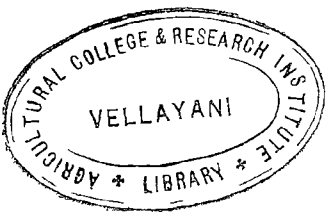
STUDIES ON THE EFFECT OF PHOSPHORUS ON THE GROWTH, YIELD AND NUTRIENT UPTAKE OF TWO NEWLY INTRODUCED RICE VARIETIES (*Tainan 3 and Taichung Native 1*)



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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 bonafide research work carried out by Shri. B. Mohankumar 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

In Kerala, rice is cultivated over an area of approximately 2 million acres and the annual production is about 10 to 11 million tons. This quantity meets only about 50 percent of the cereal requirements of the State. Scarcity of cereal food is therefore the major problem in Kerala today and an all out effort is being made to bridge the wide gap between the production and demand for rice. Extension of the area under cultivation is no more feasible because all the cultivable land in this State has already been brought under the plough. The only method by which production can be increased is by adopting intensive methods of cultivation. The introduction of high yielding varieties of rice, the judicious use of fertilizers and the adoption of improved cultural practices are among the methods suggested for intensifying the production of this crop. Recently a programme has been launched for introducing high fertilizer responsive varieties of rice into Kerala. Among the more promising varities that have been recently introduced are Tainan 3 and Taichung Native 1. These varieties which are from Taiwan are well known for their

heavy yields and they are being at present tried in the different research stations and cultivators' fields in Kerala.

The performance of Tainan 3 and Taichung Native 1 in Kerala soils has been encouraging and it is hoped that the introduction of these varieties will go a long way in finding a solution to the food problem of the State. For the successful cultivation of these varieties it is necessary that more precise information about their nutrient requirements in our soils is obtained. It is well known that high yielding varieties of rice make heavy demands on the soil for the major plant food elements. The data now available on the response of Tainan 3 and Taichung Native 1 to nitrogen, phosphorus and potassium under conditions obtained in Kerala are rather meagre. It was therefore considered essential to undertake studies for determining the effect of each of the major nutrients on the growth and yield characters of these two varieties of rice with a view to supplementing the data that may be obtained from the trials now in progress in the research stations and cultivators' fields. Accordingly, a comprehensive investigation was

started in the Agricultural College and Research Institute, Vellayani, for studying the effect of nitrogen, phosphorus and potassium on the growth, yield and nutrient absorption by Tainan 3 and Taichung Native 1. Three post graduate students including the author collaborated in this study and each one had to deal with one of the major nutrients. The work assigned to the author related to phosphorus.

The relationship of phosphorus to plant growth has long been recognised, but its important role in plant life is only now being fully realised. This element is a constituent of nucleic acid, phytin and phospholipids. Adequate supply of phosphorus in the early stages of plant growth is necessary for laying down the primordia for the reproductive parts of the plant. It has also been associated with seed formation and the early maturity of crops, particularly cereals. Phosphorus is also considered necessary for stimulating root growth and the early establishment of the plant in the soil. The deficiency of phosphorus is generally accompanied by a stunted growth, a deep green colour of foliage and a bunching together of the leaves. Fertility surveys carried out in Kerala State and the soil test data that

have accumulated in the past decade indicate that 90 percent of our soils are seriously deficient in this important plant food element. This has been further corroborated by the positive response to applications of phosphorus obtained in many research stations and cultivators' fields.

The present investigation was therefore undertaken with the following three main objectives:.

1. To determine the response of Tainan 3 and Taichung Native 1 to increasing levels of phosphorus.

2. To study the deficiency symptoms, if any, exhibited by these varieties due to lack of phosphorus, and

3. To assess the effect of phosphorus at different levels on the uptake of the major nutrients.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The literature dealing with the effect of phosphorus on the growth, yield and composition of agricultural crops is voluminous and hence a complete review of literature on this subject is not attempted here. Only publications having a direct bearing on the work embodied in this thesis are reviewed below.

A. Physiological role of phosphorus

Ishizuka and Tanaka (1952) found that increasing levels of phosphorus application caused a decrease in the starch content and an increase in the crude protein and crude fat contents of the grain in paddy. Increase in starch content due to the application of phosphatic fertilizers was recorded by Moriya and Sato (1958).

Morita (1953) noted a delay in the yellowing of the leaves of the rice plant due to lack of phosphorus. Yoshida (1958) reported that increased application of phosphorus promoted root growth and tillering and hastened maturity.

Fujiwara and Ohira (1959), while studying the physiological role of phosphorus in higher plants, observed

an inhibition of nitrogen absorption, protein synthesis and growth in rice due to an insufficient supply of phosphorus.

Gasser (1956) reported an increase in the phosphorus and calcium contents of grain, a decrease in the nitrogen content and a variable effect on potash due to the application of phosphatic fertilizers to rice.

In their study of the nutritive value of rice, Basak et al (1961) obtained a negative influence on the protein, P and Ca content of grain by the application of phosphorus along with potassium and calcium.

While studying the growth habit and nutrient uptake of Tainan 3 and Peta, Tanaka et al (1964) found that in the active straw, phosphorus levels decreased for a time after transplanting, then slowly increased and after reaching a peak again decreased towards maturity. During ripening nitrogen and phosphorus were translocated from straw to grain.

Petinov and Kharanyan (1960) concluded that phosphorus and nitrogen usually decreased the bound water content by increasing the free water, thereby increasing the respiratory rate of the leaves and roots of rice.

Lal and Prasad (1947) found that in optimal doses phosphorus improved the reproductive vigour more than the vegetative. They also noted that along with nitrogen, phosphorus tended to increase the protein content.

Burriel et al (1951) recorded an increase in dry weight, ash, crude protein, ether extractives, fibre P and Mg of spring oats by the applications of superphosphate. Mc Coy et al (1951) concluded that phosphorus was unable to increase the amount of folic acid, biotin, niacin and calcium pantothenate in oats.

In water and sand culture studies on pea, beans, maize and barley, Udovenko and Bezlyudnyi (1965) observed that improved phosphorus nutrition increased the concentration of mineral phosphorus, hexose sugar and protein in the plants while it affected the phosphotide and nucleoproteid contents to lesser extents.

Romanchuk (1958) obtained an increase in the number of chloroplasts in leaves, and starch content of tubers in potatoes by the application of phosphorus along with nitrogen, potassium, calcium and magnesium. Krapivenko (1960) recorded a remarkable increase in the chlorophyll content of leaves and accumulation of dry matter and a slight decrease in the accumulation of carbohydrates in

all organs of the rice plant due to the application of phosphorus along with nitrogen and potassium.

Okamoto (1950) reported that rice could be protected from Piricularia oryzae (Blast disease) by the application of phosphatic fertilizers, while Malaguti et al (1951) and Krishnaswami (1952) reported no effect on the incidence of blast disease by the application of this element.

Hirono and Ishii (1959) observed an increase in the number of larvae of the stem borer, Chilo suppressalis when high levels of phosphorus were applied.

Brown et al (1955) reported that rice grown on flooded soil was very susceptible to chlorosis when phosphorus and copper salts were added in excess.

B. Deficiency symptoms

Aiyar (1946) has reported phosphorus deficiency symptoms in rice in Burma, Madras and Bihar. Phosphorus deficient plants were found to be stunted, with small dark green or blue green leaves bunched together. Primary roots were elongated and deep reddish brown in colour and there was complete absence of secondary surface roots.

The crops failed to reach maturity and remained green though the ears and grain reached proper development. Phosphorus deficiency caused an accumulation of total protein and soluble nitrogen in the plant. Roots of phosphorus deficient plants contained a much higher percentage of iron than the plants manured with phosphorus. In the straw there was a positive correlation between the phosphorus content on the one hand and potassium or magnesium content on the other. The correlation between nitrogen and phosphorus contents of straw and grain was negative and highly significant.

Hayashi et al (1951) while studying the productive efficiency of phosphorus nutrition for rice observed a stoppage of root growth by the deficiency of this element.

The symptoms of phosphorus deficiency in other crops have been described by a number of workers. Mc Murtrey (1949) noted that tobacco plants were stunted and slow in growth with a rosette condition in the absence of adequate phosphorus nutrition. According to Cooper and Donald (1949), under conditions of phosphorus deficiency, cotton plants were subject to dwarfing with small leaves and a dark green colour. Jone et al (1949) noted that potato plants were retarded in growth and required a

longer period for maturation when phosphorus was deficient.

Skinner and Purvis (1949), as quoted by Raheja (1966), observed a retarded growth without leaf chlorosis and with dark green coloured leaves in tomatoes, raddish, celery, onion and leafy vegetables due to phosphorus deficiency.

Lal and Subba Rao (1960) reported a reduction in tillering, leaf number and dry weight in barley, a reduction of all the vegetative characters except leaf size in paddy and a diminution of the general vegetative growth in maize due to phosphorus deficiency.

Lal and Singh (1963) obtained a reduction in the quantity of nitrogen in the dry matter of leaf and root due to the deficiency of phosphorus.

Roy and Datta (1963) reported that lack of phosphorus inhibited root growth in maize.

C. Effect of Phosphorus on the growth and yield of Paddy

Coyaud (1949), studying the effect of chemical fertilizers on rice in Tonkin, observed that phosphorus

increased yields considerably on light soils, slightly on clayey soils and variably on alluvial soils.

Chang and Tseng's (1953) work on the rice soils of Taiwan revealed a slight increase in yield on lateritic soils and slate-alluvial soils and no increase in yield on sandstone and shale-alluvial soils due to the application of phosphorus.

An increased grain yield of 20-36 percent was recorded by Rhind et al (1949) by presoaking the paddy seeds in nutrient solutions of phosphorus. Abichandani (1959) also obtained an increase in grain yield of 8-15 percent by presoaking the paddy seeds in similar solutions.

Borasio (1951) found that renohypophosphate used in conjunction with urea and muriate of potash was more effective than superphosphate.

In Java soils Chandrarathna (1951) obtained excellent response for rice to phosphate application and he has stated that double super was very effective when applied in small, frequent doses.

Parthasarathy (1953) obtained an increase in yield due to the application of 150 lb of superphosphate and ammonium sulphate along with 4000-5000 lb per acre of green manure.

Sree Ramulu and Mariakulandai (1963) obtained increased yield of rice by the application of superphosphate along with Farm Yard Manure.

Mukherjee (1955) conducted a series of trials on cultivators' fields in Bihar and reported a positive response to the application of superphosphate.

Digar (1960) got an increase in yield by the application of phosphorus along with nitrogen but a decrease in the straw to grain ratio was also reported by him due to the application of superphosphate.

Basak et al (1960) found that in water-logged rice soils an application of 20 lb of P_2O_5 per acre as superphosphate along with nitrogen did not influence the yield. This they attributed to the low phosphorus requirement of the rice crop and to the formation of relatively unavailable compounds of iron and aluminium with phosphorus.

Ganguly and Relwani (1961) reported that the application of superphosphate at 160 lb of P_2O_5 per acre along with 60 lb per acre of N as ammonium sulphate did not produce any significant increase in the yield of paddy.

Datta and Datta (1963) recorded a progressive increase in yield (above 50 percent) using radioactive

superphosphate (21.5 percent P_2O_5) and flooding the rice soil with 5 cm of standing water. They also reported that flooding was effective in increasing the release of available soil phosphorus, uptake of soil and fertilizer phosphorus and utilization of applied phosphorus.

Ghosh (1963) stated that the higher the rate of phosphatic fertilizers applied in the form of bone meal or superphosphate, the higher was the yield of paddy.

In a comparative study of the effect of different forms of phosphatic fertilizers on rice in Bihar, Bhattacharya et al (1965) obtained the highest response to single superphosphate.

Dabin (1951) recorded a significant response for rice to phosphorus along with nitrogen and potassium. According to him the maximum utilization of phosphorus took place at the tillering stage.

Ishizuka and Tanaka (1951) obtained increased grain yield when phosphorus was applied at 20 ppm and maximum phosphorus absorption at 150 ppm. But Ariyanayagam (1953) reported that phosphorus at 30 lb per acre had no direct, residual or cumulative effect on yield, even in the presence of high levels of nitrogen.

Paul (1953) obtained no beneficial effect for an application of P_2O_5 at 20 lb per acre, but at twice this level the yield of grain and straw was significantly increased.

Raychoudhari (1953) and Desai et al (1954) got significant increase in yield due to the application of phosphorus in combination with nitrogen, while Castro et al (1956) reported that phosphorus had no effect on yield eventhough the soil was low in phosphorus.

