EFFECT OF DIFFERENT FORMS AND LEVELS OF PHOSPHORUS ON THE GROWTH, YIELD AND COMPOSITION OF THREE HIGH YIELDING VARIETIES OF RICE

(IR 8, Taichung Native I and Culture 28)

By

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THESIS

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CERTIFICATE

This is to certify that the thesis herewith submitted contains the result of bona fide research work carried out by Shri. M.P. Jagadeeschandran Nair, 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

The role of phosphorus in plant nutrition is evident from the fact that it is a constituent of nucleic acid, phytin and phospholipids. It is closely associated with seed formation and early maturity of crops, particularly cereals. The absorption of other nutrients is directly or indirectly influenced by this element. Its beneficial role in the healthy and luxurious growth of plants is a well established fact.

Numerous experiments conducted all over India on a wide variety of soils under different climatic conditions indicate that rice responds well to applications of phosphorus. Superphosphate is, by far, the most popular of the phosphatic fertilizers. Ultrafos, which is a tricalcic form, is now being extensively used in the Kuttanad area owing to its availability in acid soils and its relatively lower cost. Other forms like defluorinated rock phosphate and Thomas phosphate are also being used on a limited scale. Information regarding the relative merits of these fertilizers on the growth characters of rice, is nevertheless, meagre.

In Kerala, rice is grown over an area of 7.79 lakh hectares and the annual production is 10-11 lakh metric tons. This quantity meets only about half of the total cereal requirement of the State. The only method by which this deficit can be overcome is by the introduction of newer and high yielding varieties of rice and by the adoption of the latest research findings in the cultivation of this crop. A number of improved varieties of rice is now gaining popularity among the farmers of Kerala. Notable among them are IR 8, Taichung Native 1 and Culture 28. These varieties have totally changed our concept of grain yield potential. That food self sufficiency, which was a wishful thinking hitherto has now become a practical proposition, is evident from the enthusiasm of the Kerala farmers of these varieties. Very little information is available in regard to the relative response of these new strains to the application of different phosphatic fertilizers. It was, therefore, considered desirable to investigate the response of these improved varieties of rice to different forms and levels of phosphorus application. With this cardinal purpose in view, the present investigation was undertaken to study the influence of superphosphate, ultrafos, defluorinated rock phosphate and Thomas phosphate in increasing levels on the growth, yield and composition of the three rice varieties viz., IR 8, Taichung Native 1 and Culture 28.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

1. Relative merits of different phosphatic fertilizers

Pauw and van Der (1950) reported that on reclaimed heath soils superphosphate was markedly superior to basic slag, the availability of the latter being greatly reduced at high pH values. Only in strongly acid soils, basic slag was more effective than superphosphate.

Chand and Chiang (1953) studied the availability of phosphorus in calcium superphosphate, magnesium fused phosphate and hyperphosphate in different soils. They found that, on all the soils studied, superphosphate was the most available. The availability was more marked in acid soils than in neutral or alkaline soils.

Usmanova (1954) found that spring wheat grown on gray forest soils and on leached chernozem soils responded to all forms of phosphorus. On rich chernozem soils, he obtained the highest response to superphosphate and basic slag. Schmitt and Jungerman (1954) reported that in cylinders of dry sandy soils, phosphorus uptake by young oat plants from fertilizer applied to the ploughed layer or as top dressing was more from superphosphate than from basic slag.

In a 5 year trial using cereal-ley rotation, Agerberg (1957) found that superphosphate was more effective than basic slag, but basic slag showed a greater efficiency in the 5th (residual) year.

Sree Ramulu and Mariakulandai (1962) reported that superphosphate was better than farm yard manure when applied individually on an equal phosphorus basis.

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

Choudhury (1967) obtained higher yields of paddy for the application of superphosphate than for bonemeal.

Zannen (1951) found that basic slag was particularly suited for improving phosphorus reserves of acid soils, due to its high content of citric acid soluble P_2O_5 (16.5 - 19 per cent) in easily assimilable and nonreversible form and also due to the presence of active lime (45 - 50 per cent).

Gericke (1954), using radio active slag and taking photographs at various stages after treatment, showed that this fertilizer was rapidly dissolved in moist soils and readily taken up by plants.

Gericke and Bramann (1955) reported that dressing with basic slag at rates 30 to 120 kg P_2O_5 per hectare, progressively increased the yield of cereals.

In an investigations to study the manurial value of basic salg, Mahapatra and Padalia (1963) obtained significant grain yield due to the application of basic slag alone.

In a 5 year study, Bonnet *et al* (1954) applied different sources of phosphorus at 120 lb P_2O_5 per acre to 2 series of pots, one cropped to legumes and the other to grass. They obtained significantly high yields for most of the soluble fertilizers and found that colloidal phosphorus, defluorinated rock phosphate and tricalcium phosphate were of little value on these soils. Sodium pyrophosphate and mono ammonium phosphate produced higher yields than did 20 per cent or 45 per cent superphosphate. In gray brown loam (pH. 7.2), Chandra Ratna and Fernando (1954) found that ammonium phosphate was superior to an equivalent amount of superphosphate.

Chandnai and Obhrai (1955), in an experiment using 10 different phosphatic fertilizers, found that ammonium phosphate gave the highest and best quality yields when applied on an equal phosphorus basis and the P_2O_5 recovery was 59.25 per cent. The other fertilizers gave recovery values of 20-40 per cent.

Utagawa (1954) reported that the nutritive value of defluorinated phosphate was equal to that of superphosphate, fused phosphate or basic slag.

