9	16.8	17.4
Mean	2.0	9.5	16.6	18.3
V_2K_0	4.8	16.1	21.0	22.4
V_2K_1	6.0	17.1	20.9	21.9
V_2K_2	5.0	16.8	21.5	21.6
V_2K_3	5.5	16.2	20.9	21.3
Mean	5.3	16.5	25.1	21.8
Mean for levels K_0	..	..	..	..
Mean for levels K_1	..	..	..	..
Mean for levels K_2	..	..	..	..
Mean for levels K_3	..	..	..	..
C D (0.01) Varieties	1.81	1.5	1.6	3.1
C D Levels	..	..	..	..

TABLE 4

Height and productive tillers at harvest

Treatment	Mean height (cm)	Mean No. of productive tillers
V_1K_0	79.7	11.3
V_1K_1	81.2	10.7
V_1K_2	83.2	11.3
V_1K_3	83.9	11.3
Mean	81.7	11.1
V_2K_0	65.8	14.6
V_2K_1	65.3	15.3
V_2K_2	65.5	14.6
V_2K_3	65.5	14.9
Mean	65.5	14.9
K_0	..	..
Mean for levels K_1	..	..
K_2	..	..
K_3	..	..
C D (0.01) Varieties	2.4	1.1
C D Levels	..	..

11.3 in the latter. In both varieties the tiller counts did not show any statistical significance for the different levels of potassium applied.

It may be noted here that the plants in all the treatments had a uniform flowering duration of 70 days. The crop was harvested 33 days after flowering.

3. Influence of variety and level of potassium on yield characters

Data in respect of the various yield characters, viz., grain yield, straw yield, root weight, length of panicle, weight of panicle, 1000 grain weight and chaff percentage are given in Tables 5 to 8.

(a) Grain yield

Grain yield ranged from 243 g to 289 g per pot in Tainan 3 and 274 g to 300 g per pot in Taichung Native 1. The maximum value was recorded by Taichung Native 1 at 0 level of potassium. There was not significant difference in yield between the two varieties.

The data for Tainan 3 indicated that increased doses of potassium tended to increase yield. In Taichung Native 1 on the other hand, a negative effect was observed, the yield being depressed with increasing supply of potassium.

TABLE 5

Mean yield expressed as g per pot

Treatment		Grain	Straw	Root
V_1K_0		270	465	315
V_1K_1		243	490	253
V_1K_2		289	525	274
V_1K_3		289	572	277
Mean		273	513	279
V_2K_0		300	423	332
V_2K_1		286	440	266
V_2K_2		274	455	297
V_2K_3		290	475	299
Mean		288	448	299
Mean for levels	K_0	...	444	324
	K_1	...	465	259
	K_2	...	490	285
	K_3	...	523	288
C D Varieties		...	(0.01) 25	(0.05) 14
C D Levels		...	(0.01) 36	(0.01) 28