Results of research carried out by the Indian Council of Agricultural Research in the States of Bombay, Madras, Bengal and Madhya Pradesh (Anon. 1956) indicated an increase in yield, tiller number and vigour of plants when phosphorus was used in conjunction with nitrogen.

Chavan et al (1957), Moriya and Sato (1958) and Bhatta (1959) obtained increased yield and growth of paddy due to the application of phosphatic fertilizers.

Ota et al (1958), while studying the ripening of rice in Japan, found that shading had an inhibitive effect on the absorption of phosphorus and its translocation from straw to ear. They also observed that it reduced the rate of setting and grain weight.

Relwani (1959) obtained uneconomic response to 20 lb per acre of phosphorus for the varieties N.P. 130, N.P. 97 and Jhona 349 on an alluvial soil.

Takijima et al (1959) reported that increased phosphorus rate accelerated tillering but inhibited panicle growth.

Reviewing the results of manurial experiments on rice conducted in the past at the Agricultural Research Stations in India, Gouin and Chanda (1959) have reported an erratic response to phosphorus application. They also noted that there was no significant interaction between nitrogen and phosphorus.

+ Rijst (1960) observed an increase in yield due to the application of 100 and 200 kg of phosphate (30 percent P_2O_5) for rice in Suriname District.

+ In a solution culture experiment conducted with two indica rice varieties, Ptb.10 and T.141 at the Central Rice Research Institute, Cuttack (1961), the optimum grain yield was obtained when the phosphatic fertilizers were applied at the initial stages of growth.

Russel (1961) reported that excess of phosphates over the amount required by the crop sometimes depressed crop yields.

Sahu (1963) obtained an average response of 3 mds and 5.3 mds of rice for an application of 20 and 40 lb per acre of P_2O_5 respectively for paddy in Orissa.

NPK fertilizer demonstrations conducted in U.P. by the D.C.M. Chemical Works, Rallis India Ltd. and the Indian Potash Supply Agency Ltd. (1963) indicated a distinctive profitable increase in grain yield in paddy for NPK (1183 kg of grain per acre) over all other treatments. NP application (1065 kg of grain per acre) was found to be superior to NK application (999 kg of grain per acre). Nitrogen, P_2O_5 and K_2O were applied at the rate of 10 kg per acre.

A response of 24.7 lb of rice grain per pound of P_2O_5 was obtained by Arunachalam et al (1964) and they pointed out that the 'Rabi' season was favourable for maximum response to P_2O_5 and K_2O.

The Annual Report of the International Rice Research Institute, Philippines Tanaka et al (1964) showed that an increase in the application of phosphorus to Tainan 3 and Peta resulted in an increase in panicle weight, percentage of phosphorus in straw and also the phosphorus content of plant.

Daji (1965) obtained better response to nitrogen and phosphorus in combination as compared to individual application in cultivators' fields in Andhra Pradesh.

Gupta et al (1965) emphasised that the number of ears at tillering stage was correlated positively with leaf nitrogen and phosphorus and negatively with leaf potassium.

Patnaik et al (1965) obtained optimum grain yield for a medium duration indica rice variety by the application of a solution culture of phosphorus at tillering stage and they suggested the need of an early application of phosphatic fertilizers for rice.

Srinivasulu and Pawar (1965) got no significant effect on plant height, number of ear bearing tillers, length of panicle, 1000 grain weight, number of mature and chaffy grains per panicle, and root:shoot ratio by the application of phosphorus for two indica x japonica hybrids (Hr. 19 x Norin 18).

Daji (1966) reported an average response for paddy to phosphorus when superphosphate was applied at 30 lb P_2O_5 per acre.

Mariakulandai and Chamy (1967) reported that the response to phosphorus was affected by different liming

factors such as effect of placement, response to indirect manuring through legumes, effect of combination with green manure, Farm Yard Manure, nitrogen and potassium and the effect of lime.

D. Effect of Phosphorus on the growth and yield of crops other than Paddy

Russel and Watson (1940) as quoted by Sharma (1964) have emphasised the necessity of applying nitrogen along with phosphorus to increase the yield of wheat.

Woltz et al (1949) have reported an increase in total growth and phosphorus uptake by tobacco due to the application of higher rates of phosphorus.

In an experiment on barley involving the application of superphosphate in different doses from 20-100 lb per acre, Das (1959) obtained the maximum height of plants and yield at 80 lb per acre, maximum tillering at 20 lb per acre and the maximum number of ears per plant at 60 lb per acre.

Datta et al (1959) reported an enhancement in the yield of maize due to the application of phosphorus at 40-80 lb of P_2O_5 per acre while Ganguly and Belwani (1961)

obtained no significant difference in the yield of berseem due to the application of 80 lb per acre and 160 lb per acre of P_2O_5.

Powar et al (1961) recorded an increase in yield for spring wheat due to the application of increasing doses of phosphorus (0-30 lb P_2O_5 per acre).

Positive response was reported by Russel (1961) for swedes, potatoes, barley, sorghum and maize to application of phosphorus.

Abraham et al (1963) got an economic response for rice and wheat to the application of 20 lb P_2O_5 per acre. Potato, groundnut, sugarcane and gram were also found to give good response, whereas maize and cotton gave little response.

Meagher and Armson (1963) obtained an increase in uptake and thereby an increase in yield for white spruce due to the application of increasing rates of phosphorus. Finn and Mack (1964) got similar results but reported that a rise in soil temperature from 10 to 20°C and soil moisture from 25 to 75 percent of soil moisture capacity decreased the effect of applied phosphorus.

E. Influence of other nutrients on the uptake of phosphorus

1) Nitrogen

Tidburg (1956), while studying the interaction of nitrogen and phosphorus on rice, found that higher rates of nitrogen were required for maximum response to medium levels of phosphorus and vice versa. At low levels of fertilizer application nitrogen and phosphorus exchanged each other's effects.

The studies of Grunes and Krantz (1958) on the effect of nitrogen on NPK content of oats revealed the effect of nitrogen in affecting the phosphorus and potassium uptake through increased root growth and better nutrient absorbing capacity.

Yoshida (1958) stressed the essentiality of a low N/P ratio in the plant through every stage of growth for increasing yields.

Rennie (1954) as quoted by Sauchelli (1959) reported that nitrogen promoted the uptake of nutrient phosphorus by cereal grains sown on fallow land.

Grunes (1959) obtained a marked increase in the absorption of phosphorus due to the addition of nitrogenous fertilizers and found that ammoniacal form of nitrogen was superior to nitrate form in this respect.

Maung Mya Thaung (1960) reported an improvement in growth and reproduction by the application of phosphorus along with nitrogen.

Simpson (1961) obtained a strong positive interaction between rates of applied nitrogen and the uptake of phosphorus in potatoes.

2) Potassium

Robertson et al (1954) while studying phosphorus absorption by corn found that utilization of fertilizer phosphorus was increased by high NK applications but it was unaffected by adding potassium to phosphorus and tended to decrease on adding potassium to NP.

In greenhouse and field experiments using labelled superphosphate Fine (1955) found that increased available potassium content of soil had little effect on fertilizer phosphorus utilization by crops.

Bartz (1959) observed that monopotassium phosphate gave a greater growth response and tissue phosphorus concentration than monocalcium phosphate.

Jung and Smith (1959) reported that a K:P ratio of 5:2 was optimum in respect of the cold resistance of lucerne.

Kanwar and Meelu (1963) stated that wheat fared best with NPK application, the next best being of NK applications.

MATERIALS AND METHODS

MATERIALS AND METHODS

In view of the importance of phosphorus in plant nutrition and crop yields the present work was undertaken to study the influence of this element on the growth, yield and nutrient uptake of two high yielding varieties of rice recently introduced into Kerala. The investigation was carried out in a pot culture experiment in randomised block design with 8 treatments and 3 replications. The details of the experiment are given below.

A. Pot culture Experiment

1. Treatments

The treatments used in the study were the following:

1. V_1P_0NK — P_0 - No application
2. V_1P_1NK — P_1 - 40 kg P_2O_5 per hectare
3. V_1P_2NK — P_2 - 80 kg P_2O_5 per hectare
4. V_1P_3NK — P_3 - 120 kg P_2O_5 per hectare
5. V_2P_0NK — N - 100 kg N per hectare
6. V_2P_1NK — K - 80 kg K_2O per hectare
7. V_2P_2NK — V_1 - Variety Tainan 3
8. V_2P_3NK — V_2 - Variety Taichung Native 1

2. Preparation of pots

Reinforced concrete pots of size 100 cm x 100 cm x 15 cm were used for the experiment. River sand collected from the Thiruvallum river bed near the Agricultural College and Research Institute, Vellayani, was used as the growth medium. Its mechanical composition and chemical composition are given in Table I below.

Table I

Mechanical and Chemical Composition of the Sand used in the pot culture experiment

Mechanical analysis			Chemical analysis		
Coarse sand	(percent)	90.6	pH	6.2	
			Nitrogen	0.013	percent
Fine sand	(percent)	5.5	Phosphorus (P_2O_5)	0.010	,,
Silt	(percent)	1.5			
Clay	(percent)	1.1	Potassium (K_2O)	0.006	,,
			Calcium (CaO)	0.071	,,
			Magnesium (MgO)	0.092	,,
			Sesquioxides	1.170	,,
			Iron (Fe_2O_3)	0.800	,,
			Insolubles	97.150	,,

The object of using this medium for growth was to study the deficiency symptoms that may be exhibited in a soil that is very deficient in phosphorus and at the same time not completely devoid of this element.

3. Application of lime and fertilizers

All pots received a basal application of calcium and magnesium in the form of calcium carbonate and magnesium carbonate at the rate of 5 g per pot (50 kg/ha). Micronutrients were also applied basally in the form of a commercial product known as 'Spartin' manufactured by M/s Swati Industries Private Limited, Bombay, and having the following composition:-

Fe	-	1.65 percent
Mn	-	0.36 ,,
Cu	-	0.16 ,,
Zn	-	0.16 ,,
B	-	0.02 ,,
Ca	-	19.00 ,,
Mg	-	5.25 ,,

In addition, all pots received equal applications of N and K_2O at the rates of 100 and 80 kg per hectare respectively in the form of ammonium sulphate (21 percent N) and muriate of potash (60 percent K_2O). The different

levels of phosphorus in the various treatments, viz., 40, 80 and 120 kg P_2O_5 per hectare were applied in the form of superphosphate (16 percent P_2O_5). The nitrogen, phosphorus and potassium were applied in five split doses as given below, for both varieties.

	$N_{100}P_0K_{80}$ (Treatments V_1P_0NK and V_2P_0NK)	$N_{100}P_{40}K_{80}$ (Treatments V_1P_1NK and V_2P_1NK)
Basal	$N_{10}P_0K_{10}$	$N_{10}P_{10}K_{10}$
15th day	$N_{30}P_0K_{30}$	$N_{30}P_{20}K_{30}$
30th day	$N_{30}P_0K_{20}$	$N_{30}P_{10}K_{30}$
45th day	$N_{10}P_0K_{10}$	$N_{10}P_0K_{10}$
60th day	$N_{20}P_0K_{10}$	$N_{20}P_0K_0$

	$N_{100}P_{80}K_{80}$ (Treatments V_1P_2NK and V_2P_2NK)	$N_{100}P_{120}K_{80}$ (Treatments V_1P_3NK and V_2P_3NK)
Basal	$N_{10}P_{10}K_{10}$	$N_{10}P_{10}K_{10}$
15th day	$N_{30}P_{30}K_{30}$	$N_{30}P_{30}K_{30}$
30th day	$N_{30}P_{30}K_{30}$	$N_{30}P_{30}K_{30}$
45th day	$N_{10}P_{10}K_{10}$	$N_{10}P_{30}K_{10}$
60th day	$N_{20}P_0K_0$	$N_{20}P_{20}K_0$

4. Seeds and sowing

The paddy strains selected were two high yielding, non-lodging varieties recently introduced into Kerala viz., Tainan 3 (Japonica) and Taichung Native 1 (Indica). Holes were made in the basally treated sand in the pots at a distance of 20 cm apart, the total number of holes in one pot being 25 (5 x 5). Four sprouted seeds were dibbled in each hole on 18-12-1966 and optimum moisture conditions maintained with tap water. After 14 days when the seedlings were well established their number per hole was thinned to two. The rest of the seedlings were cut into small bits and buried in the sand in the respective pots.

5. Irrigation

The crop was irrigated periodically with tap water so as to maintain a constant level of 3 cm of water above the surface of sand.

Plant protection measures were taken by spraying the plants with "Folidol-E 605" as a prophylactic measure against pest attack.

6. Harvest

The plants except those in the pots getting no

phosphorus treatment were harvested on 1-4-1967. As the plants in the treatments V_2P_0 and V_1P_0 came to flowering considerably late they could be harvested only on 10-4-1967 and 29-4-1967 respectively.