Edward (1956) measured the comparative response of rock phosphate and superphosphate for various crops and found that brassicas responded well to rock phosphate in calcareous soils while potato crops responded poorly even in acid soils.

2. <u>Effect of phosphorus on the growth and yield of paddy</u>

Bhind *et al* (1949) recorded an increased grain yield of 20-30 per cent by pre-soaking the paddy seeds in a nutrient solution containing phosphorus.

In nutrient solution containing 0-200 ppm of P_2O_5, Ishizuka and Tanaka (1951) observed the highest yields of paddy at 20 ppm level. At levels of 5-20 ppm, the plant phosphorus content was constant but outside these levels it increased with increasing P_2O_5 supply. The maximum absorption of P_2O_5 appeared to occur at 150 ppm. But Ariyanayagam (1953) reported that phosphorus at 30 lb P_2O_5 per acre had no direct or cumulative effect on yield even in the presence of high levels of nitrogen.

Dabin (1951) recorded a significant response to rice by phosphorus along with nitrogen and potassium. According to him the maximum utilisation of phosphorus occurred at the tillering stage.

Parthasarathy (1953) reported an increase in yield by the application of 150 lb of superphosphate and ammonium sulphate along with 4000-5000 lb of green manure per acre. Sree Ramulu and Marialmulandai (1963) obtained higher yields of rice by the application of superphosphate along with farm yard manure.

Paul (1952) obtained no beneficial effect for an application of phosphorus at 20 lb P_2O_5 per acre, but at twice this level the yield of grain and straw was significantly increased.

Raychoudhuri (1953) got significant increase in the yield of rice due to the application of phosphorus in combination with nitrogen.

The work carried out by Chang and Teong's (1953) on the soils of Taiwan, revealed only a slight increase in the yield of rice on lateritic soils and slate alluvial soils and no increase in yield on sand-stone and slate alluvial soils due to the application of phosphorus.

Ghose et al (1956) reported that a crop yielding about 3000 lb of grain and 3500 lb of straw per acre removed on an average, 40 lb of N, 30 lb of P_2O_5 and 79 lb of K_2O per acre.

In a field experiment, Cassidy et al (1956) observed beneficial effects for P_2O_5 on tillering and grain production under flooded condition

(Castro et al (1956) reported that phosphorus had no effect on the yield of rice, even though the soil was low in phosphorus.) But the results of research carried out by the Indian Council of Agricultural Research in the States of Bombay, Bengal and Madhya Pradesh (Anonymous 1956) indicated an increase in the yield, tiller number and vigour of plants when phosphorus was applied along with nitrogen.

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

Tanaka *et al* (1958) reported that growth and grain yield were optimal with 5-10 ppm of P_2O_5 and 20 ppm of K_2O. Application of phosphorus at levels higher than 40 ppm of P_2O_5 reduced grain yield and P_2O_5 application at rates more than 100 ppm caused a high accumulation of nitrogen and phosphorus. They also found that low phosphorus levels produced stunted growth, poor tillering, reduced ear formation and consequently low grain yield. The leaves were bluish green in colour and the stem base developed a purple streak.

In sand cultures, Kasai and Asada (1959) found that phosphorus absorption was greater for high phosphorus levels upto the time of flowering. They also reported that the acid soluble phosphorus was more in the grain at higher levels of phosphorus application, whereas the level of insoluble phosphorus was unaffected.

In a discussion of the findings of over 2500 demonstrations and trials conducted on paddy in Madras State, Mariakulandai and Sreenivasan (1959) reported that a combination of P_2O_5 and N was superior to the other treatments and was responsible for increasing the yield by 30.4 per cent.

Takijima *et al* (1959) reported that increased rates of phosphorus application 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 by paddy to the application of phosphorus. They also found that there was no significant interaction between nitrogen and phosphorus.

Digar (1960) reported that in lateritic loams of low fertility, the highest yields of paddy were obtained in the year of application of ammonium sulphate at 30 lb of N per acre and 60 lb of P_2O_5 per acre.

Basak et al (1960) found that in waterlogged 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 the formation of relatively unavailable phosphates by combination with iron and aluminium.

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

Salm (1963) stated that the average response of rice was about 1.3 md per acre higher, when the dosage of phosphorus was increased from 20 lb P_2O_5 to 40 lb P_2O_5 per acre. Higher response of about 10.7 md per acre was obtained by the combination of 20 lb of N and 40 lb of P_2O_5 per acre.

Datta and Datta (1963) recorded a progressive increase in yield (about 50 per cent) by using radio-active superphosphate (21.5 per cent

P_2O_5) and flooding the soils 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.

Tanaka et al (1964) showed that an increase in the application of phosphorus to Tainan 3 and Peta, resulted in an increase in panicle length and weight, percentage of phosphorus in straw and also the phosphorus content of the plant.

Daji (1965) obtained better response to nitrogen and phosphorus in combinations, as compared to the individual application in cultivators' fields in Andhra Pradesh. Daji (1966), also reported an average response for paddy to phosphorus, when superphosphate was applied at 30 lb of P_2O_5 per acre.

Gupta et al (1965) got a positive correlation between the number of ears at tillering stage and the nitrogen and phosphorus contents of leaf.

Sreenivasulu and Pawar (1965) obtained no significant effect on the 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).

Mariakulandai and Chary (1967) reported that the response to phosphorus was effected by different factors such as the depth of placement, indirect manuring through legumes, combination with green manure, F.Y.M. nitrogen and phosphorus and the application of lime.

Mohan Kumar (1967), while studying the effect of phosphorus on the growth habits of Tainan 3 and Taichung Native 1, reported an increase in the height and number of tillers due to increasing levels of phosphorus. He also reported that in both varieties application of phosphorus resulted in significantly higher yields of grain, straw and root but the increase in yield for the different levels was not significant.