FIG 1 HISTOGRAM SHOWING THE YIELD OF RICE GRAIN AND STRAW FOR DIFFERENT POTASSIUM TREATMENTS

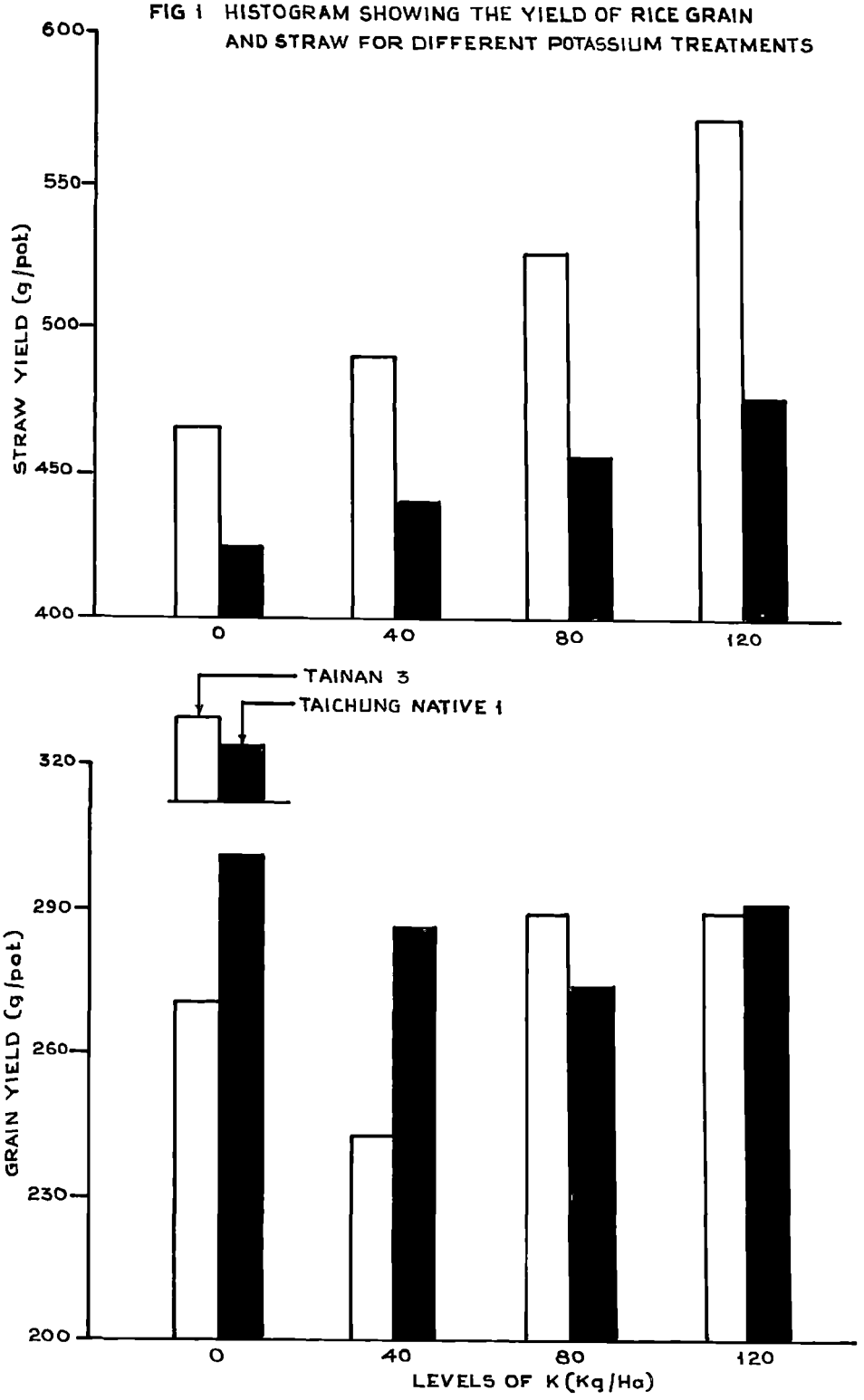


TABLE 6

Mean yield expressed as kg per hectare

Treatments		Grain	Straw	Root
	V_1K_0	2700	4650	3150
	V_1K_1	2430	4900	2520
	V_1K_2	2890	5250	2740
	V_1K_3	2890	5720	2770
	Mean	2730	5130	2790
	V_2K_0	3000	4230	3320
	V_2K_1	2860	4400	2660
	V_2K_2	2740	4550	2970
	V_2K_3	2900	4750	2990
	Mean	2880	4480	2990
Mean for Levels	K_0	..	4440	3240
	K_1	..	4650	2590
	K_2	..	4900	2850
	K_3	..	5230	2880
C D Varieties		..	(0.01) 250	(0.05) 140
C D Levels		..	(0.01) 360	(0.01) 280

Application of potassium at all levels had no significant effect on grain yield.

(b) Straw yield

The values for straw yield varied from 469 g to 572 g per pot in Tainan 3 and 423 g to 475 g per pot in Taichung Native 1. Straw weight increased with increasing doses of potassium in both varieties, Tainan 3 being superior to Taichung Native 1. In Tainan 3 application of potassium at 120 kg K_2O/ha gave the maximum yield followed by treatments supplying 80,40 and 0 kg K_2O/ha. Taichung Native 1 showed similar behaviour except that the values for the three highest levels of potassium were statistically identical. The results were highly significant both for variety and treatment.

(c) Root weight

The weight of root ranged from 263 g to 315 g per pot in Tainan 3 and 266 g to 332 g per pot in Taichung Native 1. In both the varieties the maximum weight was recorded at 0 level of potassium, the values being 315 g per pot (3150 kg/ha) for Tainan 3 and 332 g per pot (3320 kg/ha) for Taichung Native 1. The data indicated that both variety and level of potassium had significant effect on this yield character.

(d) Length of panicle

Panicle length ranged from 20.2 cm to 20.6 cm in Tainan 3 and 19.4 cm to 20.2 cm in Taichung Native 1. The differences in this yield character due to variety and treatment were not statistically significant.

Weight of panicle

(e) Weight of panicle

Panicle weight varied from 1.62 g to 2.18 g in Tainan 3 and 1.34 g to 1.50 g in Taichung Native 1. Tainan 3 recorded a higher mean panicle weight (1.93 g) than Taichung Native 1 (1.43 g). This yield character was significantly influenced by variety but not by treatment.

(f) 1000 grain weight

The values for 1000 grain weight ranged from 22.01 g to 23.95 g in Tainan 3 and 20.59 g to 23.64 g in Taichung Native 1. Tainan 3 was superior to Taichung Native 1 in this yield character. Potassium application at all levels gave almost identical results in Tainan 3 while in Taichung Native 1 the values for treatments K_3 and K_1, K_1 and K_2 and K_2 and K_0 were statistically equal. The effect of variety and level of potassium on 1000 grain weight was significant.