B. Plant performance studies

The following observations were made regarding the growth and yield characteristics of the two varieties for the different levels of phosphorus.

i. Height of plant

This was recorded at intervals of fifteen days from the date of sowing. The measurement was made from the base of the plant to the uppermost leaf-tip for all plants and the mean taken.

ii. Number of vegetative tillers

This was also noted and recorded at fortnightly intervals from the time of sowing. The tillers in all the hills were counted and the average noted.

iii. Number of productive tillers

The productive tiller counts were made one day before harvest for all plants in all the hills and the average taken.

iv. Length of panicle

Ten plants were selected at random in each replication and the average length of panicle measured.

v. Weight of panicle

From each replication ten random samples were selected and the average weight of panicle observed.

vi. Number of filled grains per panicle

The number of filled grains was counted in ten randomly selected panicles in each replication and the mean taken.

vii. Grain-chaff ratio

The completely filled grains and unfilled grains in the above ten randomly selected panicles were separately counted. The grain-chaff ratio was then calculated for each replication.

viii. Yield of grain per pot

This was recorded for each pot separately after air drying.

ix. Yield of straw per pot

The weight of straw was also recorded for each pot separately after air drying.

x. Yield of root

The roots were carefully gathered from each pot, washed with water to free from sand particles and the weight recorded after air drying.

xi. Thousand grain weight

This was noted by randomly selecting 1000 grains from each replication and observing the weight.

xii. Deficiency symptoms

The symptoms of deficiency of plants in the pots which had received no phosphorus application were also noted.

C. Laboratory Studies

The grain and straw were dried to constant weight in an air oven at 105°C. The dried straw was cut into small pieces with a pair of scissors and the grain ground in an electric grinder. The samples of straw and grain thus prepared were stored in air-tight, labelled glass containers for chemical analysis. They were analysed for their N, P and K contents using standard analytical procedures. Nitrogen was estimated by the Kjeldahl method as described in A.O.A.C. (1960). Phosphorus and potassium

were estimated after wet digestion with the triple acid mixture. The colorimetric method suggested by Jackson (1962) was used for the determination of phosphorus and the volumetric procedure detailed by Piper (1950) was followed for the estimation of potassium.

RESULTS

R E S U L T S

The results obtained in the pot culture experiment to study the influence of phosphorus on the growth, yield and nutrient content of two high yielding varieties of rice are given below. The data have been statistically analysed and conclusions drawn.

A. GROWTH

The various growth measurements made were height of plant, number of tillers, number of productive tillers and length of panicle. The data are presented in Tables II, III, IV and VII.

1. Height of plant

The measurement of plant height at four different stages of growth revealed that at all the stages the treatment differences were significant at 1 percent level. The difference between the two varieties was also highly significant. Significant interaction was noted between variety and level of phosphorus as well.

Though Taichung Native 1 is a well known dwarf variety it was found to be taller than Tainan 3 in the

Table II

Effect of different levels of phosphorus on the height of two varieties of rice at four stages of growth

Treatment	Height of plant (cm) on the			
	15th day	30th day	45th day	60th day
V_1P_0	12.8	16.8	17.8	15.2
V_1P_1	17.2	31.1	51.7	61.5
V_1P_2	17.8	31.6	52.9	64.5
V_1P_3	16.9	32.5	51.7	65.0
Mean	16.2	27.9	43.5	51.7
V_2P_0	20.4	29.8	35.4	44.3
V_2P_1	22.5	37.6	49.2	53.5
V_2P_2	22.9	37.3	49.6	54.2
V_2P_3	22.5	37.3	49.1	53.9
Mean	22.1	35.5	45.8	51.5
P_0	16.6	23.3	26.6	29.8
Mean for level P_1	19.9	34.3	50.5	57.5
P_2	20.4	34.5	51.3	59.3
P_3	19.7	34.9	50.4	59.5
C.D.(0.05) for level	2.64	4.05	4.27	4.63
C.D.(0.05) for variety	1.86	3.17	-	-
C.D.(0.05) for interaction	-	-	6.01	6.44

initial stages of growth. However, the difference in height between the two varieties was found to be insignificant at later stages. For treatment P_0 the plants were stunted in growth, and bunched together with a deep green colour. Treatments P_1, P_2 and P_3 (40, 80, 120 kg P_2O_5/ha respectively) produced normal and healthy growth of plants, but there was no significant difference between the treatments. However, treatments P_2 and P_3 tended to produce taller plants than treatment P_1. As might be expected, the height of plants increased with increase in the period of growth and reached a maximum at harvest. The maximum height reached by Tainan 3 was 68.1 cm, while for Taichung Native 1 the corresponding value was 67.8 cm. Treatment P_2 produced the maximum height for Tainan 3 while P_3 induced the maximum height for Taichung Native 1.

2. Number of tillers

There was very significant difference in the number of tillers produced by the two varieties for the different treatments, especially at the early stages of growth. At all stages of growth Taichung Native 1 produced more tillers than Tainan 3. The number of tillers increased upto the 45th day whereafter it tended to decrease. The maximum number of tillers produced by Taichung Native 1 was 20.9 per hill (2 plants) as compared to 13.6 for the other

Table III

Effect of different levels of phosphorus on the number of tillers of two varieties of rice at four stages of growth

Treatment		Number of tillers on the			
		15th day	30th day	45th day	60th day
V_1P_0		2.0	2.2	2.1	1.7
V_1P_1		2.0	7.9	17.3	14.5
V_1P_2		2.0	8.4	17.5	13.9
V_1P_3		2.0	8.2	17.5	15.4
Mean		2.0	6.7	13.6	11.4
V_2P_0		3.3	10.0	11.6	13.6
V_2P_1		6.3	22.0	23.2	20.7
V_2P_2		6.4	24.0	24.6	22.0
V_2P_3		5.9	23.0	24.5	22.4
Mean		5.4	19.8	20.9	19.7
Mean for level	P_0	2.7	6.1	6.8	7.7
	P_1	4.1	15.0	20.3	17.6
	P_2	4.2	16.2	21.1	17.9
	P_3	3.9	15.6	21.0	18.9
C.D.(0.05) for level		0.43	2.10	2.32	2.42
C.D.(0.05) for variety		0.38	1.48	1.63	1.72
C.D.(0.05) for interaction		0.59	3.00	-	-

variety. Application of phosphorus resulted in the production of more tillers, but there was no significant difference between treatments P_1, P_2 and P_3.

3. Number of productive tillers

In the matter of productive tillers also Taichung Native 1 excelled Tainan 3. The maximum number of productive tillers was 17.0 for an application of 120 kg P_2O_5/ha for Taichung Native 1. In the case of Tainan 3 the maximum number of productive tillers was only 9.6 for the highest level of phosphorus application. When the average number of tillers for all the treatments was compared the figure for Taichung Native 1 was 14.5 as against 7.3 for Tainan 3. Increasing levels of phosphorus application tended to increase the number of productive tillers even though the difference was not statistically significant.

4. Length of panicle

The length of panicle was found to vary significantly with variety and treatment. The maximum length (20.1 cm) was found for Taichung Native 1 for an application of 120 kg P_2O_5/ha. In the case of Tainan 3 the longest panicle measured only 19.5 cm for the same rate of phosphate application. The average length of panicle

Table IV

Effect of different levels of phosphorus on the height and number of productive tillers of two rice varieties at harvest

Treatment		Height (cm)	Number of productive tillers
V_1P_0		44.5	1.6
V_1P_1		73.3	9.3
V_1P_2		83.5	8.7
V_1P_3		77.8	9.6
Mean		68.1	7.3
V_2P_0		57.9	8.8
V_2P_1		69.2	15.2
V_2P_2		72.1	16.9
V_2P_3		72.2	17.0
Mean		67.8	14.5
	P_0	51.2	5.2
Mean for level	P_1	71.2	12.3
	P_2	74.5	12.6
	P_3	75.0	13.6
C.D.(0.05) for level		6.19	2.23
C.D.(0.05) for variety		-	1.56
C.D.(0.05) for interaction		8.58	-

for all treatments was 19.1 cm in the case of Taichung Native 1 and 16.9 cm for Tainan 3. Although the differences between levels of phosphorus application were not statistically significant, increasing levels of this nutrient resulted in an increase in the length of panicle.

5. Flowering duration

The data on flowering duration showed that phosphorus treatment had a significant effect on this character. The varietal difference was also significant. Flowering duration was longest (101 days) for Tainan 3 for no phosphorus treatment whereas for Taichung Native 1 plants getting no phosphorus treatment flowered after 82 days. When the average figures for the different levels of phosphorus application were compared it was found that for Taichung Native 1 the flowering duration was only 72 days as against 79 days for Tainan 3.

B. YIELD

The results relating to the effect of variety and level of phosphorus on yield characters, such as weight of grain, weight of straw, weight of root, weight of 1000 grains, number of grains per earhead, grain:chaff ratio and the weight of panicle are presented in Tables V, VI and VII.

1. Yield of grain (Figure 1)

As far as the yield of grain was concerned, Taichung Native 1 was found to be superior to Tainan 3. The highest yield of 393.0 g/pot (3930.0 kg/ha) was obtained for Taichung Native 1 for a phosphorus application of 120 kg P_2O_5/ha. For Tainan 3 the maximum yield obtained was only 214.7 g/pot (2147.0 kg/ha) for the same treatment. The application of phosphorus significantly increased the yield of grain over no phosphorus treatment. Increasing levels of phosphorus application resulted in a correspondingly increasing yield of grain, but the results were not statistically significant. This was true for both the varieties studied.

2. Yield of straw (Figure 1)

The yield of straw also showed significant difference between the two varieties. As in the case of grain yield, Taichung Native 1 produced the highest yield of straw viz., 690.3 g/pot (6903.0 kg/ha) for a phosphate application of 120 kg P_2O_5/ha. In the case of Tainan 3 the maximum straw yield was only 348.0 g/pot (3480.0 kg/ha) for the same rate of phosphate application. In both varieties application of phosphorus resulted in significant and appreciable increase in yield of straw over control.

Table V

Effect of different levels of phosphorus on the yield of grain, straw and root of two varieties of rice (Expressed as g/pot)

Treatment		Grain	Straw	Root
V_1P_0		24.0	34.0	22.0
V_1P_1		148.7	332.3	220.0
V_1P_2		179.7	329.0	277.0
V_1P_3		214.7	348.0	302.3
Mean		141.7	260.8	205.3
V_2P_0		155.7	274.7	175.0
V_2P_1		365.7	527.0	288.3
V_2P_2		364.7	634.0	323.3
V_2P_3		393.0	690.3	324.7
Mean		319.8	531.5	277.8
	P_0	89.8	154.3	98.5
Mean for level	P_1	257.2	429.7	254.2
	P_2	272.2	481.5	300.2
	P_3	303.8	619.2	313.5
C.D.(0.05) for level		73.53	83.23	74.51
C.D.(0.05) for variety		51.90	58.77	59.85
C.D.(0.05) for interaction		-	-	-

Table VI

Effect of different levels of phosphorus on the yield of grain, straw and root of two varieties of rice (Expressed as kg/ha)

Treatment		Grain	Straw	Root
V_1P_0		240.0	340.0	220.0
V_1P_1		1487.0	3323.0	2200.0
V_1P_2		1797.0	3290.0	2770.0
V_1P_3		2147.0	3480.0	3023.0
Mean		1417.0	2608.0	2053.0
V_2P_0		1557.0	2747.0	1750.0
V_2P_1		3657.0	5270.0	2883.0
V_2P_2		3647.0	6340.0	3233.0
V_2P_3		3930.0	6903.0	3247.0
Mean		3198.0	5315.0	2778.0
	P_0	898.0	1543.0	985.0
Mean for level	P_1	2572.0	4297.0	2542.0
	P_2	2722.0	4815.0	3002.0
	P_3	3038.0	6192.0	3135.0
C.D.(0.05) for level		735.3	832.3	745.1
C.D.(0.05) for variety		519.0	587.7	598.5
C.D.(0.05) for interaction		-	-	-

However, there were no statistically significant differences in the yields of straw for the different levels of phosphorus application, although the general tendency for this yield character was to increase steadily with increase in the level of this element.

3. Yield of root

The root yield was also found to vary significantly with variety and treatment. The maximum yield of root viz., 324.7 g/pot (3247.0 kg/ha) was obtained for Taichung Native 1 for an application of 120 kg P_2O_5/ha whereas for Tainan 3 the same rate of phosphate application produced only 302.3 g/pot (3023.0 kg/ha) of root. When the average figures for the two varieties are compared Taichung Native 1 is seen to have produced the highest yield of 277.8 g root/pot (2778.0 kg/ha) as against 205.3 g/pot (2053.0 kg/ha) for Tainan 3. In the case of this character also the application of phosphorus resulted in appreciable increase in yield of root over control for both the varieties. Increasing levels of phosphate application tended to increase the root yield, but the differences between them were not statistically significant.