3. Physiological role of Phosphorus

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

Hayashi et al (1951) found that, in rice plants phosphorus deficiency caused stunted growth of roots.

Ishizuka and Tanaka (1952) reported a decrease in the starch content of rice due to the application of phosphorus. But the crude protein content and the fat content of grain increased with an increased supply of phosphorus.

A delay in the yellowing of the leaves of rice plant due to the lack of phosphorus was noted by Morita (1953).

Scharrer and Preissner (1954) observed that increasing amounts of phosphorus were beneficial for the optimum concentration of vitamin B_1.

Takahashi *et al* (1955) found that heading was accelerated and the ratio of the weight of ears to the weight of straw was increased by increasing phosphorus supply. The application of phosphorus shortened the period from transplanting to the completion of heading.

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

An increase in the starch content of grain due to the application of phosphorus was reported by Moriya and Sato (1958).

Yoshida (1958) found that increased application of phosphorus promoted root growth and tillering and hastened maturity in rice plants.

Fujiwara and Ohira (1959) observed an inhibition in nitrogen absorption, and protein synthesis in rice, due to the insufficient supply of phosphorus.

Karapivenko (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.

Basak *et al* (1961), in their study of the nutritive value of rice as influenced by the application of phosphorus along with calcium found a negative influence for this treatment on the protein, phosphorus and calcium content of grain.

While studying the uptake of phosphorus by 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 level decreased towards maturity. During maturity nitrogen and phosphorus were translocated from straw to grain.

Burriel et al (1951) reported an increase in the dry weight, ash, crude protein, other extractive, fibre, phosphorus and magnesium of spring oats by the application of superphosphate.

Thomas et al (1951) noted that oats receiving 5 times the control amount of phosphorus contained more of folic acid, biotin, niacin and calciumpantothenate and the plants receiving one-tenth of the control amount contained less of these constituents.

Koperzhinski (1953) reported an increase in respiration by the generative organs of plants by an increased supply of phosphorus. Under a limited supply of carbohydrates to these organs the process of seed development was disturbed by this increased respiration. Tamman and Poluyanova (1956) found that the application of phosphorus to potato plants increased the assimilative surface and the development of root system. Increase in growth, water and protein content, irrespective of nitrogen levels was noted in flax by Tilgor (1956).

Wenzel (1957) showed that the concentrations of inorganic phosphorus and phytin phosphorus increased and that of phospholipids and nucleic acids remained more or less constant, in the dry matter of mature plants receiving increased amounts of fertilizer phosphorus.

In pot experiments with sunflower and tomatoes and in field experiments with potatoes and fodder beet, Roglev (1957) noted an increase in the fibrovascular bundles and xylum vessels due to the increased application of phosphorus.

Moriya and Sato (1958) reported an increase in the starch content of plants as a result of phosphorus application.

Okamoto (1950) found that rice could be protected from Piricularia oryzae (blast disease) by the application of phosphatic fertilizers. But Krishnaswami (1952) reported no effect on the incidence of blast by the application of this element.

Ota et al (1957) observed that plants were less susceptible to blast and stem borer disease by the application of iron slag.

Hirano and Ishii (1959) reported an increase in the number of larvae of stem borer when high levels of phosphorus were applied.

4. Effect of phosphorus on the uptake of other nutrients

Nitrogen

William (1948) found that phosphorus deficiency greatly depressed nitrogen uptake in the early stages of growth, apparently due to the differential effect of phosphorus on the growth of roots and shoots. Thomas et al (1951) demonstrated a direct P-N relation in plants.

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

In pot experiments on poor sandy soils of pH 6.3, Kanapathy (1957) found that increased levels of nitrogen and phosphorus resulted in an increased uptake of phosphorus.

Satyanarayana (1958) reported an increased recovery of nitrogen in crops when this element was used with superphosphate. When 30 lb N were applied to paddy only 4-9 lb were recovered in the grain depending upon the soil type. When the same amount of nitrogen was applied with 30 lb of N per acre 19-53 per cent of the nitrogen were recovered. He also reported that less nitrogen was lost and more nitrogen was utilised when nitrogen was used jointly with phosphorus.

Grunes and Krantz (1958), while studying the effect of nitrogen on the NPK content of oats, revealed the effect of nitrogen in increasing the phosphorus and potassium uptake through increased root growth and better nutrient capacity.

Gruner (1959) found that the addition of nitrogenous fertilizers had a marked effect on the absorption of soil and fertilizer phosphorus. Some of these effects were releated to increased growth of plant tops and concurrently the increased uptake of phosphorus. He also found that the ammonia form of nitrogen frequently increased the uptake of phosphorus rather than the nitrate form.

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

Digar (1960) reported that a combination of 30 lb of N and 60 lb of P_2O_5 per acre was the optimum for the maximisation of paddy yields.

Potassium

Lawton et al (1952) found a reduction in potassium percentage in legume hay, when superphosphate was applied to soils containing added potash.

While studying the absorption of phosphorus by the corn plants, Robertson et al (1954) found that utilisation of fertilizer phosphorus was increased by high NPK application. But it was unaffected by adding potassium to phosphorus and tended to decrease on adding to potassium to NP.

In green house and field experiments using labelled superphosphate, Fine (1955) reported that the increased available potassium content had little effect on the utilisation of phosphurus by crops.

Bartz (1959) observed that monopotassium phosphate gave a greater growth response and phosphorus concentrations in tissues, than did monocalcium phosphate.

Kanwar and Meelu (1963) stated that wheat faired best with NPK, the next best being NP application.