(g) Chaff percentage

The percentage of chaff varied from 16.5 to 25.7

TABLE 7

Mean length and weight of panicle, and 1000 grain weight

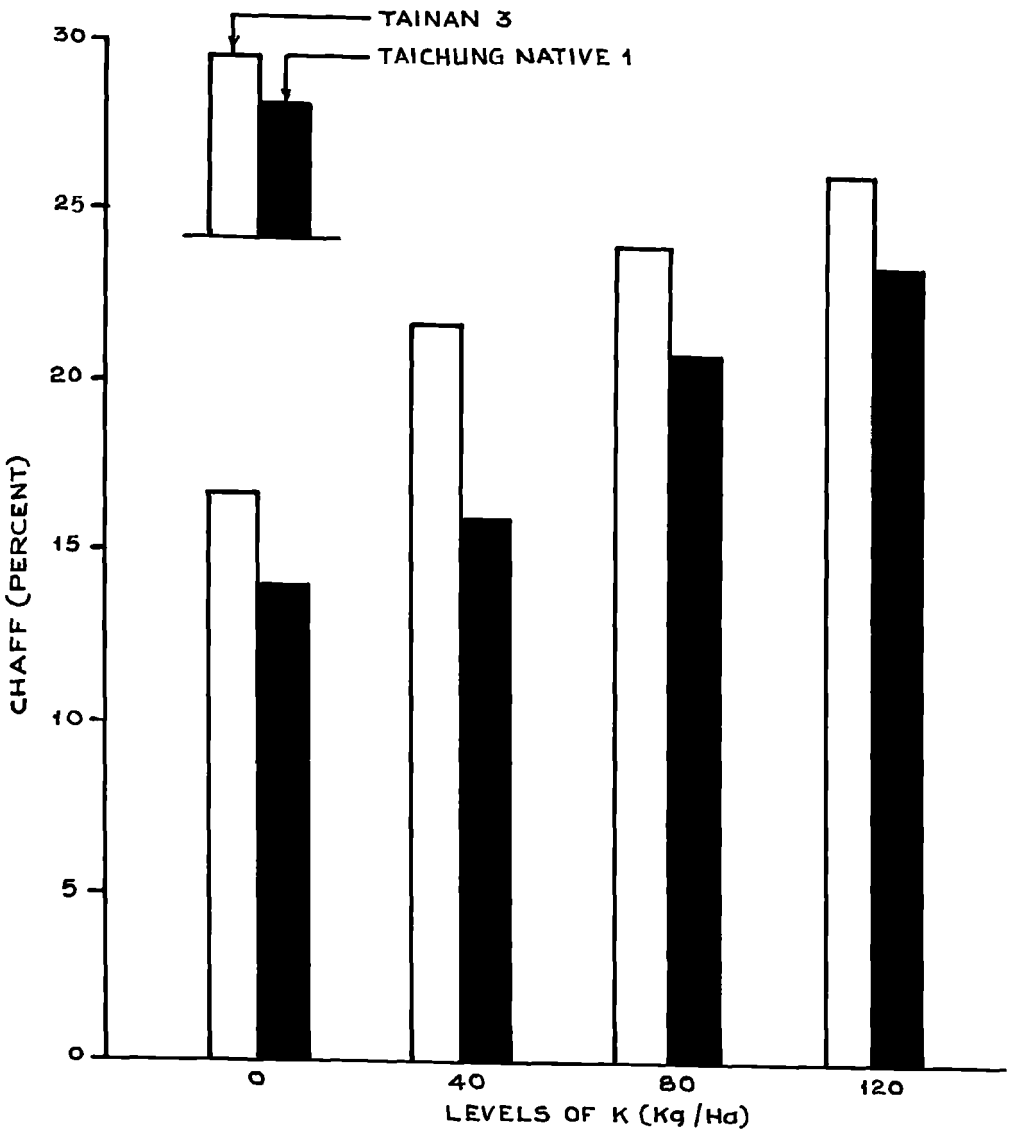
Treatment		Length of panicle(cm)	Weight of panicle (g)	1000 Grain weight (g)
V_1K_0		20.2	1.62	22.01
V_1K_1		20.3	2.03	23.36
V_1K_2		20.6	2.18	22.47
V_1K_3		20.5	1.89	23.95
Mean		20.4	1.93	22.94
V_2K_0		19.9	1.48	20.59
V_2K_1		20.2	1.34	23.02
V_2K_2		20.0	1.43	21.17
V_2K_3		19.4	1.50	23.64
Mean		19.9	1.44	21.26
Mean for Levels	K_0	..	..	21.28
	K_1	..	..	23.19
	K_2	..	..	21.82
	K_3	..	..	23.79
C D (0.05) Varieties		..	0.55	..
C D (0.01) Levels		..	..	2.05

TABLE 8

Mean chaff percentage

Treatment		Chaff (%)
V_1K_0		16.5
V_1K_1		21.5
V_1K_2		23.7
V_1K_3		25.7
Mean		21.9
V_2K_0		13.8
V_2K_1		16.5
V_2K_2		20.5
V_2K_3		23.2
Mean		18.5
Mean for Levels	K_0	15.2
	K_1	19.0
	K_2	22.0
	K_3	24.5
C D (0.01) Varieties		1.8
C D (0.01) Levels		1.3

FIG 2 HISTOGRAM SHOWING PERCENTAGE OF CHAFF IN RICE FOR DIFFERENT POTASSIUM TREATMENTS



in Tainan 3 and 13.8 to 23.2 per cent in Taichung Native 1. In both varieties the maximum amount of chaff was recorded for the highest level of potassium application (120 kg K_2O/ha) viz., 25.7 per cent and 23.2 per cent in Tainan 3 and Taichung Native 1 respectively. It was observed that the percentage of chaff increased progressively with increasing supply of potassium in both the varieties. The results showed that variety and treatment significantly influenced the percentage of chaff.

4. Influence of variety and level of potassium on nutrient uptake by grain and straw

Data showing the influence of variety and different level of potassium application on nutrient uptake as indicated by the nitrogen, phosphorus and potassium content of grain and straw are reported in Tables 9 to 12.

(a) Nitrogen

(i) Grain

The nitrogen content of grain varied from 0.79 to 1.16 per cent. Tainan 3 assimilated more of this element than Taichung Native 1 for equal amounts of potassium application. In both varieties the maximum absorption was recorded for potassium supply at 80 kg K_2O/ha. It may also be noted that the uptake of nitrogen was lowest for the highest level of potassium applied. The data revealed that the

TABLE 9

Nutrient content of grain

	Treatment	N (%)	P_2O_5 (%)	K_2O (%)
	V_1K_0	0.79	0.77	1.73
	V_1K_1	0.82	0.68	1.81
	V_1K_2	0.97	0.76	1.91
	V_1K_3	0.79	0.74	1.96
	Mean	0.85	0.74	1.85
	V_2K_0	0.86	0.80	1.09
	V_2K_1	0.94	0.75	1.24
	V_2K_2	1.16	0.78	1.35
	V_2K_3	0.84	0.71	1.48
	Mean	0.95	0.76	1.29
Mean for Levels	K_0	0.82	..	1.41
	K_1	0.88	..	1.51
	K_2	1.07	..	1.63
	K_3	0.81	..	1.72