4. Number of grains per panicle

The number of grains per panicle differed signifi-

cantly with treatment. Significant interaction was also noted between level of phosphorus and variety, but the varietal difference was not statistically significant. The maximum number of 62.1 grains per panicle was produced by Tainan 3 for an application of 120 kg P_2O_5/ha, while Taichung Native 1 produced panicles with a maximum number of 56.7 grains only for the same treatment. For Tainan 3 an application of 120 kg P_2O_5/ha produced panicles with the maximum number of grains whereas for Taichung Native 1, panicles with the largest number of grains were obtained for an application of 40 kg P_2O_5/ha.

5. Grain:chaff ratio

In the case of Tainan 3 the average grain:chaff ratio was found to be as low as 3.8 while for Taichung Native 1 this ratio was 4.2. The lowest ratio in both varieties was obtained for treatment P_0. Phosphate application had a beneficial influence on this ratio but the differences between the various phosphorus treatments were not significant.

6. Thousand grain weight

The weight of 1000 grains did not vary significantly with variety, but it was found to depend on phosphorus

Table VII

Effect of different levels of phosphorus on the flowering duration and yield characters of two varieties of rice

Treatment		Flowering duration (days)	No. of grains per panicle	Grain: chaff ratio	Length of panicle (cm)	Wt. of panicle (g)	Wt. of 1000 grains (g)
V_1P_0		101	20.5	2.2	11.8	0.48	16.52
V_1P_1		72	50.7	3.9	18.2	1.63	26.16
V_1P_2		71	61.4	5.0	18.5	1.74	26.86
V_1P_3		71	62.1	3.9	19.5	1.92	26.57
Mean		79	48.7	3.8	16.9	1.44	24.03
V_2P_0		82	50.7	3.5	17.3	1.05	20.94
V_2P_1		67	57.9	4.5	18.8	1.63	25.88
V_2P_2		69	54.9	4.3	20.0	1.60	24.03
V_2P_3		68	56.7	4.3	20.1	1.65	24.10
Mean		72	55.1	4.2	19.1	1.48	23.74
	P_0	91	35.6	2.8	14.6	0.76	18.73
Mean for level	P_1	69	54.3	4.4	18.5	1.63	26.02
	P_2	70	58.1	4.6	19.2	1.67	25.45
	P_3	69	59.4	4.1	19.8	1.79	25.34
C.D.(0.05) for level		2.57	9.39	0.52	1.14	0.37	1.72
C.D.(0.05) for variety		1.82	-	-	0.79	-	-
C.D.(0.05) for interaction		3.58	13.41	-	1.61	-	2.36

treatment. Significant interaction was also obtained between treatment and variety. The average 1000 grain weight for Tainan 3 was 24.03 g as compared to 23.74 g for Taichung Native 1, but the difference was not significant. The maximum weight for 1000 grains (26.86 g) for Tainan 3 was obtained for an application of 80 kg P_2O_5/ha while for Taichung Native 1 the maximum 1000 grain weight (25.88 g) was secured for an application of 40 kg P_2O_5/ha.

7. Weight of panicle

The weight of panicle was found to vary significantly with level of phosphorus although the varietal difference was not statistically significant. In the case of Tainan 3 the maximum weight of panicle (1.92 g) was obtained for an application of 120 kg P_2O_5/ha. For Taichung Native 1 also panicle with the maximum weight (1.65 g) was obtained for the same treatment. The general tendency was for the panicle weight to increase with increase in phosphorus application although the differences were not statistically significant.

C. NUTRIENT CONTENT

Data relating to the influence of variety and level of phosphorus on the nutrient content in the grain and straw of rice are presented in Tables VIII and IX.

1. Grain (Figure 2)

(a) Nitrogen

The data show that both variety and level of phosphorus influenced appreciably the nitrogen content of grain. The results were significant at 1 percent level for variety and at 5 percent level for treatment. The interaction between variety and level of phosphorus was also highly significant.

The highest nitrogen content of 1.12 per cent was obtained for Taichung Native 1 for no phosphorus treatment and the lowest value of 0.92 percent was found in the case of Tainan 3 for a phosphorus application of 120 kg P_2O_5/ha. The mean value for all treatments was 1.06 percent for Taichung Native 1 as compared to 0.99 percent for Tainan 3. Although the nitrogen content of grain for the different levels of phosphorus application varied only within insignificant levels, the general tendency was for this element to decrease with increased applications of phosphorus.

(b) Phosphorus

The phosphorus content of grain was appreciably influenced by treatment, but the influence of variety was found to be less pronounced. There was practically no

difference between the mean phosphorus contents of the grain of Tainan 3 and Taichung Native 1, the figures for the two varieties being 0.62 percent and 0.61 percent respectively. However, in both the varieties the phosphorus content of grain tended to increase with increasing levels of phosphorus application. The highest phosphorus content of 0.81 percent was obtained for Tainan 3 for an application of 120 kg P_2O_5/ha whereas for Taichung Native 1 it was only 0.75 percent for the same treatment.

(c) Potassium

Both variety and level of phosphorus were found to have significant influence on the potassium content of grain at 5 percent level. Significant interaction was also noted between variety and level of phosphorus.

The highest potassium content of 1.19 percent was obtained for Tainan 3 for applications of phosphorus at the rates of 80 and 120 kg P_2O_5/ha. In the case of Taichung Native 1 also the same value was obtained for an application of 80 kg P_2O_5/ha. The mean value for all treatments was 1.13 percent for Tainan 3 as compared to 0.99 for Taichung Native 1.

Table VIII

Effect of different levels of phosphorus on the nutrient content of grain of two varieties of rice (Expressed as percent)

Treatment		N	P_2O_5	K_2O
V_1P_0		1.01	0.20	1.06
V_1P_1		0.98	0.70	1.07
V_1P_2		1.06	0.76	1.19
V_1P_3		0.92	0.81	1.19
Mean		0.99	0.62	1.13
V_2P_0		1.12	0.31	0.99
V_2P_1		1.08	0.65	0.76
V_2P_2		1.02	0.73	1.19
V_2P_3		1.02	0.75	1.05
Mean		1.06	0.61	0.99
	P_0	1.07	0.25	1.03
Mean for level	P_1	1.03	0.68	0.92
	P_2	1.04	0.74	1.18
	P_3	0.97	0.78	1.13
C.D.(0.05) for level		0.064	0.064	0.160
C.D.(0.05) for variety		0.047	-	0.036
C.D.(0.05) for interaction		0.150	-	-

2. Straw (Figure 3)

(a) Nitrogen

The data in Table IX show that both variety and level of phosphorus had significant effect on the nitrogen content of straw. The results were significant at 1 percent level for variety and at 5 percent level for treatment.

The highest nitrogen content of 0.67 percent was obtained for Tainan 3 for no phosphorus application and the lowest value of 0.34 percent was found in the case of Taichung Native 1 for an application of 80 kg P_2O_5/ha. When the mean values for all treatments are compared, Tainan 3 is found to contain 0.59 percent nitrogen and Taichung Native 1 0.43 percent. As in the case of the nitrogen content of grain, the nitrogen content of straw was also found to vary only insignificantly for the different phosphorus treatments. But the general tendency was for the nitrogen content to decrease with increasing levels of phosphorus application.

(b) Phosphorus

Although the varietal influence on the phosphorus content of straw was not statistically significant, the level of phosphorus application markedly influenced the

content of this element in the straw. Significant interaction between level of phosphorus and variety was also observed. As in the case of the phosphorus content of grain, the phosphorus content of straw was also not influenced by variety. But increasing levels of phosphorus application tended to increase the phosphorus content of straw, although the differences were not statistically significant. The highest phosphorus content of 0.43 percent was obtained for Taichung Native 1 for an application of 120 kg P_2O_5/ha, whereas for Tainan 3 the maximum value was 0.40 percent for an application of 80 kg P_2O_5/ha. The average values for all the treatments for the two varieties were very similar. For Tainan 3 it was 0.28 percent and for Taichung Native 1 it was 0.27 percent.

(c) Potassium

The potassium content of straw was considerably influenced by variety, as well as the rate of phosphorus application. The results were significant at 1 percent level. Significant interaction between variety and treatment was also noted. The highest potassium content of 2.63 percent was obtained for Taichung Native 1 for an application of 80 kg P_2O_5/ha, whereas for Tainan 3 it was 1.72 percent for no phosphate application. The mean value for all treatments was 2.24 percent for Taichung Native 1 as compared to 1.22 percent for Tainan 3.

Table IX

Effect of different levels of phosphorus on the nutrient content of straw of two varieties of rice (Expressed as percent)

Treatment		N	P_2O_5	K_2O
V_1P_0		0.67	0.12	1.72
V_1P_1		0.59	0.24	0.77
V_1P_2		0.64	0.40	0.82
V_1P_3		0.49	0.37	1.57
Mean		0.59	0.28	1.22
V_2P_0		0.51	0.14	2.24
V_2P_1		0.44	0.19	2.06
V_2P_2		0.34	0.33	2.63
V_2P_3		0.42	0.43	2.01
Mean		0.43	0.27	2.24
	P_0	0.59	0.13	1.98
Mean for level	P_1	0.51	0.22	1.42
	P_2	0.49	0.37	1.73
	P_3	0.46	0.40	1.79
C.D.(0.05) for level		0.09	0.03	0.17
C.D.(0.05) for variety		0.06	0.02	0.11
C.D.(0.05) for interaction		-	0.04	0.24

D. NUTRIENT REMOVAL

The data relating to the removal of nutrients by the two rice varieties are furnished in Tables X, XI, XII and XIII.

1. Grain (Figure 4)

(a) Nitrogen

The total nitrogen removal by grain was found to be more for Taichung Native 1 than for Tainan 3. The maximum nitrogen uptake (4.009 g/pot - 40.09 kg/ha) was by Taichung Native 1 for an application of 120 kg P_2O_5/ha and the lowest value (0.242 g/pot - 2.42 kg/ha) was for Tainan 3 for no phosphorus application. The mean value for all the treatments was 3.355 g/pot (33.55 kg/ha) for Taichung Native 1 and 1.396 g/pot (13.96 kg/ha) for Tainan 3.

(b) Phosphorus

Taichung Native 1 absorbed more phosphorus (2.117 g/pot - 21.17 kg/ha) than Tainan 3 (1.046 g/pot - 10.46 kg/ha). Increasing levels of phosphorus application resulted in increased uptake of phosphorus by grain. The maximum phosphorus uptake of 2.947 g/pot (29.47 kg/ha) was by Taichung Native 1 for an application of 120 kg P_2O_5/ha as compared to 1.739 g/pot (17.39 kg/ha) by Tainan 3 for the same treatment. When the average values for all the

treatments are compared it is found to be 2.117 g/pot (21.17 kg/ha) for Taichung Native 1 and 1.046 g/pot (10.46 kg/ha) for Tainan 3.

(c) Potassium

The uptake of potassium was very high for Taichung Native 1 (3.121 g/pot - 31.21 kg/ha) as compared to Tainan 3 (1.635 g/pot - 16.35 kg/ha). The maximum uptake of 4.339 g/pot (43.39 kg/ha) was for Taichung Native 1 for an application of 80 kg P_2O_5/ha, while for Tainan 3 it was 2.555 g/pot (25.55 kg/ha) for an application of 120 kg P_2O_5/ha.

2. Straw (Figure 5)

(a) Nitrogen

As in the case of the uptake of nitrogen by grain, the removal of this element in straw by Taichung Native 1 was much greater than that by Tainan 3. The maximum uptake by Taichung Native 1 was 2.899 g/pot (28.99 kg/ha) for an application of 120 kg P_2O_5/ha, whereas it was only 2.106 g/pot (21.06 kg/ha) for Tainan 3 for an application of 80 kg P_2O_5/ha. The average value for all treatments was 2.193 g/pot (21.93 kg/ha) for Taichung Native 1 as compared to 1.500 g/pot (15.00 kg/ha) for Tainan 3.

(b) Phosphorus

As observed in the case of the absorption of phosphorus by grain the uptake of this element by straw increased considerably with increased levels of phosphorus application, though the differences were not significant. The maximum uptake of 2.968 g/pot (24.68 kg/ha) was for Taichung Native 1 for an application of 120 kg P_2O_5/ha and the corresponding figure for Tainan 3 was 1.316 g/pot (13.16 kg/ha) for an application of 80 kg P_2O_5/ha.