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

MATERIALS AND METHODS

MATERIALS AND METHODS

The influence of different forms and levels of phosphorus on the growth, yield and composition of three improved rice varieties was studied in a pot culture experiment, in randomised block design with 39 treatments and 3 replications. The treatment details are given below:

1. Forms of phosphorus

P_1	..	Superphosphate
P_2	..	Ultrafos
P_3	..	Defluorinated rock phosphate
P_4	..	Thomas phosphate

2. Levels of phosphorus

L_0	..	Control
L_1	..	25 kg P_2O_5 per ha
L_2	..	50 kg P_2O_5 per ha
L_3	..	75 kg P_2O_5 per ha

3. Rice varieties

V_1	..	Culture 28
V_2	..	IR 8
V_3	..	Taichung Native 1

The various treatment combinations were as follows:

$L_0 V_1$	$L_0 V_2$	$L_0 V_3$
$P_1 L_1 V_1$	$P_1 L_1 V_2$	$P_1 L_1 V_3$
$P_1 L_2 V_1$	$P_1 L_2 V_2$	$P_1 L_2 V_3$
$P_1 L_3 V_1$	$P_1 L_3 V_2$	$P_1 L_3 V_3$
$P_2 L_1 V_1$	$P_2 L_1 V_2$	$P_2 L_1 V_3$
$P_2 L_2 V_1$	$P_2 L_2 V_2$	$P_2 L_2 V_3$
$P_2 L_3 V_1$	$P_2 L_3 V_2$	$P_2 L_3 V_3$
$P_3 L_1 V_1$	$P_3 L_1 V_2$	$P_3 L_1 V_3$
$P_3 L_2 V_1$	$P_3 L_2 V_2$	$P_3 L_2 V_3$
$P_3 L_3 V_1$	$P_3 L_3 V_2$	$P_3 L_3 V_3$
$P_4 L_1 V_1$	$P_4 L_1 V_2$	$P_4 L_1 V_3$
$P_4 L_2 V_1$	$P_4 L_2 V_2$	$P_4 L_2 V_3$
$P_4 L_3 V_1$	$P_4 L_3 V_2$	$P_4 L_3 V_3$

The soil used in this study was collected from the unmanured area of the Vellayani Kayal land. The mechanical and chemical composition of the soil are given in Tables 1 (a) and 1 (b).

TABLE 1(a)

Mechanical composition of the soil used for the pot culture experiment

Coarse sand	..	32.20%
Fine sand	..	17.34%
Silt	..	13.82%
Clay	..	35.78%

TABLE 1(b)

Chemical composition of the soil used for the pot culture experiment

pH	..	4.5
Total nitrogen	..	0.088%
Total P_2O_5	..	0.045%
Total K_2O	..	0.082%
Total CaO	..	0.190%
Total MgO	..	0.004%
Total sesquioxides	..	7.632%
Total Fe_2O_3	..	4.280%
Available P_2O_5	..	0.0003%
Available K_2O	..	0.001%
Insolubles	..	91.630%

Preparation of pots

Earthenware pots of diameter and depth 1 foot were used for the experiment. 5.75 kg of air dried and seived soil was weighed into each pot.

Application of Fertilizers

The different forms of phosphatic fertilizer used in this study were superphosphate (17.3 per cent P_2O_5), ultrafos (30 per cent P_2O_5), defluorinated rock phosphate (20.7 per cent P_2O_5) and Thomas phosphate (19.6 per cent P_2O_5). The pots for the different treatments were selected at random. The required quantities of fertilizers were weighed out, applied to the appropriate pots, and mixed uniformly with the soil.

In addition, all the pots received a uniform application of nitrogen and potassium at 75 kg N per ha and 75 kg K_2O per ha respectively as ammonium sulphate (20 per cent N) and muriate of potash (60 per cent K_2O) in three split doses. The first dose of N and K_2O at the rate of 25 kg per ha was given at the time of sowing as basal dressing. The second and third doses of N and K_2O, both at 25 kg per ha, were applied on the 30th and 60th day respectively after sowing.

Choice of varieties and sowing

The rice varieties selected for the study were IR 8 (125 days) Taichung Native 1 (121 days) and Culture 28 (95 days). Of these three varieties, IR 8 and Taichung Native 1 were only recently introduced into the State. Variety IR 8 has become very popular with the farmers. Taichung Native 1 is also a promising variety but it has not been cultivated on a large scale because of its susceptibility to bacterial blight. Culture 28 was evolved at the Central Rice Research Station, Pattambi by hybridisation between Taichung Native 1 and Ptb. 10.

Three holes were made in the basally treated soil in the pots and four sprouted seeds were dibbled in each hole on the 12th November, 1967. After two weeks when the seedlings were well established their number per hole was reduced to one. The rest of the seedlings were cut into small bits and buried in the respective pots.

__Irrigation__

The crop was irrigated periodically with tap water so as to maintain a constant level of 2 cm of water above the surface of the soil.

__Plant protection measures__

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

Harvest

Culture 28 was harvested on the 16th February, 1968. Taichung Native 1 and IR 8 were harvested on 13th March, 1968 and 17th March, 1968 respectively.

Plant Performance Studies

Pre-harvest studies

i. Height of plant

The height of the plant was recorded at intervals of twenty days and also at the time of harvest. The measurement was made from the base of the plant to the upper most leaf tip for all the plants in the pot and the mean taken.

ii. Number of vegetative tillers

This observation was taken at intervals of twenty days and the average noted.

iii. Number of productive tillers

The productive tiller count was made in all the plants one day before harvest and the mean taken.