TABLE 10

Nutrient content of straw

Treatment		N (%)	P_2O_5 (%)	K_3O (%)
V_1K_0		0.46	0.25	2.29
V_1K_1		0.47	0.36	2.51
V_1K_2		0.68	0.39	2.81
V_1K_3		0.33	0.28	2.97
Mean		0.49	0.32	2.65
V_2K_0		0.44	0.24	2.14
V_2K_1		0.46	0.28	2.78
V_2K_2		0.92	0.30	2.87
V_2K_3		0.46	0.25	2.99
Mean		0.57	0.27	2.69
Mean for Levels	K_0	0.45	0.24	2.22
	K_1	0.47	0.32	2.65
	K_2	0.80	0.34	2.84
	K_3	0.40	0.26	2.97
C D (0.01) Varieties		0.01	0.008	0.020
C D (0.01) Levels		0.02	0.010	0.002

TABLE 11

Nutrient uptake by grain

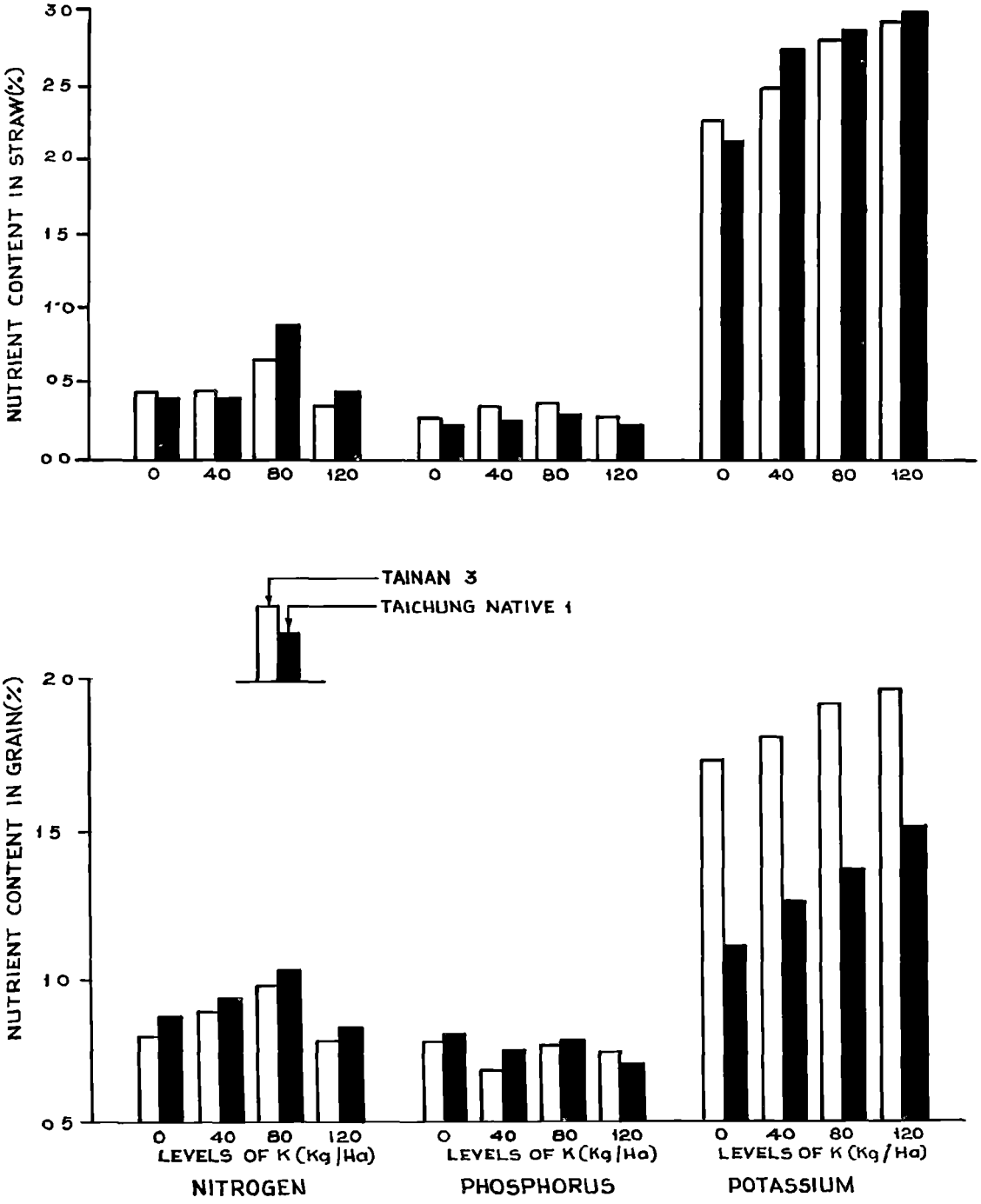
Treatment	N g/pot	P_2O_5 g/pot	K_2O g/pot
V_1K_0	2.13	2.08	4.67
V_1K_1	1.99	1.65	3.78
V_1K_2	2.80	2.19	5.52
V_1K_3	2.83	2.14	5.66
Mean	2.44	2.02	4.91
V_2K_0	2.58	2.40	3.27
V_2K_1	2.69	2.15	3.55
V_2K_2	3.13	2.14	3.69
V_2K_3	2.44	2.06	4.29
Mean	2.72	2.19	3.70

TABLE 12

Nutrient uptake by straw

Treatment	N g/pot	P_2O_5 g/pot	K_2O g/pot
V_1K_0	1.24	0.68	6.18
V_1K_1	1.14	0.88	6.09
V_1K_2	1.97	1.13	8.12
V_1K_3	0.96	0.81	8.58
Mean	1.33	0.88	7.24
V_2K_0	1.32	0.72	6.42
V_2K_1	1.32	0.80	7.95
V_2K_2	2.52	0.82	7.86
V_2K_3	1.33	0.73	8.67
Mean	1.62	0.77	7.72

FIG 3 HISTOGRAM SHOWING NUTRIENT CONTENT IN RICE GRAIN AND STRAW FOR DIFFERENT POTASSIUM TREATMENTS



influence of variety and level of potassium on the nitrogen content of grain was highly significant. There was also significant interaction between these factors.