(c) Potassium

The data showed that the removal of potassium by straw was more in the case of Taichung Native 1 than in Tainan 3. The highest uptake was 16.674 g/pot (166.74 kg/ha) by Taichung Native 1 for an application of 80 kg P_2O_5/ha and the lowest uptake of 0.585 g/pot (5.85 kg/ha) was by Tainan 3 for no phosphate application. The mean value for all treatments was 11.889 g/pot (118.89 kg/ha) for Taichung Native 1 as compared to 2.826 g/pot (28.26 kg/ha) for Tainan 3.

Table X

Effect of different levels of phosphorus on nutrient removal by grain in two varieties of rice (Expressed as g/pot)

Treatment		N	P_2O_5	K_2O
V_1P_0		0.242	0.048	0.254
V_1P_1		1.461	1.041	1.591
V_1P_2		1.905	1.356	2.138
V_1P_3		1.975	1.739	2.555
Mean		1.396	1.046	1.635
V_2P_0		1.743	0.483	1.541
V_2P_1		3.949	2.377	2.775
V_2P_2		3.719	2.662	4.339
V_2P_3		4.009	2.947	3.829
Mean		3.355	2.117	3.121
	P_0	0.990	0.265	0.897
Mean for level	P_1	2.705	1.709	2.183
	P_2	2.812	2.009	3.238
	P_3	2.992	2.343	3.192
C.D.(0.05) for level		0.729	0.601	0.751
C.D.(0.05) for variety		0.124	0.446	0.536
C.D.(0.05) for interaction		-	-	-

Table XI

Effect of different levels of phosphorus on nutrient removal by straw in two varieties of rice (Expressed as g/pot)

Treatment		N	P_2O_5	K_2O
V_1P_0		0.228	0.041	0.585
V_1P_1		1.961	0.797	2.559
V_1P_2		2.106	1.316	2.698
V_1P_3		1.705	1.287	5.464
Mean		1.500	0.860	2.826
V_2P_0		1.401	0.385	6.153
V_2P_1		2.318	1.001	10.856
V_2P_2		1.156	2.092	16.674
V_2P_3		2.899	2.968	13.875
Mean		2.193	1.612	11.889
Mean for level	P_0	0.815	0.213	3.369
	P_1	2.139	0.899	6.797
	P_2	2.131	1.704	9.686
	P_3	2.302	2.127	9.669
C.D.(0.05) for level		0.472	0.654	1.502
C.D.(0.05) for variety		0.322	0.463	1.073
C.D.(0.05) for interaction		0.665	-	2.170

Table XII

Effect of different levels of phosphorus on nutrient removal of grain in two varieties of rice (Expressed as kg/ha)

Treatment		N	P_2O_5	K_2O
V_1P_0		2.42	0.48	2.54
V_1P_1		14.61	10.41	15.91
V_1P_2		19.05	13.56	21.38
V_1P_3		19.75	17.39	25.55
Mean		13.96	10.46	16.35
V_2P_0		17.43	4.83	15.41
V_2P_1		39.49	23.77	27.75
V_2P_2		37.19	26.62	43.39
V_2P_3		40.09	29.47	38.29
Mean		33.55	21.17	31.21
Mean for level	P_0	9.90	2.65	8.97
	P_1	27.05	17.09	21.83
	P_2	28.12	20.09	32.38
	P_3	29.92	23.43	31.92
C.D.(0.05) for level		7.29	6.01	7.51
C.D.(0.05) for variety		1.24	4.46	5.36
C.D.(0.05) for interaction		-	-	-

Table XIII

Effect of different levels of phosphorus on nutrient removal by straw in two varieties of rice (Expressed as kg/ha)

Treatment		N	P_2O_5	K_2O
V_1P_0		2.28	0.41	5.85
V_1P_1		19.61	7.97	25.59
V_1P_2		21.06	13.16	26.98
V_1P_3		17.05	12.87	54.64
Mean		15.00	8.60	28.26
V_2P_0		14.01	3.85	61.53
V_2P_1		23.18	10.01	108.56
V_2P_2		21.56	20.92	166.74
V_2P_3		28.99	29.68	138.75
Mean		21.93	16.12	118.89
	P_0	8.15	2.13	33.69
Mean for level	P_1	21.39	8.99	67.07
	P_2	21.31	17.04	96.86
	P_3	23.02	21.27	96.69
C.D.(0.05) for Level		4.72	6.54	15.02
C.D.(0.05) for variety		3.22	4.63	10.73
C.D.(0.05) for interaction		6.65	-	21.70

DISCUSSION

DISCUSSION

The results obtained in the present study are briefly discussed below:-

Growth characters

The beneficial effect of phosphorus on the growth of the rice plant is clear from the increased height attained by plants receiving phosphorus application as compared to treatments devoid of this element which recorded the minimum plant height at all the five stages of growth. This result is in accordance with the findings of Chavan et al (1957), Moriya and Sato (1958) and Bhatta (1959) who got increased growth due to application of phosphorus. But the effects of different levels of phosphorus in the present study were not very significant among themselves. This might be due to the fact that the lowest level of phosphorus applied, viz., 40 kg P_2O_5/ha was sufficient to meet the minimum requirements of the crop for this element, so that the higher levels of P_2O_5 applied could not bring about any significant difference. This conclusion is in conformity with the results obtained by Srinivasulu and Pawar (1965) who got no significant effect on plant height due to the application

of increasing levels of phosphorus to two indica x japonica hybrids (Hr. 19 x Norin 18). Plants under the no phosphorus treatment in the present investigation exhibited marked deficiency symptoms. The symptoms were a stunted growth, deep green colour of the foliage and a bunching together of the leaves. The external symptoms noted in this study agree with those reported by Aiyar (1946) and Hayashi et al (1951) for P deficiency.

Tiller number at all the five stages of growth was found to be more for Taichung Native 1 than for Taimna 3. The production of tillers is presumably a varietal character. The influence of phosphorus in increasing the number of tillers is noteworthy. While the plants under the no phosphorus treatment showed the least number of tillers, the increased application of this nutrient resulted in a progressive increase in the tiller number. This is in agreement with the findings of Takijima et al (1959), Srinivasulu and Pawar (1965), Das (1959), Lal and Subba Rao (1960) and Yoshida (1958), all of whom have reported a beneficial effect for phosphorus on tillering. Though an application of 40 kg P_2O_5/ha resulted in significantly larger number of tillers over control, the differences in the tiller number for the different levels of phosphorus were not significant. This, as explained

earlier, must be attributed to the fact that even an application of 40 kg P_2O_5/ha is adequate to meet the normal requirements of the crop for this element.

The length of panicle is a varietal character and in the present study it was observed that Taichung Native 1 had slightly longer panicles than Tainan 3. Phosphorus application has influenced this character within certain limits. While the application of this element at 40 kg P_2O_5/ha helped to produce significantly longer panicles over P_0 treatment in both varieties, there was no significant difference between the various levels of phosphorus used. The beneficial effect of phosphorus on panicle length noted in this study is in agreement with the findings of Lal and Subba Rao (1960) who has reported that the deficiency of phosphorus may result in a reduction in all vegetative characters except leaf size in paddy. However, Takijima et al (1959) and Srinivasulu and Pawar (1965) did not obtain any significant effect for phosphorus application on panicle length. It is likely that in the latter case the soil in which the experiment was conducted already contained a minimum level of phosphorus for producing fairly normal panicles, whereas in the present case the medium used being sand,

which was highly deficient in phosphorus, the deficiency of this element resulted in abnormally shorter panicles.

Yield characters

In the matter of grain yield the varietal difference between Taichung Native 1 and Tainan 3 has been amply brought out in the present study. Taichung Native 1 produced significantly higher yields over Tainan 3 at every level of phosphorus application. In the same variety phosphorus application resulted in significantly higher yields over no phosphorus treatment. Increase in yield due to the application of phosphorus has been reported by Ishizuka and Tanaka (1951), Raychoudhari (1953), Parthasarathi (1953), Paul (1953), Desai et al (1954), Digar (1960), Sree Ramulu and Mariakulandai (1963) and several other workers. However, the differences in yield for the different levels of phosphorus were not statistically significant. As explained earlier, this might be due to the fact that an application of phosphorus at 40 kg P_2O_5/ha satisfies the normal requirements of the crop for this element and higher applications would result only in insignificantly higher yields.

As in the case of grain yield, the yield of straw was also significantly higher for Taichung Native 1 than for Tainan 3. Obviously the large number of tillers produced by Taichung Native 1 more than compensates for the shortness in height of this variety. Again, the application of phosphorus has helped to produce significantly higher yields of straw in both varieties. Neverthless, the yields of straw for the different levels of phosphorus application were not significantly different, evidently for the same reasons as discussed above in relation to the grain yield. However, the tendency was discernible for straw yields to increase with increased applications of phosphorus. The beneficial effect of phosphorus in increasing straw yield has been reported by Paul (1953), Digar (1960) and Sree Ramulu and Mariakulandai (1963). It is possible that phosphorus enhances straw yield indirectly by its effect on a better utilization of nitrogen by the plants.

One of the most important functions attributed to phosphorus as a plant nutrient is its stimulating effect on root growth and development. (Russell, 1961). Phosphorus promotes root development and helps in the early establishment of the plant in the soil. In the present study also phosphorus application has resulted in

a more vigourous and healthy root system as evidenced from the data obtained. However, there is no significant difference in the yields of root for the various levels of phosphorus application, as in the case of grain and straw yields. Hayashi et al (1951) reported a stoppage of root growth due to phosphorus deficiency. In the present case also the yield of root was significantly low for the no phosphorus treatment.

For all treatments other than P_0 Tainan 3 contained a larger number of grains per panicle than Taichung Native 1. The mean number of grains per panicle, however, was more for Taichung Native 1 but the difference was not significant. Application of phosphorus has resulted in considerably larger number of grains per panicle over no phosphorus treatment. The differences between the various levels of phosphorus, neverthless, were not significant.

Phosphorus is credited with the role of inducing flowering and producing well-formed and fully-filled grains in cereals and this has been brought about by the results of the present study. It is noteworthy that in the absence of phosphorus both Taichung Native 1 and Tainan 3 required considerably longer periods for coming to flower. Taichung Native 1 required 82 days to flower under the P_0 treatment

while it required only 67-69 days under the three levels of phosphorus application. Similarly, Tainan 3 under the no phosphorus treatment required 101 days to reach the flowering stage as compared to 71-72 days for plants under the different phosphorus treatments. It may be noted that the deficiency of phosphorus has resulted in a delay of about 13 days for Taichung Native 1 and 29 days for Tainan 3 in the flowering duration. This observation points strongly to the necessity of adequate phosphorus fertilization for inducing flowering in plants at the right time.

In the matter of producing well-filled grains also phosphorus has to play an important role. This is evident from the beneficial effect of this element on the grain-chaff ratio as obtained in the present study. For no phosphorus treatment this ratio was 2.2 for Tainan 3 and 3.5 for Taichung Native 1. For the various phosphorus treatments the ratio was 3.4 - 5.0 for Tainan 3 and 4.3 - 4.5 for Taichung Native 1. The weight of 1000 grains is also markedly influenced by phosphorus application. Under the no phosphorus treatment 1000 grains of Tainan 3 weighed only 16.52 g which increased to 26.16 - 26.96 g under applications of phosphorus. Similarly, for Taichung Native 1 the 1000 grain weight was only 20.94 g for no

phosphorus treatment as compared to a weight of 24.03 - 25.88 g under the different levels of phosphorus application. This result indicates the importance of phosphorus nutrition for producing a higher proportion of well-formed and fully-filled rice grains.

Nutrient absorption

The level of phosphorus application influences considerably the levels of the different nutrients absorbed by the crop. The nitrogen contents of grain and straw are, for instance, negatively correlated to the level of phosphorus in the plant. The highest nitrogen content in the plant was obtained in the treatment without phosphorus and the lowest level of nitrogen for the highest rate of phosphorus application. This is in agreement with the observations of Aiyar (1946), Gasser (1956) and Basak et al (1961) who noted that the nitrogen content decreased with an increase in the level of phosphorus applied. However, when the total nitrogen removal per pot is considered, it is observed that the increase in the levels of phosphorus results in an increase in the amount of total nitrogen absorbed. This, obviously, is an indirect effect of the influence of phosphorus in increasing the total yield.

As might be expected, increasing rates of phosphorus application have resulted in increasing levels of this element in the plant. Many workers including Burriel et al (1951), Gasser (1956) and Udevenko and Bezlyudnyi (1965) have reported increased phosphorus content of plants due to the application of phosphorus. In the work carried out at the International Rice Research Institute, Philippines, (Tanaka et al, 1964) also similar results were obtained. As increasing rates of phosphorus application have resulted in increased yields, as well as increased levels of this element in the plant, it is evident that the total removal of this element by the crop is also positively influenced by phosphorus application.