Post-harvest studies

i. Length of panicle

From each replication ten panicles were selected randomly and the average length noted.

ii. Number of filled grains per panicle

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

iii. Grain: Chaff ratio

The number of completely filled grains and unfilled grains in the above ten panicles was found out separately. The grain:chaff ratio was calculated for each replication.

iv. Yield of grain per pot

The yield of grain was recorded for each pot separately after air drying.

v. Yield of straw per pot

This was recorded by weighing the straw separately for each pot after air drying.

Laboratory Studies

The laboratory studies consisted of soil studies and the analysis of the plant material.

1. Soil studies

The soil was examined for available phosphorus and pH at intervals of 30 days from the date of sowing. Soils from pots receiving the same treatment, irrespective of the varieties, were mixed, dried, seived and analysed for available P_2O_5 colorimetrically using Bray's extractant No. 1 (0.025 HCl and 0.03 NH_4F) as outlined by Jackson (1958).

The pH of the above soil samples was determined in a 1:2 soil-water suspension.

2. Analysis of plant material

The grain and straw were dried at 70°C in an air oven. The dried straw was cut into small pieces and ground in an electrical grinder. The samples of the straw and grain thus prepared were stored in labelled bottles for chemical analysis. They were analysed for nitrogen, phosphorus and potassium.

Nitrogen and phosphorus were estimated in 0.1 g of the ground sample after digestion of the material by the micro-Kjeldahl-Gunning method as adopted by Poidevin and Robinson (1964).

Potassium was estimated by the turbidimetric method detailed by Lindner (1944) in a suitable aliquot of the triple acid extract of 2 g of the material.

RESULTS

RESULTS

The experimental results relating to the influence of different forms and levels of phosphorus on the growth, yield and composition of three varieties of rice are given below. The data have been analysed statistically for drawing valid conclusions.

A. GROWTH

The results pertaining to the effect of different treatments on the growth characters of rice viz., the height of plants, number of vegetative and productive tillers, and the length of panicles are given in Tables II, III, IV, V, VI, VII, VIII, IX and X.

1. Height of plant (Tables II, III, IV and V)

The data reveal that the differences in the height of plants for the different levels of phosphorus application were significant at all the four stages of observation. The differences between the varieties were also significant. But the effect of different forms of phosphorus and the interaction between forms and levels were not significant.

During the initial stages of growth the height of the plants was not found to be significant, but it attained significant differences towards maturity. The different levels of phosphorus such as 25, 50 and 75 kg P_2O_5/ha produced healthy plants and the differences between them were also found to be significant. As might

TABLE II

Effect of different forms and levels of phosphorus on the height (cm) of three varieties of rice: 20th day

Forms	Level kg P_2O_5	Rice variety: Culture 28	IR 8	Taichung Native 1	Mean
Control	0	23.6	26.2	24.2	23.7
Superphosphate	25	29.4	27.4	28.8	..
	50	31.8	28.4	32.7	..
	75	31.9	32.2	32.8	..
	Mean	31.0	29.3	31.4	30.6
Ultrafos	25	28.6	27.3	27.3	..
	50	30.1	28.8	29.6	..
	75	33.9	32.5	34.1	..
	Mean	30.9	29.5	30.3	30.2
Defluorinated rock phosphate	25	31.3	27.8	27.5	..
	50	30.9	31.2	34.9	..
	75	33.1	33.8	33.1	..
	Mean	31.8	30.9	31.8	31.5
Thomas phosphate	25	28.4	28.6	27.7	..
	50	29.9	30.7	33.9	..
	75	29.9	30.4	30.3	..
	Mean	29.7	29.9	30.6	30.1
All forms	25	29.7	27.8	27.8	28.4
	50	30.7	29.8	32.8	31.1
	75	42.2	32.2	32.6	35.7
Mean for variety	..	30.9	29.9	31.0	..

C.D. (0.05) between:

1.	Levels of the same form in variety	4.61
2.	Levels in a variety over all forms	2.30
3.	Levels	1.53

TABLE III

Effect of different forms and levels of phosphorus on the height (cm) of three varieties of rice: 40th day.

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	29.2	32.1	27.0	29.6
Superphosphate	25	37.5	38.8	38.1	..
	50	44.4	41.0	41.5	..
	75	46.7	43.3	44.5	..
	Mean	42.9	41.0	41.4	41.8
Ultrafos	25	37.1	37.8	37.1	..
	50	40.1	38.4	38.0	..
	75	44.0	42.8	41.1	..
	Mean	40.4	39.7	38.7	39.9
Defluorinated rock phosphate	25	40.4	38.0	39.3	..
	50	43.3	41.4	42.9	..
	75	43.3	44.9	41.6	..
	Mean	42.3	41.4	41.3	41.7
Thomas phosphate	25	37.5	39.1	38.4	..
	50	41.3	40.0	40.8	..
	75	42.0	40.2	39.9	..
	Mean	40.3	39.9	39.7	40.0
All forms	25	38.1	38.4	38.2	38.2
	50	42.3	40.2	40.8	41.1
	75	44.0	42.8	41.8	42.9
Mean for variety	..	41.5	40.5	40.3	..