(ii) Straw

The amount of nitrogen in straw ranged from 0.33 to 0.92 per cent. As in grain, in both the varieties studied the maximum assimilation of this element was observed for potassium application at 60 kg K_2O/ha. In Tainan 3 the uptake of nitrogen was lowest for the highest level of potassium applied. In Taichung Native 1 the nitrogen content was minimum for the 0 potassium treatment. The differences observed in the level of nitrogen in straw due to variety and treatment were statistically significant.

(b) Phosphorus

(i) Grain

The amount of P_2O_5 in grain varied from 0.68 to 0.77 per cent in Tainan 3 and from 0.71 to 0.80 per cent in Taichung Native 1. In both varieties the maximum assimilation of this element occurred when no potassium was applied. The variation in the phosphorus content of grain due to variety and treatment was narrow and the data were not statistically significant.

(ii) Straw

The P_2O_5 content of straw ranged from 0.25 to 0.39 per cent in Tainan 3 and from 0.25 to 0.30 per cent in Taichung Native 1. Potassium application at 80 kg K_2O/ha recorded the maximum uptake of this element. The level of phosphorus in straw was significantly influenced both by variety and level of potassium.

(c) Potassium

(i) Grain

The content of potassium in grain was higher than that of nitrogen and phosphorus. The level of K_2O varied from 1.73 to 1.96 per cent in Tainan 3 and from 1.09 to 1.48 per cent in Taichung Native 1. In both varieties there was progressive increase in the uptake of this nutrient with increasing levels of potassium application. The data indicated that variety, as well as treatment, had significant effect on the amount of potassium in grain.

(ii) Straw

Potassium was found to accumulate in straw in much greater amounts than nitrogen and phosphorus. The level of K_2O ranged from 2.39 to 2.97 per cent in Tainan 3 and from 2.14 to 2.99 per cent in Taichung Native 1. The assimilation of this nutrient by straw followed the same pattern as in

grain, increasing progressively with increasing supply of potassium. The results obtained showed that the difference in the potassium content of straw due to variety and treatment was highly significant.

DISCUSSION

DISCUSSION

According to Pawar et al. (1960) most of the experiments conducted at various research stations in India have given very little or no response to potash. but Raheja et al. (1958) have reported that simple trials carried out in recent years in cultivators' fields showed without doubt that the application of potash was imperative to get maximum benefit from optimum doses of nitrogen and phosphate in several States in India including Kerala. Large areas in Kerala which grow rice are deficient in potash due mainly to the heavy rainfall in the State. The problem of potash manuring of rice has assumed considerable importance in the context of the serious deficit in food production in Kerala. Precise data on the influence of potash on the growth and yield characters of rice, especially high fertility strains, is therefore urgently needed. The work reported here was an attempt to meet this need to some extent and relates to the performance of two strains of rice recently introduced into Kerala, viz., Tainan 3 and Taichung Native 1, which are reputed to give heavy yields of more than 4000 kg per hectare. The results of this study are discussed hereunder.

Growth characters

Plants of Taichung Native 1 which is a dwarf variety were superior in height to plants of Tainan 3 in the early stages of growth. But from the critical tillering stage until maturity Tainan 3 plants grew faster and attained greater height. Ramiah (1953) has pointed out that plant height in rice is a varietal character governed by genes and this accounts for the observed differences between the two strains.

The results also indicated that in both the varieties studied potash had little influence on plant height. The application of this nutrient even at the highest level of 120 kg K_2O/ha had no significant effect on this character. This is not surprising as vegetative growth is promoted only by nitrogen and in the present study all the treatments included a uniform level of this nutrient.

Taichung Native 1 showed much higher tiller count than Tainan 3 at all stages during the growth period. Variation in tiller number according to Ramiah (1953) is due to difference in the genetic make up of individual strains.

In both the varieties potash at all levels had no significant effect on tiller number. This may be attributed to the fact that the production of tillers in cereals

is a function of nitrogen and to a lesser extent of phosphorus whereas potash has hardly anything to do with it.

Yield characters

The difference in grain yield between the two strains studied was not statistically significant. The mean values of 2730 kg/ha for Tainan 3 and 2880 kg/ha for Taichung Native 1 clearly showed that there was little to choose between these varieties from the point of yield.

It is also evident from the data that the application of potash even at high levels had no significant effect on the yield of grain. Vaidyanathan (1938) and Pawar et al. (1960) made the same observation in reviewing the results of experiments carried out in India to study the response of paddy to potash. Potash applied at 80 kg K_2O/ha and 120 kg K_2O/ha to Tainan 3 gave identical yields which were only slightly higher than the control. In Taichung Native 1 there was a downward trend in grain yield with increasing supply of this nutrient. Panse et al. (1945), Tseng and Wang (1958) and Dubey and Das (1961) have also recorded depression in yield in cereals with higher levels of potash application. In the present study the response of both the strains to potash was erratic and merits further investigation. Crop response to potash, as with other

major nutrients, is best determined by field experiments.

As regards straw yield, Tainan 3 proved significantly superior to Taichung Native 1. This is to be expected as the latter is a short statured and less succulent variety than the former.