Whereas it appears that phosphorus application has a definite negative or positive influence on the nitrogen and phosphorus contents of the rice plant nothing for certain can be said about its effect on the absorption of potassium. In both varieties the straw has invariably contained a higher level of this element as compared to the grain. But as regards the effect of different levels of phosphorus on potassium content and its absorption it is noted that the amount of K_2O absorbed follows no regular relationship with the level of phosphorus applied.

This is in conformity with the findings of Gasser (1956) who obtained a variable effect on potassium absorption due to the application of phosphorus.

The results in the present study throw light on the total quantity of NPK removed per hectare by these newly introduced high yielding varieties. Disregarding the amount of nutrients retained in the root it is observed that Tainan 3 removes from an hectare of land 18.40 kg of N, 15.13 kg of P_2O_5, 40.09 kg of K_2O in the grain and straw for the highest application of phosphorus viz., 120 kg P_2O_5/ha. The corresponding figures for Taichung Native 1 are 34.54 kg of N, 29.57 kg of P_2O_5, 88.52 kg of K_2O per hectare for the same treatment. These results provide valuable data for assessing the nutrient requirements of these varieties and for formulating suitable manurial schedule for them.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

To study the influence of phosphorus on the growth, yield and nutrient uptake of two high yielding varieties of rice recently introduced into Kerala a pot culture experiment was carried out in randomised block design with 8 treatments and 3 replications. The varieties used were Tainan 3 and Taichung Native 1. The levels of phosphorus applied were 0, 40, 80 and 120 kg P_2O_5/ha in the form of superphosphate over and above adequate amounts of nitrogen, potassium and the other essential elements. The main findings are given hereunder:-

1. The height of plants was more for Taichung Native 1 during the early stages of growth but after the 45th day Tainan 3 assumed more vigourous growth and reached a greater height. In both varieties the height of plants receiving phosphorus was significantly more than those under the no phosphorus treatment. Plant height tended to increase with increase in the rate of phosphorus application but the differences were not significant.

2. In the matter of tiller number variety Taichung Native 1 was superior to variety Tainan 3. Application of phosphorus resulted in significantly larger number of tillers over the no phosphorus treatment. Increasing levels of phosphorus application tended to produce increased number of tillers but the differences were not significant.

3. Variety Taichung Native 1 produced significantly longer panicles than variety Tainan 3. Significant increase in panicle length was noted for applications of phosphorus but the results were not significant for the different levels of this nutrient.

4. Flowering duration was delayed by as many as 29 days in variety Tainan 3 and by 13 days in variety Taichung Native 1 under conditions of phosphorus deficiency.

5. Variety Taichung Native 1 was superior to variety Tainan 3 in yield of grain, straw and root. In both varieties application of phosphorus resulted in significantly higher yield of grain, straw and root and with increasing applications of phosphorus the yields also tended to increase. But the increases in yield for the different levels of phosphorus were not significant.

6. Varietal influence was not significant in other yield characters such as number of grains per panicle, grain:chaff ratio, 1000 grain weight and weight of panicle. But these were markedly influenced by the different levels of phosphorus applied.

7. There was appreciable difference between the two varieties in the matter of nutrient absorption. Variety Taichung Native 1 absorbed more of nitrogen and potassium than Tainan 3. In both varieties the nitrogen content decreased and the phosphorus content increased with increase in the rate of phosphate application. The relationship between potassium and phosphorus contents was variable.

8. Variety Taichung Native 1 removed a maximum of 34.54 kg N/ha, 29.57 kg P_2O_5/ha and 88.52 kg K_2O/ha for a phosphorus application of 120 kg P_2O_5/ha in the grain and straw. The corresponding figures for Tainan 3 were 18.40 kg N/ha, 15.13 kg P_2O_5/ha and 40.09 kg K_2O/ha for the same treatment.

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APPENDIX

Appendix 1

Analysis of variance for plant height (15th day)

Source	S.S.	Df	Variance	F ratio
Total	355.45	23		
Block	22.15	2	11.08	2.46
Treatment	270.18	7	38.60	8.86**
V	209.81	1	209.81	46.52**
P	54.43	3	18.14	4.02*
VP	5.94	3	1.98	1
Error	63.12	14	4.51	

Appendix 2

Analysis of variance for plant height (30th day)

Source	S.S.	Df	Variance	F ratio
Total	1171.73	23		
Block	48.17	2	24.08	2.25
Treatment	973.91	7	139.13	13.02**
V	339.91	1	339.91	31.79**
P	570.44	3	190.15	17.79**
VP	63.56	3	21.19	1.98
Error	149.65	14	10.69	

* Significant at 5 percent level

** Significant at 1 percent level

Appendix 3

Analysis of variance for plant height (45 th day)

Source	S.S.	Df	Variance	F ratio
Total	3345.99	23		
Block	67.38	2	28.69	2.43
Treatment	3123.44	7	446.21	37.81**
V	31.74	1	31.74	2.69
P	2618.84	3	872.95	73.98**
VP	472.86	3	157.62	13.36**
Error	165.17	14	11.80	

Appendix 4

Analysis of variance for plant height (60th day)

Source	S.S.	Df	Variance	F ratio
Total	5763.80	23		
Block	48.97	2	24.48	1.75
Treatment	5518.83	7	788.40	56.31**
V	0.05	1	0.05	1
P	3806.90	3	1268.97	90.64 *
VP	1711.88	3	570.63	40.76**
Error	196.00	14	14.00	

** Significant at 1 percent level

Appendix 5

Analysis of variance for plant height at harvest

Source	S.S.	Df	Variance	F ratio
Total	3120.62	23		
Block	93.68	2	46.84	1.87
Treatment	2675.53	7	382.22	15.23**
V	0.40	1	0.40	1
P	2298.46	3	766.15	30.52**
VP	376.67	3	125.56	5.00*
Error	351.37	14	25.10	-

Appendix 6

Analysis of variance for tiller count (15th day)

Source	S.S.	Df	Variance	F ratio
Total	92.58	23		
Block	0.55	2	0.27	2.3
Treatment	90.32	7	12.90	105.5**
V	71.41	1	71.41	595.1**
P	9.68	3	3.23	26.9**
VP	9.23	3	3.07	25.6**
Error	1.71	14	0.12	-

* Significant at 5 percent level

** Significant at 1 percent level

Appendix 7

Analysis of variance for tiller count (30th day)

Source	S.S.	Df	Variance	F ratio
Total	1533.99	23		
Block	0.27	2	0.13	1
Treatment	1493.06	7	213.30	73.55**
V	1024.42	1	1024.42	353.25**
P	411.40	3	137.13	47.29**
VP	57.24	3	19.08	6.58**
Error	40.66	14	2.90	

Appendix 8

Analysis of variance for tiller count (45th day)

Source	S.S.	Df	Variance	F ratio
Total	1268.39	23		
Block	4.44	2	2.22	1
Treatment	1214.79	7	173.54	49.44**
V	324.87	1	324.87	92.55**
P	879.62	3	293.21	83.54 *
VP	10.30	3	3.43	1
Error	49.16	14	3.51	

** Significant at 1 percent level.

Appendix 9

Analysis of variance for tiller count (60th day)

Source	S.S.	Df	Variance	F ratio
Total	1003.25	23		
Block	7.85	2	3.92	1.02
Treatment	941.70	7	133.10	34.66**
V	412.52	1	412.52	107.42**
P	501.34	3	167.11	43.52**
VP	27.84	3	9.28	2.42
Error	53.70	14	3.84	

Appendix 10

Analysis of variance for tiller count at harvest

Source	S.S.	Df	Variance	F ratio
Total	624.97	23		
Block	1.15	2	0.57	1
Treatment	578.59	7	82.65	25.59**
V	311.04	1	311.04	96.30**
P	263.33	3	87.78	27.18**
VP	4.22	3	1.41	1
Error	45.23	14	3.23	

Appendix 11

Analysis of variance for length of panicle

Source	S.S.	Df	Variance	F ratio
Total	168.960	23		
Block	5.627	2	2.81	3.31
Treatments	151.353	7	21.62	25.33**
V	25.620	1	25.62	30.14 *
P	101.310	3	33.44	39.34*
VP	24.423	3	8.14	9.58**
Error	11.980	14	0.85	

Appendix 12

Analysis of variance for grain yield

Source	S.S.	Df	Variance	F ratio
Total	422440.50	23		
Block	11867.25	2	5933.63	1.7
Treatment	361350.50	7	51621.50	14.6**
V	190104.00	1	190104.00	54.6 *
P	165671.17	3	55223.72	15.7**
VP	5575.33	3	1858.44	0.5
Error	49222.75	14	3515.91	-

** Significant at 1 percent level

Appendix 13

Analysis of variance for straw yield

Source	S.S.	Df	Variance	F ratio
Total	1047555.33	23		
Block	33090.58	2	16545.29	3.66
Treatment	951147.33	7	135878.18	30.04**
V	439562.66	1	438562.66	97.20**
P	492081.66	3	164027.22	36.30**
VP	19503.01	3	6501.00	1.40
Error	63317.42	14	4522.67	

Appendix 14

Analysis of variance for root yield

Source	S.S.	Df	Various	F ratio
Total	389601.84	23		
Block	13237.46	2	6618.73	1.4
Treatment	310878.17	7	44411.17	9.6**
V	152541.05	1	152541.05	32.7**
P	144342.68	3	48114.23	10.3**
VP	13994.44	3	4664.81	1
Error	65486.21	14	4677.58	-

** Significant at 1 percent level

Appendix 15

Analysis of variance for flowering duration

Source	S.S.	Df	Variance	F ratio
Total	2859.96	23		
Block	11.08	2	5.54	1.2
Treatment	2788.62	7	393.33	91.1**
V	330.04	1	330.04	76.04**
P	2168.79	3	722.93	166.57**
VP	289.79	3	96.59	22.25**
Error	60.26	14	4.34	-

Appendix 16

Analysis of variance for number of grains per panicle

Source	S.S.	Df	Variance	F ratio
Total	4852.30	23		
Block	290.72	2	145.36	2.517
Treatment	3753.02	7	536.15	9.284**
V	244.48	1	244.48	4.233
P	2203.03	3	734.34	12.716**
VP	1305.51	3	435.17	7.535**
Error	808.56	14	57.75	

** Significant at 1 percent level

Appendix 17

Analysis of variance for Grain:chaff ratio

Source	S.S.	Df	Variance	F ratio
Total	15.440	23		
Block	0.422	2	0.211	01.2
Treatment	14.760	7	2.108	11.46 *
V	0.960	1	0.960	5.30*
P	10.710	3	3.570	19.30**
VP	3.090	3	1.030	5.50*
Error	0.258	14	0.184	

Appendix 18

Analysis of variance for 1000 grain weight

Source	S.S.	Df	Variance	F ratio
Total	288.8550	23		
Block	2.9538	2	1.4769	1
Treatments	264.4265	7	37.7752	24.63**
V	0.5065	1	0.5065	1
P	213.9206	3	71.3069	46.49**
VP	49.9994	3	16.6665	10.87**
Error	21.4747	14	1.5339	-

* Significant at 5 percent level

** Significant at 1 percent level

Appendix 19

Analysis of variance for panicle weight

Source	S.S.	Df	Variance	F ratio
Total	6.4398	23		
Block	0.7976	2	0.3988	5.03*
Treatment	4.5330	7	0.6476	8.20**
V	0.0100	1	0.0100	0.13
P	4.0042	3	1.3347	16.84**
VP	0.5188	3	0.1729	2.20
Error	1.1092	14	0.0792	

Appendix 20

Analysis of variance for nitrogen content of grain

Source	S.S.	Df	Variance	F ratio
Total	0.21	23		
Block	0.08	2	0.040	13.33**
Treatment	0.08	7	0.010	3.33**
V	0.03	1	0.030	10.00**
P	0.03	3	0.010	3.33*
VP	0.02	3	0.070	23.33 *
Error	0.05	14	0.003	

* Significant at 5 percent level

** Significant at 1 percent level

Appendix 21

Analysis of variance for phosphorus content of grain

Source	S.S.	Df	Variance	F ratio
Total	1.160	23		
Block	0.030	2	0.015	5.00*
Treatment	1.090	7	1.557	519.00**
V	0.002	1	0.002	0.67
P	1.070	3	0.357	119.00**
VP	0.018	3	0.006	2.00
Error	0.040	14	0.003	