C.D. (0.05) between:

1. Levels of the same form in a variety 4.01
2. Levels in a variety over all forms 2.00
3. Forms in a variety 2.32
4. Forms 1.03
5. Levels 1.16

TABLE IV

Effect of different forms and levels of phosphorus on the height (cm) of three varieties of rice: 60th day

Forms	Level kg P_2O_5/ha	Rice variety: Culture 28	Rice variety: IR 8	Rice variety: Taichung Native 1	Mean
Control	0	30.7	43.5	38.2	39.5
Superphosphate	25	43.8	48.6	47.6	..
	50	48.0	50.1	48.8	..
	75	51.5	47.3	49.8	..
	Mean	47.8	48.7	48.7	48.4
Ultrafos	25	41.5	46.6	45.9	..
	50	46.9	44.3	46.6	..
	75	48.4	50.9	47.9	..
	Mean	45.6	47.3	46.8	46.6
Defluorinated rock phosphate	25	46.6	49.1	47.3	..
	50	47.2	49.5	48.4	..
	75	46.5	50.5	48.6	..
	Mean	46.8	49.7	48.1	48.2
Thomas phosphate	25	43.5	46.8	47.0	..
	50	47.9	47.5	48.4	..
	75	47.5	48.6	45.6	..
	Mean	46.3	47.6	47.0	47.0
All forms	25	43.8	47.8	46.9	46.2
	50	47.5	47.9	48.1	48.2
	75	48.5	49.3	48.0	48.6
Mean for variety	..	46.8	48.3	45.2	..

C.D. (0.05) between:

1. Levels of the same form in a variety 4.15
2. Levels in a variety over all forms 2.07
3. Varieties 1.17
4. Levels 1.17

TABLE V

Effect of different forms and levels of phosphorus on the height (cm) of three varieties of rice at harvest

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	44.1	54.9	48.8	49.3
Superphosphate	25	50.2	58.3	56.9	..
	50	51.7	56.2	56.0	..
	75	55.5	57.8	55.1	..
	Mean	52.5	57.4	56.0	55.3
Ultrafos	25	45.8	55.9	54.6	..
	50	53.4	53.4	55.2	..
	75	52.8	58.9	54.6	..
	Mean	50.7	56.1	54.8	53.9
Defluorinated rock phosphate	25	52.7	53.4	55.3	..
	50	51.1	57.4	53.8	..
	75	49.7	58.1	55.6	..
	Mean	51.2	56.3	54.9	54.1
Thomas phosphate	25	49.4	54.3	55.5	..
	50	54.9	54.9	55.9	..
	75	52.9	57.2	51.5	..
	Mean	52.4	55.5	54.3	54.1
All forms	25	49.5	55.5	55.6	53.5
	50	52.8	55.5	55.2	54.5
	75	52.7	58.0	54.2	55.0
Mean for variety	..	51.7	56.3	55.0	..

C.D. (0.05) between:

Varieties 1.4

be expected, the height of the plants increased with increase in the period of growth and reached a maximum at harvest. The maximum height reached by IR 8 was 56.3 cm, while for Taichung Native 1 and Culture 28 the corresponding values were 55.0 cm and 51.7 cm respectively. Though forms of phosphorus had no significant effect on the height of plants, superphosphate and defluorinated rock phosphate tended to produce taller plants than ultrafos and Thomas phosphate.

2. Number of vegetative tillers (Tables VI, VII and VIII)

The results indicate that the difference between forms of phosphorus as regards this character was significant at 1 per cent level. Significant interaction between the form and level of phosphorus was also obtained.

Among the different forms of phosphatic fertilizers tried superphosphate and defluorinated rock phosphate produced the maximum number of tillers. However, the difference between them was not statistically significant. Ultrafos and Thomas phosphate produced lesser number of tillers and were significantly inferior to superphosphate. The difference between varieties was also found to be significant at 1 per cent level. During the early stages of growth Culture 28 produced the maximum number of tillers, while Taichung Native 1 produced the maximum number at the later stages. In this

TABLE VI

Effect of different forms and levels of phosphorus on the number of tillers of three varieties of rice: 20th day

Forms	Level kg P_2O_5/ha	Rice variety: Culture 28	Rice variety: IR 8	Rice variety: Taichung Native 1	Mean
Control	0	1.0	1.0	1.0	1.0
Superphosphate	25	1.5	1.0	1.6	..
	50	1.9	1.4	1.7	..
	75	2.0	1.6	2.0	..
	Mean	1.8	1.3	1.6	1.6
Ultrafos	25	1.2	1.0	1.0	..
	50	1.4	1.1	1.2	..
	75	1.8	1.3	1.4	..
	Mean	1.5	1.1	1.2	1.3
Defluorinated rock phosphate	25	1.4	1.0	1.6	..
	50	2.2	1.5	2.1	..
	75	2.3	1.4	1.8	..
	Mean	2.0	1.3	1.6	1.6
Thomas phosphate	25	1.3	1.1	1.1	..
	50	1.4	1.2	1.5	..
	75	1.4	1.2	1.4	..
	Mean	1.4	1.2	1.3	1.3
All forms	25	1.4	1.0	1.4	1.3
	50	1.7	1.3	1.8	1.6
	75	1.9	1.4	1.9	1.7
Mean for variety	..	1.7	1.2	1.7	..

C.D.(0.05) between:

1. Levels of the same form in a variety	0.45
2. Levels in a variety over all forms	0.23
3. Forms in a variety	0.26
4. Varieties	0.13
5. Forms	0.15
6. Levels	0.13

TABLE VII

Effect of different forms and levels of phosphorus on the number of tillers of three varieties of rice: 40th day

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	4.3	3.4	4.1	3.9
Superphosphate	25	6.4	6.6	6.0	..
	50	7.8	6.9	8.1	..
	75	7.4	9.0	7.7	..
	Mean	7.2	7.5	7.3	7.3
Ultrafos	25	6.4	5.6	6.1	..
	50	7.5	6.4	6.9	..
	75	7.9	7.1	6.9	..
	Mean	7.3	6.4	6.6	6.8
Defluorinated rock phosphate	25	6.5	6.2	6.7	..
	50	8.1	6.8	7.8	..
	75	7.9	7.0	7.4	..
	Mean	7.5	6.7	7.3	7.2
Thomas phosphate	25	5.8	5.5	6.9	..
	50	6.7	6.6	7.4	..
	75	6.0	6.8	6.8	..
	Mean	6.2	6.3	7.0	6.5
All forms	25	6.3	6.0	6.4	6.2
	50	7.5	6.7	7.6	7.3
	75	7.3	7.5	7.2	7.3
Mean for variety	..	7.1	6.7	7.1	..