There was a linear increase in straw yield in both the strains with increasing doses of potash. This finding is in agreement with the results obtained by Sugawara (1952) and Singh (1953).

Root weight was significantly influenced by variety and Taichung Native 1 produced more roots than Tainan 3 for equal doses of potash. This appears to be due to the higher tiller count in the former variety as Ramiah (1953) found a close correlation in rice between the number of tillers and the number of roots per plant.

The effect of potash on root weight was striking. It was found that the three graded doses of potash (viz., 40 kg, 80 kg and 120 kg K_2O/ha) gave increasing weight of roots whereas the value recorded for 0 kg level was the maximum.

There was little difference in panicle length between the two varieties. It was also noted that potash

at all levels had no marked effect on this plant character. Ahamed Bavappa and Hanumantha Rao (1956) obtained increased length of panicle when potassium was applied in conjunction with lime.

Tainan 3 being a 'panicle weight type' recorded higher panicle weight than Taichung Native 1 which is a 'panicle number type'. This confirms the observation made earlier by Tanaka (1964) at I.R.R.I., Manila.

There was marked difference in 1000 grain weight between the two strains. Tainan 3 gave a higher mean value as it is a 'panicle weight type' variety. In respect of this character, both the strains showed significant positive response to potash applied at various levels. This is to be expected as potassium plays an important role in grain formation and gives plump heavy kernels. Cuthbertson (1960) obtained similar results in water culture studies on the nutrition of paddy.

Tainan 3 recorded considerably higher percentage of chaff than Taichung Native 1 for equivalent doses of potash. The influence of potash on chaff percentage was very marked. In both varieties there was a linear increase in the percentage of chaff with increasing doses of potash. This is contrary to the widely held belief that potash tends to reduce the amount of chaff in cereals. The

observation made in the present study is therefore noteworthy. This anomaly is difficult to explain satisfactorily and can only be attributed to a possible imbalance between potassium and other major nutrients.

Nutrient uptake

The percentage composition of the crop grown for the present study was determined with a view to assessing the NPK requirements of the two strains. The data showed that grain of Taichung Native 1 was richer in nitrogen but poorer in potash than Tainan 3. There was but little difference between the varieties in phosphorus content. As regards the composition of straw, Taichung Native 1 recorded higher values than Tainan 3 for both nitrogen and potash but a lower content of phosphorus.

A careful scrutiny of the results revealed that the total mean uptake of nitrogen by Tainan 3 during its entire period of growth was 37.7 kg/ha as compared to 43.4 kg/ha by Taichung Native 1. The absorption of phosphorus by the two strains was almost equal, the mean values for Tainan 3 and Taichung Native 1 being 29.0 kg/ha and 29.6 kg/ha respectively. As compared to nitrogen and phosphorus, the total uptake of potash by the crop was very high. Tainan 3 assimilated 121.5 kg K_2O/ha and Taichung Native 1, 114.2 kg K_2O/ha. There is apparently not much difference

in the potash requirements of these two strains. It is evident that both Tainan 3 and Taichung Native 1 are capable of removing large amounts of this nutrient, the greater part of it accumulating in the straw. This high uptake of potash by the crop was, however, not manifested in higher grain yield in the present study. This is presumably due to imbalance of major nutrients brought about by luxury consumption of potash. Recent experiments carried out at Coimbatore on Tainan 3 and Taichung Native 1 showed that balanced application of N, P and K gave maximum response as in other varieties of rice.

The uptake of the major nutrients was influenced considerably by the level of applied potash. The assimilation of nitrogen and phosphorus in general was maximum for potash treatment at 80 kg K_2O/ha. Absorption of potash generally increased with increasing doses of this nutrient. However, for optimum uptake of all the three major nutrients the application of potash at 80 kg K_2O/ha appears to be most favourable. Higher doses may prove uneconomic and wasteful.

Potash deficiency symptoms

Potash deficiency symptoms in cereals are less striking than in many other crops and are often unnoticed. The most common symptoms of deficiency of this nutrient

in rice are "coppering" and "scorching" described by Sircar and Datta (1957) and Takahashi (1961) and the appearance of dark brown spots on the leaves reported by I.R.R.I., Manila (1964). These symptoms, however, are sometimes masked. Noguchi and Sugawara (1952) reported the non-appearance of brown spots under potassium deficient conditions and attributed it to the lack of iron and other elements in the soil.

None of the plants grown in connection with the present study exhibited any of the typical potash deficiency symptoms. It is strange that even the plants that did not receive any potash at all were quite normal. It is possible that in this case the trace of potash present in the growth medium (sand) was adequate to meet the minimum requirements of the crop for this nutrient.

The results of this investigation on the response of Tainan 3 and Taichung Native 1 to graded doses of potash point to the need for further work to re-examine some of the important observations made in the present study. The findings that merit special attention are the following:

(i) The negative response of Taichung Native 1 to incremental doses of potash, and

(ii) The significant linear increase in chaff percentage with increased levels of potash application in both the varieties.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A pot culture study was carried out at the Agricultural College & Research Institute, Vellayani, to determine the influence of Potassium on the growth and yield characters of two varieties of rice recently introduced into Kerala, viz., Tainan 3 and Taichung Native 1. The uptake of major nutrients by the two strains was also assessed.

The experiment was laid out in randomised block design with 8 treatments and 3 replications. The levels of potash applied were 0, 40, 80 and 120 kg K_2O/ha.

The main findings are given below:

(i) Tainan 3 and Taichung Native 1 showed small varietal differences in plant height and tiller number. Potash had no significant effect on both these growth characters.

(ii) The grain yield of the two varieties was almost equal. The influence of potash on the yield of Tainan 3 was not significant. Taichung Native 1 showed a negative response to incremental doses of potash application.