Appendix 22

Analysis of variance for potassium content of grain

Source	S.S.	Df	Variance	F ratio
Total	1.15	23		
Block	0.45	2	0.225	11.84**
Treatment	0.43	7	0.061	3.21*
V	0.10	1	0.100	5.21*
P	0.25	3	0.083	4.37*
VP	0.08	3	0.027	1.32
Error	0.27	14	0.019	-

*Significant at 5 percent level

**Significant at 1 percent level

Appendix 23

Analysis of variance for nitrogen content of straw

Source	S.S.	Df	Variance	F ratio
Total	0.44	23		
Block	0.09	2	0.045	9.0 *
Treatment	0.28	7	0.040	8.0**
V	0.18	1	0.180	36.0**
P	0.06	3	0.020	4.0*
VP	0.06	3	0.013	2.6
Error	0.07	14	-	-

Appendix 24

Analysis of variance for phosphorus content of straw

Source	S.S.	Df	Variance	F ratio
Total	0.330	23		
Block	0.010	2	0.0050	12.50**
Treatment	0.310	7	0.0440	110.00**
V	0.001	1	0.0010	2.50
P	0.300	3	0.1000	250.00 *
VP	0.009	3	0.0030	7.50**
Error	0.010	14	0.0004	

* Significant at 5percent level

** Significant at 1 percent level

Appendix 25

Analysis of variance for potassium content of straw

Source	S.S.	Df	Variance	F ratio
Total	10.01	23		
Block	0.66	2	0.33	16.50 *
Treatment	9.10	7	1.30	65.00**
V	6.18	1	6.18	309.00**
P	1.00	3	0.33	16.50**
VP	1.92	3	0.64	32.00**
Error	0.25	14	0.02	

Appendix 26

Analysis of variance for nitrogen removal by grain

Source	S.S.	Df	Variance	F ratio
Total	52.6542	23		
Block	7.1197	2	3.55985	10.22**
Treatment	40.6437	7	5.80620	16.67**
V	25.0480	1	25.0480	71.91**
P	14.8354	3	4.9451	11.32**
VP	0.7603	3	0.2534	1
Error	4.8908	14	0.3483	

** Significant at 1 percent level

Appendix 27

Analysis of variance for phosphorus removal by grain

Source	S.S.	Df	Variance	F ratio
Total	30.9452	23		
Block	4.4640	2	2.2320	8.51**
Treatment	22.8084	7	3.2583	12.42**
V	6.6753	1	6.6753	25.44**
P	15.1390	3	5.0463	19.20**
VP	0.9941	3	0.3314	1.22
Error	3.6728	14	0.2623	-

Appendix 28

Analysis of variance for potassium removal by grain

Source	S.S.	Df	Variance	F ratio
Total	46.4534	23		
Block	5.0176	2	2.5088	6.61**
Treatment	36.1242	7	5.1606	13.60**
V	13.2314	1	13.2314	34.87**
P	21.8571	3	7.2857	19.21**
VP	1.0357	3	0.3452	0.909
Error	5.3116	14	0.3794	-

** Significant at 1 percent level

Appendix 29

Analysis of variance for nitrogen removal by straw

Source	S.S.	Df	Variance	F ratio
Total	13.314	23		
Block	0.140	2	0.070	0.48
Treatment	12.972	7	1.853	12.86**
V	2.655	1	2.655	18.43**
P	8.632	3	2.874	19.95**
VP	1.685	3	0.562	3.904
Error	0.202	14	0.144	

Appendix 30

Analysis of variance for phosphorus removal by straw

Source	S.S.	Df	Variance	F ratio
Total	24.3813	23		
Block	1.6691	2	0.8346	2.979
Treatment	18.7900	7	2.6843	9.58**
V	3.4732	1	3.4732	13.28**
P	13.2475	3	4.4158	15.76**
VP	2.0693	3	0.6898	2.46
Error	3.9222	14	0.2802	

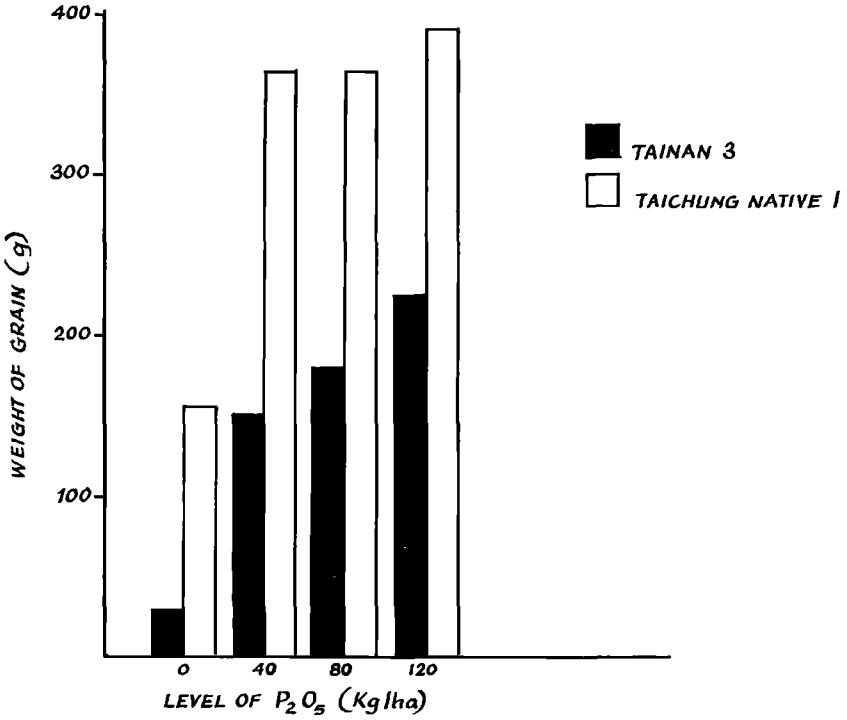
** Significant at 1 percent level

Appendix 31

Analysis of variance for potassium removal by straw

Source	S.S.	Df	variance	F ratio
Total	763.687	23		
Block	39.544	2	19.772	13.16**
Treatment	703.113	7	100.445	66.86**
V	396.734	1	396.734	264.15**
P	128.968	3	42.989	28.6**
VP	177.411	3	59.137	39.3**
Error	21.030	14	1.502	