C.D.(0.05) between:

1. Levels of the same form in a variety	1.28
2. Levels in a variety over all forms	0.64
3. Forms in a variety	0.74
4. Forms	0.43
5. Levels	0.37

TABLE VIII

Effect of different forms and levels of phosphorus on the number of tillers of three varieties of rice: 60th day

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	6.3	6.3	6.8	6.5
Superphosphate	25	8.5	7.6	9.1	..
	50	9.8	9.0	10.7	..
	75	10.3	10.4	9.6	..
	Mean	9.5	9.0	9.8	9.4
Ultrafos	25	8.5	7.1	8.7	..
	50	9.1	9.0	9.4	..
	75	9.3	9.3	9.4	..
	Mean	9.0	8.5	9.2	8.9
Defluorinated rock phosphate	25	8.7	8.1	9.3	..
	50	9.9	8.4	10.2	..
	75	9.9	9.1	10.5	..
	Mean	9.5	8.5	10.0	9.3
Thomas phosphate	25	8.9	8.7	9.6	..
	50	8.3	8.0	10.1	..
	75	8.6	8.3	8.3	..
	Mean	8.6	8.3	9.3	8.7
All forms	25	8.7	7.9	9.2	8.5
	50	9.3	8.6	10.1	9.3
	75	9.5	9.3	9.5	9.4
Mean for variety	..	9.2	8.6	9.6	..

C.D. (0.05) between:

1.	Levels of the same form in a variety	1.22
2.	Levels in a variety over all forms	0.61
3.	Forms in a variety	0.71
4.	Varieties	0.35
5.	Forms	0.41
6.	Levels	0.35

character the efficiency of IR 8 was less compared to the other two varieties but the differences were not significant. The number of tillers increased with increase in the growth period and reached a maximum on the 60th day. The average number of tillers produced by Taichung Native 1 was 9.6 per hill (one plant) whereas IR 8 and Culture 28 produced 8.6 and 9.2 tillers per hill respectively. Application of phosphorus resulted in the production of a larger number of tillers and the treatments of 50 and 75 kg P_2O_5/ha were found to be superior to the treatments of 0 and 25 kg P_2O_5/ha.

3. Number of productive tillers (Table IX)

In the matter of productive tillers also Taichung Native 1 excelled the other two varieties. The maximum number of effective tillers produced by Taichung Native 1 was 7.9 for an application of superphosphate at 50 kg P_2O_5/ha. In the case of IR 8 the corresponding value was 7.6 for the application of superphosphate at 75 kg P_2O_5/ha. For Culture 28 the maximum number of tillers noted was 7.3 for an application of defluorinated rock phosphate at 50 kg P_2O_5/ha. When the average number of tillers was compared, the figure for Taichung Native 1 was 7.1 as against 6.6 and 6.4 for Culture 28 and IR 8 respectively.

The number of productive tillers was influenced by the different forms and levels of phosphorus as well. Among the different

TABLE IX

Effect of different forms and levels of phosphorus on the number of productive tillers of three varieties of rice at harvest

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	5.0	4.9	5.5	5.1
Superphosphate	25	6.0	5.7	7.0	..
	50	7.0	6.8	7.9	..
	75	6.8	7.6	7.1	..
	Mean	6.6	6.7	7.3	6.9
Ultrafos	25	6.1	5.1	7.1	..
	50	6.9	6.3	7.1	..
	75	6.9	6.7	7.2	..
	Mean	6.6	6.0	7.1	6.6
Defluorinated rock phosphate	25	6.4	6.2	7.2	..
	50	7.3	6.4	7.7	..
	75	6.9	6.6	7.8	..
	Mean	6.9	6.4	7.6	7.0
Thomas phosphate	25	6.5	6.1	6.9	..
	50	6.3	6.1	7.5	..
	75	6.4	6.7	5.0	..
	Mean	6.4	6.3	6.5	6.4
All forms	25	6.3	5.8	7.1	6.4
	50	6.9	6.4	7.8	7.0
	75	6.8	6.9	6.8	6.8
Mean for variety	..	6.6	6.4	7.1	..

C.D. (0.05) between:

1. Levels of the same form in a variety	1.00
2. Levels in a variety over all forms	0.50
3. Forms in a variety	0.58
4. Varieties	0.20
5. Forms	0.34
6. Levels	0.29

TABLE X

Effect of different forms and levels of phosphorus on the length of panicle (cm) of three varieties of rice

Forms	Level kg P_2O_5/ha	Rice variety: Culture 28	IR 8	Taichung Native 1	Mean
Control	0	16.9	17.5	16.1	16.8
Superphosphate	25	17.1	20.1	18.2	..
	50	17.5	18.9	18.1	..
	75	18.1	18.8	17.8	..
	Mean	17.6	19.3	18.0	18.3
Ultrafos	25	15.9	18.1	18.2	..
	50	17.8	18.2	18.4	..
	75	17.6	18.4	18.1	..
	Mean	17.1	18.6	18.2	18.0
Defluorinated rock phosphate	25	17.2	19.1	18.6	..
	50	16.8	18.1	16.7	..
	75	16.8	19.0	18.3	..
	Mean	16.9	18.7	17.9	17.8
Thomas phosphate	25	16.4	19.0	18.3	..
	50	16.9	18.4	18.1	..
	75	17.1	17.2	17.7	..
	Mean	16.8	18.2	18.0	17.7
All forms	25	16.7	19.1	18.3	18.0
	50	17.3	18.2	17.8	17.8
	75	17.4	18.4	18.0	17.9
Mean for variety	..	17.1	18.7	18.0	..