(iii) Tainan 3 gave higher straw yield than Taichung Native 1. Increasing levels of potash enhanced straw

yield significantly in both the varieties.

(iv) The percentage of chaff in Tainan 3 was greater than that in Taichung Native 1. In both the varieties there was a highly significant increase in chaff percentage with increasing doses of potash.

(v) Difference in panicle length between the two varieties was small. But Tainan 3 was superior to Taichung Native 1 in panicle weight and 1000 grain weight. Potash had no effect on length and panicle weight but significantly influenced 1000 grain weight in both the varieties.

(vi) Taichung Native 1 recorded higher root weight than Tainan 3. In both the varieties the no potash treatment gave the maximum weight of roots. The other treatments gave increased root weight with increasing doses of potash.

(vii) Tainan 3 assimilated 37.7 kg N, 29.0 kg P_2O_5 and 121.6 kg K_2O per hectare during its entire growth period. The corresponding values for Taichung Native 1 were 43.4 kg N, 29.6 kg P_2O_5 and 114.2 kg K_2O per hectare. Potash applied at 80 kg K_2O/ha was the most favourable dose for optimum absorption of nitrogen, phosphorus and potash.

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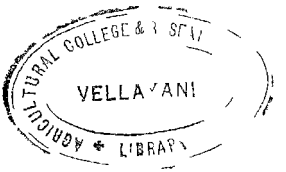
* Original not seen

APPENDIX



APPENDIX 1

Analysis of variance for height on the 15th day

Source	SS	DF	Variance	F ratio
Total	374.31	23	--	--
Replication	24.02	2	12.01	2.04
Treatment	267.76	7	38.25	6.49**
V	230.02	1	230.02	39.05**
K	27.42	3	9.14	1.55
VK	10.32	3	3.44	0.58
Error	82.53	14	5.89	--

** Significant at 1% level

APPENDIX 2

Analysis of variance for height on the 30th day

Source	SS	DF	Variance	F Ratio
Total	132.87	23	--	--
Replication	1.51	2	0.755	0.182
Treatment	73.18	7	10.454	2.52
V	24.20	1	24.200	5.82*
K	29.23	3	9.743	2.34
VK	19.75	3	6.583	1.58
Error	58.18	14	4.155	--

* Significant at 5% level

APPENDIX 3

Analysis of variance for height on the 45th day

Source	SS	DF	Variance	F ratio
Total	636.62	23	--	--
Replication	0.72	2	0.36	1
Treatment	54.99	7	7.85	1
V	46.46	1	46.46	1.12
K	6.30	3	2.10	1
VK	2.23	3	0.74	1
Error	580.91	14	41.49	--

APPENDIX 4

Analysis of variance for height on the 60th day

Source	SS	DF	Variance	F ratio
Total	1185.98	23	--	--
Replication	10.12	3	5.06	1.45
Treatment	1126.85	7	160.98	45.99**
V	1088.10	1	1088.10	310.89**
K	27.42	3	9.14	2.61
VK	11.33	3	3.78	1.08
Error	49.01	14	3.50	--

** Significant at 1% level

APPENDIX 5

Analysis of variance for height at harvest

Source	SS	DF	Variance	F ratio
Total	1674.46	23	--	--
Replication	4.44	2	2.22	1
Treatment	1613.51	7	230.50	57.19**
V	1584.38	1	1584.38	393.15**
K	13.03	3	4.34	1.08
VK	16.10	3	5.36	1.33
Error	56.51	14	4.03	--

** Significant at 1% level

APPENDIX 6

Analysis of variance for tiller counts on the 15th day

Source	SS	DF	Variance	F ratio
Total	83.60	23	--	--
Replication	2.32	2	1.160	0.272
Treatment	69.09	7	23.030	5.396**
V	66.23	1	66.230	15.518**
K	1.37	3	0.456	0.107
VK	1.49	3	0.496	0.116
Error	59.75	14	4.268	--

** Significant at 1% level

APPENDIX 7

Analysis of variance for tiller counts on the 30th day

Source	SS	DF	Variance	F ratio
Total	334.06	23	--	--
Replication	3.03	2	1.515	0.99
Treatment	309.62	7	44.231	28.91**
V	297.51	1	297.51	194.45**
K	5.63	3	1.88	1.23
VK	6.48	3	2.16	1.41
Error	21.41	14	1.53	--

** Significant at 1% level

APPENDIX 8

Analysis of variance for tiller counts on the 45th day

Source	SS	DF	Variance	F ratio
Total	145.47	23	--	--
Replication	0.11	2	0.55	0.31
Treatment	120.79	7	17.25	9.85**
V	119.26	1	119.26	68.14**
K	1.23	3	0.41	0.23
VK	0.30	3	0.10	0.57
Error	24.67	14	1.75	--

** Significant at 1% level

APPENDIX 9

Analysis of variance for tiller counts on the 60th day

Source	SS	DF	Variance	F ratio
Total	284.00	23	--	--
Replication	10.56	2	5.28	1
Treatment	129.64	7	18.52	2.76*
V	71.76	1	71.76	10.71**
K	24.98	3	8.32	1.24
VK	32.90	3	10.96	1.64
Error	93.80	14	6.70	--

* Significant at 5% level

** " " 1% level

APPENDIX 10

Analysis of variance for productive tiller counts

Source	SS	DF	Variance	F ratio
Total	96.86	23	--	--
Replication	0.12	2	0.06	1
Treatment	85.42	7	12.21	15.26**
V	83.63	1	83.63	104.54**
K	0.10	3	0.33	1
VK	1.75	3	0.58	1
Error	11.26	14	0.80	--