** Significant at 1 percent level



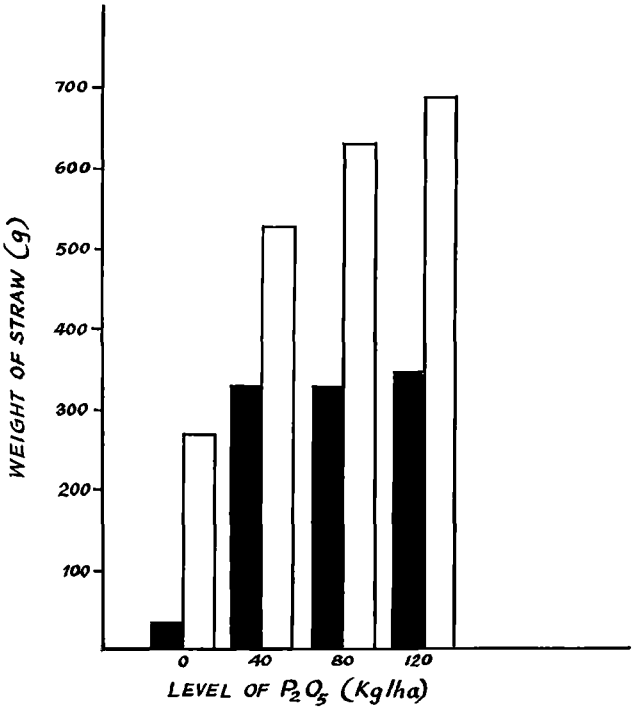


FIG 1 HISTOGRAMS SHOWING YIELD OF RICE GRAIN AND STRAW FOR DIFFERENT PHOSPHORUS TREATMENTS

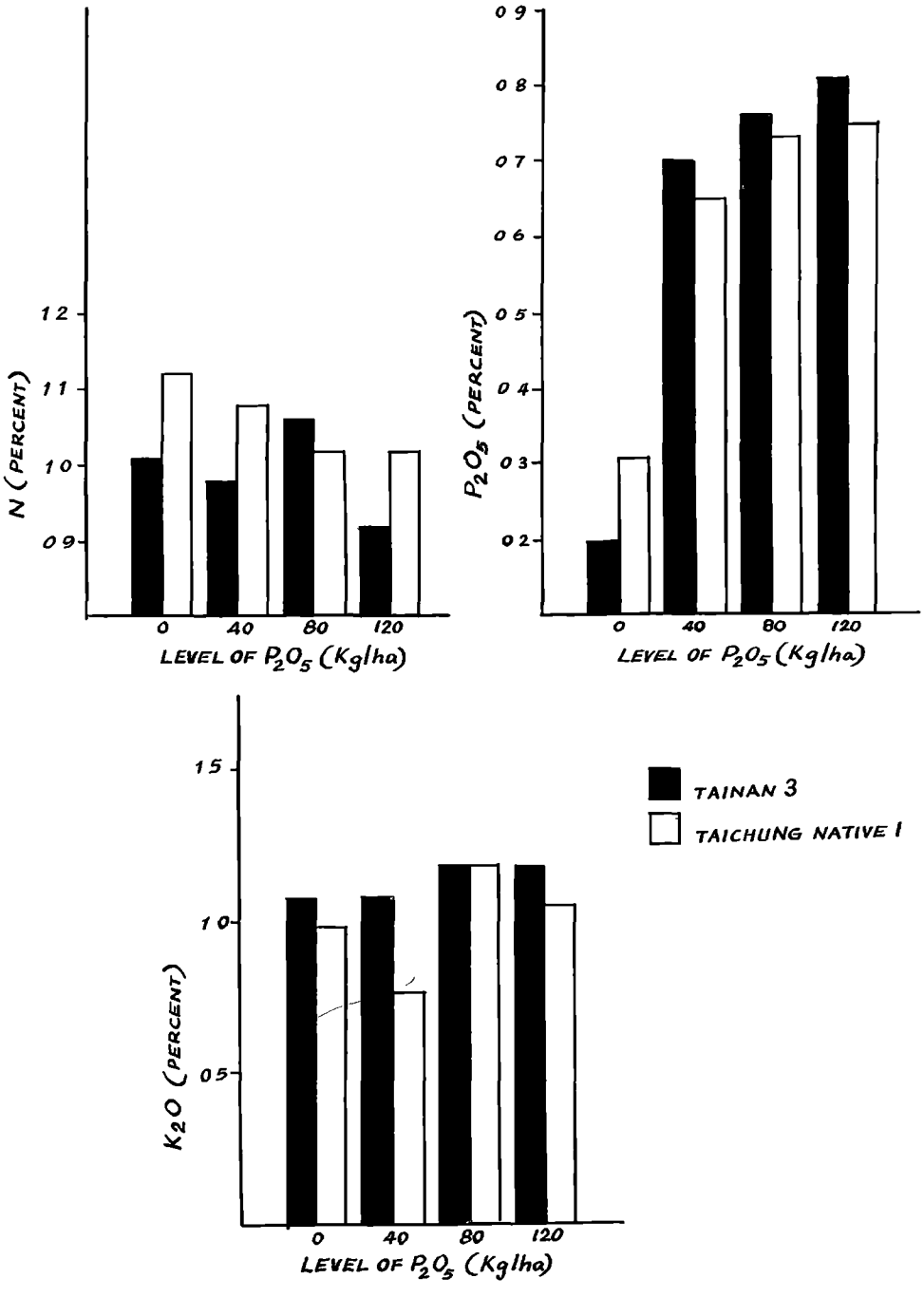


FIG 2 HISTOGRAMS SHOWING NUTRIENT CONTENT OF RICE GRAIN FOR DIFFERENT PHOSPHORUS TREATMENTS

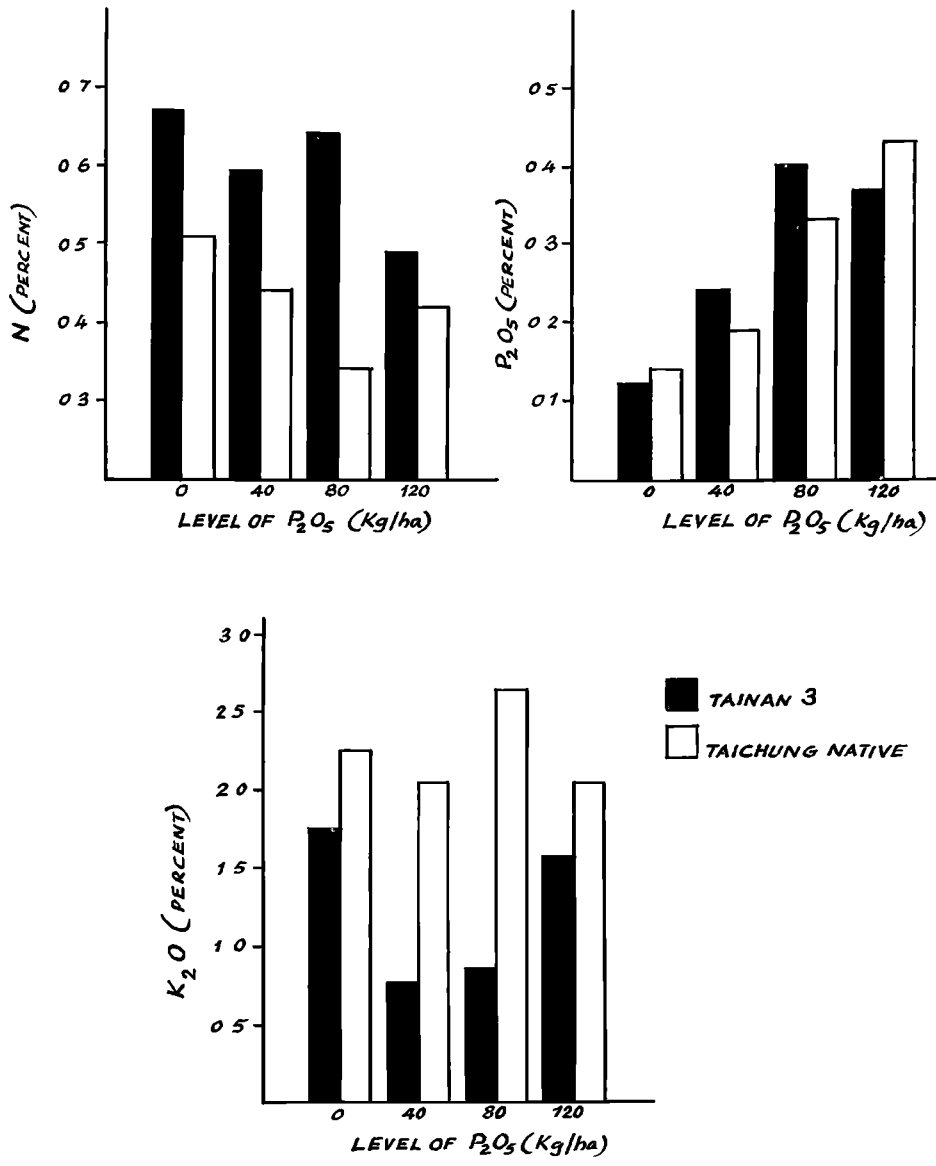


FIG 3 HISTOGRAMS SHOWING NUTRIENT CONTENT OF RICE STRAW FOR DIFFERENT PHOSPHORUS TREATMENTS

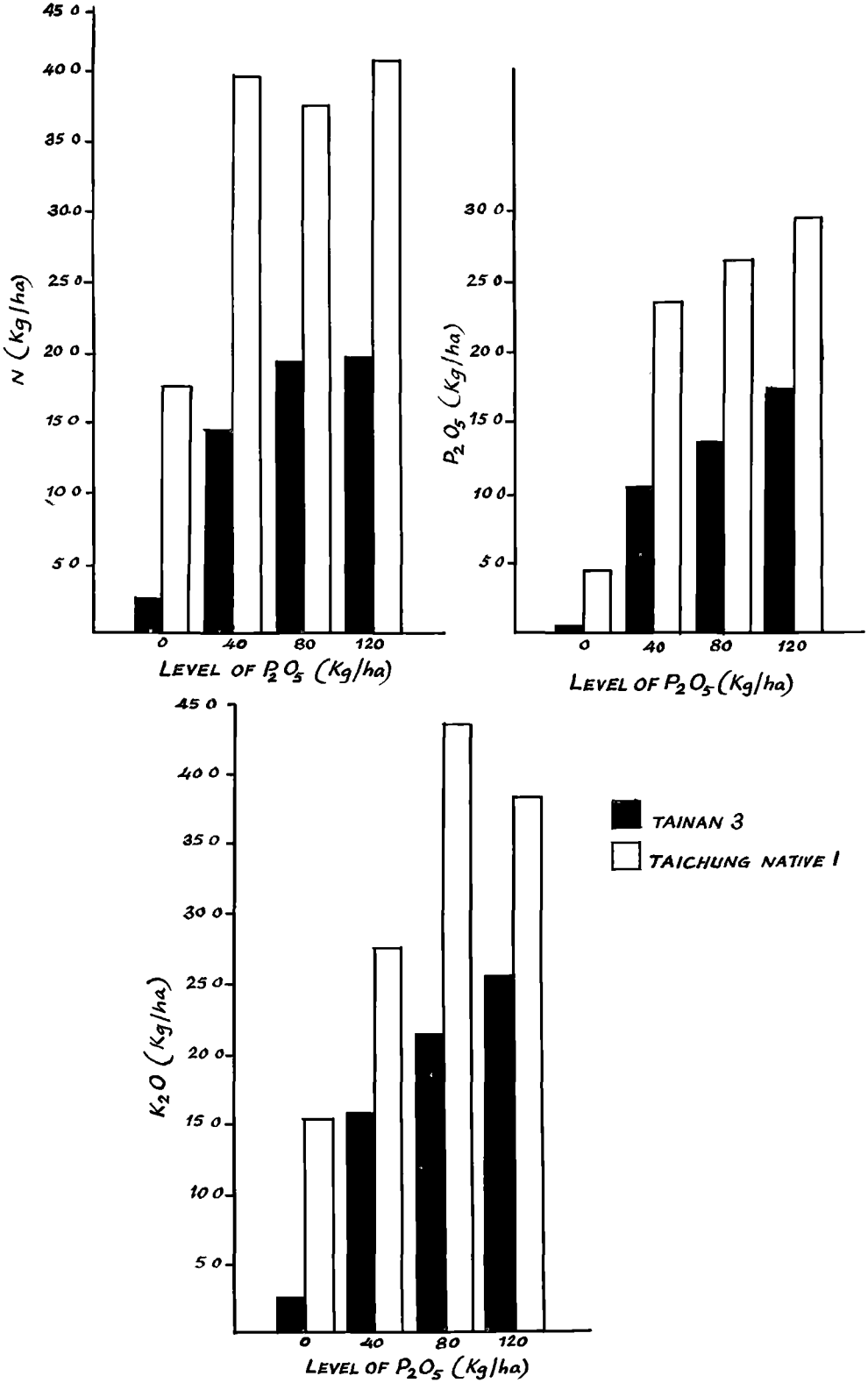


FIG 4 HISTOGRAMS SHOWING NUTRIENT REMOVAL IN RICE GRAIN FOR DIFFERENT PHOSPHORUS TREATMENTS

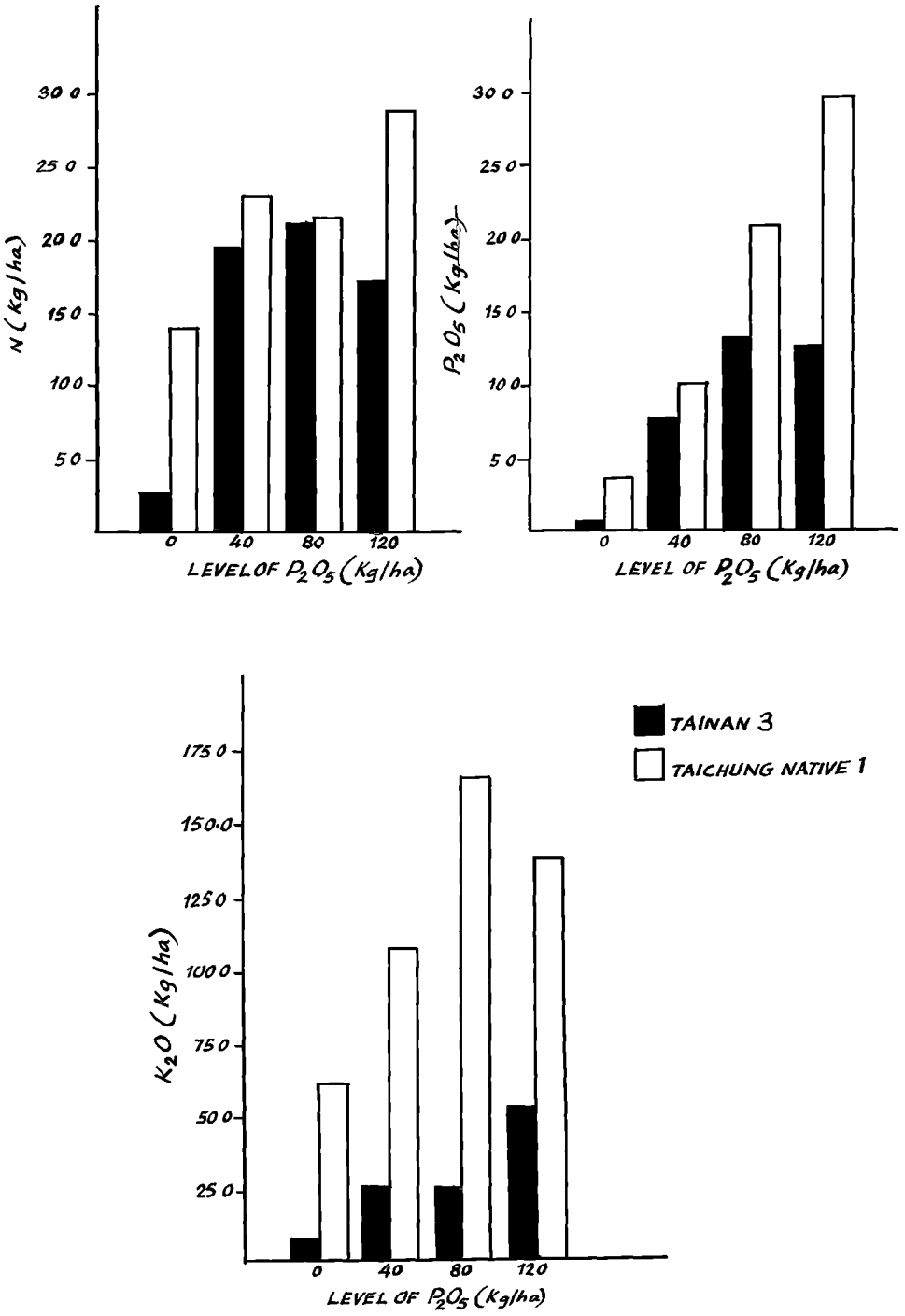
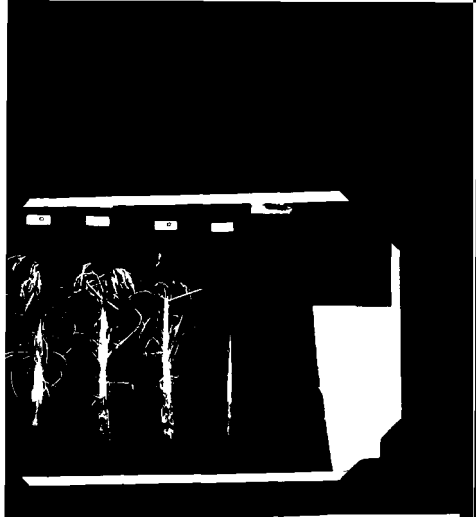
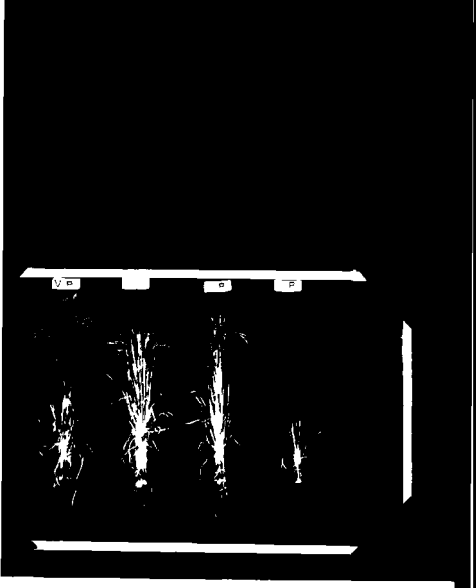


FIG 5 HISTOGRAMS SHOWING NUTRIENT REMOVAL IN RICE STRAW FOR DIFFERENT PHOSPHORUS TREATMENTS



6. Effect of different levels of phosphorus on the growth of Tainan-3.



7. Effect of different levels of phosphorus on the growth of Taichung Native-1.