** Significant at 1% level

APPENDIX 11

Analysis of variance for grain weight

Source	SS	DF	Variance	F ratio
Total	32655.33	23	--	--
Replication	7551.08	2	3775.54	2.87
Treatment	6674.00	7	953.43	0.72
V	1261.43	1	1261.43	0.958
K	2168.33	3	722.77	0.549
VK	3244.24	3	1081.41	0.821
Error	18430.25	14	1316.45	--

APPENDIX 12

Analysis of variance for straw weight

Source	SS	DF	Variance	F ratio
Total	60715.62	23	--	--
Replication	6043.75	2	3021.87	7.01**
Treatment	48632.29	7	6947.47	16.10**
V	25026.04	1	25026.04	58.01**
K	20911.45	3	6970.48	16.16**
VK	2694.80	3	898.26	2.08
Error	6039.58	14	431.39	--

** Significant at 1% level

APPENDIX 13

Analysis of variance for root weight

Source	SS	DF	Variance	F ratio
Total	21238.6	23	--	--
Replication	2817.7	2	1408.85	5.51**
Treatment	14839.8	7	2119.97	8.29**
V	2166.0	1	2166.0	8.47*
K	12583.5	3	4194.5	16.39**
VK	90.3	3	30.1	0.12
Error	3581.0	14	255.8	--

* Significant at 5% level

** Significant at 1% level

APPENDIX 14

Analysis of variance for percentage of chaff

Source	SS	DF	Variance	F ratio
Total	379.74	23	--	--
Replication	17.27	2	8.635	7.779**
Treatment	360.91	7	51.558	46.448**
V	68.34	1	68.340	61.567**
K	286.70	3	95.567	86.096**
Vk	5.86	3	1.953	1.759
Error	1.56	14	0.111	--

** Significant at 1% level

APPENDIX 15

Analysis of variance for length of panicle

Source	SS	DF	Variance	F ratio
Total	49.42	23	--	--
Replication	41.54	2	20.77	56.12**
Treatment	2.66	7	0.38	1.03
V	1.30	1	1.30	3.70
K	0.46	3	0.15	0.41
VK	0.90	3	0.30	0.81
Error	5.22	14	0.37	--

** Significant at 1% level

APPENDIX 16

Analysis of variance for weight of panicle

Source	SS	DF	Variance	F ratio
Total	2.48	23	--	--
Replication	0.17	2	0.085	0.38
Treatment	2.00	7	0.286	1.29
V	1.43	1	1.430	6.47*
K	0.20	3	0.067	1
VK	0.37	3	0.123	1
Error	0.31	14	0.221	1

* Significant at 5% level

APPENDIX 17

Analysis of variance for 1000 grain weight

Source	SS	DF	Variance	F ratio
Total	55.88	23	--	--
Replication	0.08	2	0.040	--
Treatment	30.53	7	4.361	3.006*
V	4.33	1	4.330	2.986
K	24.54	3	8.180	5.640**
VK	1.66	3	0.553	1
Error	20.23	14	1.450	--

* Significant at 5% level

** " " 1% level

APPENDIX 18

Analysis of variance for nitrogen in grain

Source	SS	DF	Variance	F ratio
Total	0.3484	23	--	--
Replication	0.0071	2	0.0035	3.5
Treatment	0.3268	7	0.0466	46.7**
V	0.0683	1	0.0683	68.3**
K	0.2483	3	0.0828	82.8**
VK	0.0102	3	0.0034	3.4*
Error	0.0145	14	0.0010	--

* Significant at 5% level

** Significant at 1% level

APPENDIX 19

Analysis of variance for P_2O_5 in grain

Source	SS	DF	Variance	F ratio
Total	0.3510	23	--	--
Replication	0.0006	2	0.0003	0.013
Treatment	0.0322	7	0.0046	0.210
V	0.0032	1	0.0032	0.140
K	0.0222	3	0.0074	0.320
VK	0.0068	3	0.0023	0.100
Error	0.3182	14	0.0227	--

APPENDIX 20

Analysis of variance for K_2O in grain

Source	SS	DF	Variance	F ratio
Total	2.2538	23	--	--
Replication	0.0066	2	0.0033	1.74
Treatment	2.2201	7	0.3172	166.96**
V	1.8848	1	1.8848	992.00**
K	0.2245	3	0.1082	56.95**
VK	0.0108	3	0.0036	1.89
Error	0.0271	14	0.0019	--

** Significant at 1% level

APPENDIX 21

Analysis of variance for nitrogen in straw

Source	SS	DF	Variance	F ratio
Total	0.7372	23	--	--
Replication	0.0026	2	0.0013	13.00**
Treatment	0.7327	7	0.1047	1047.00**
V	0.0449	1	0.0449	449.00**
K	0.6151	3	0.2050	2050.00**
VK	0.0727	3	0.0242	242.00**
Error	0.0019	14	0.0001	--

** Significant at 1% level

APPENDIX 22

Analysis of variance for P_2O_5 in straw

Source	SS	DF	Variance	F ratio
Total	0.0651	23	--	--
Replication	0.0009	2	0.0004	10.0**
Treatment	0.0637	7	0.0091	227.5**
V	0.0171	1	0.0171	427.5**
K	0.0409	3	0.0136	340.0**
VK	0.0057	3	0.0019	47.5**
Error	0.0005	14	0.00004	--

** Significant at 1% level

APPENDIX 23

Analysis of variance for K_2O in straw

Source	SS	DF	Variance	F ratio
Total	2.1113	23	--	--
Replication	0.0078	2	0.0039	19.5**
Treatment	2.1009	7	0.3001	1500.5**
V	0.0113	1	0.0113	56.5**
K	1.9502	3	0.6501	3250.5**
VK	0.1394	3	0.0465	232.5**
Error	0.0026	14	0.0002	--

** Significant at 1% level