C.D. (0.05) between:

Varieties 0.44

forms of phosphorus tried superphosphate and defluorinated rock phosphate gave significant results as compared to the other two forms. As regards the effect of level, the best results were obtained for an application of phosphorus at 50 kg P_2O_5/ha. The number of effective tillers was the lowest for the zero treatment while the other two levels viz., 25 and 75 kg P_2O_5/ha gave intermediate results.

4. Length of panicle (Table X)

The length of panicle was found to vary significantly with variety. Hence this should be considered as a purely varietal character which is not appreciably influenced either by the form or level of phosphorus applied. Variety IR 8 produced panicles of maximum length (20.1 cm) for an application of superphosphate at 25 kg P_2O_5/ha. The maximum length of panicle for Taichung Native 1 (18.6 cm) was obtained for an application of defluorinated rock phosphate at 25 kg P_2O_5/ha, while for Culture 28 the maximum length (18.1 cm) was recorded for the application of superphosphate at 75 kg P_2O_5/ha. The average length of panicle was 18.7 cm in the case of IR 8, 18.0 cm in the case of Taichung Native 1 and 17.1 cm for Culture 28. In this regard IR 8 was statistically superior to Taichung Native 1 and Culture 28.

B. YIELD

The results relating to the effect of form and level of phosphorus on the yield characters, such as the number of grains per earhead, grain: chaff ratio, weight of grain and the weight of straw are presented in Tables XI, XII, XIII and XIV.

1. Yield of grain (Table XI and Fig. 1 & 2)

As far as the yield characters are concerned, variety Taichung Native 1 was found to be superior to Culture 28 and IR 8. The highest yield record for Taichung Native 1 was 24.7 g/pot for an application of superphosphate at 75 kg P_2O_5/ha. For IR 8 the maximum yield obtained was 21.7 g/pot for an application of defluorinated rock phosphate at 75 kg P_2O_5/ha, while the highest yield (21.7 g/pot) for Culture 28 was obtained for an application of superphosphate at 75 kg P_2O_5/ha. Eventhough the difference between the various forms of phosphorus was not statistically significant superphosphate and defluorinated rock phosphate generally produced better yields as compared to ultrafos and Thomas phosphate. The yield tended to increase with increasing levels of phosphorus, the highest yield (21.7 g/pot) being obtained for an application of phosphorus at 75 kg P_2O_5/ha.

2. Yield of straw (Table XII and Fig. 1 & 2)

The data reveal that there was no significant difference in the yield of straw for the different phosphorus treatments. However, among the different phosphatic fertilizers tried superphosphate produced the maximum yield of 26.40 g straw per pot. Of the different varieties used IR 8 produced the maximum yield of 27.8 g straw per pot

TABLE XI

Effect of different forms and levels of phosphorus on the yield of grain (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	14.0	15.7	17.0	15.6
Superphosphate	25	17.0	19.0	24.0	..
	50	21.0	18.0	24.3	..
	75	21.7	20.0	24.7	..
	Mean	19.9	19.0	24.3	21.1
Ultrafos	25	16.3	18.0	24.1	..
	50	17.7	20.3	24.3	..
	75	20.3	21.0	23.3	..
	Mean	18.1	19.8	23.9	20.6
Defluorinated rock phosphate	25	17.0	18.3	22.8	..
	50	19.0	19.0	23.7	..
	75	20.5	21.7	24.6	..
	Mean	18.8	19.7	23.7	20.7
Thomas phosphate	25	17.7	17.0	23.3	..
	50	19.0	17.3	24.3	..
	75	20.3	19.0	24.0	..
	Mean	19.0	17.8	23.9	20.2
All forms	25	17.0	18.1	23.5	19.5
	50	19.2	18.7	24.2	20.7
	75	20.7	20.2	24.2	21.7
Mean for variety	..	19.0	19.1	24.0	..

C.D. (0.05) between:
1. Levels of the same form in a variety 2.10
2. Levels in a variety over all forms 1.05
3. Varieties 0.61
4. Levels 0.61

TABLE XII

Effect of different forms and levels of phosphorus on the yield of straw (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	20.3	22.7	24.7	22.6
Superphosphate	25	24.0	27.7	25.3	..
	50	25.0	28.0	26.3	..
	75	27.0	28.7	25.7	..
	Mean	25.3	28.1	25.8	26.4
Ultrafos	25	20.3	25.7	25.7	..
	50	23.7	27.0	26.3	..
	75	24.0	28.3	25.3	..
	Mean	22.7	27.0	25.7	25.10
Defluorinated rock phosphate	25	21.3	26.7	24.0	..
	50	23.7	29.0	25.3	..
	75	25.3	29.0	25.7	..
	Mean	23.4	28.2	25.0	25.53
Thomas phosphate	25	23.3	28.0	25.0	..
	50	24.0	27.3	26.3	..
	75	25.0	28.0	25.3	..
	Mean	24.1	27.8	25.5	25.8
All forms	25	22.2	27.0	25.0	24.7
	50	24.1	27.8	20.1	25.7
	75	25.3	28.5	25.5	26.4
Mean for variety	..	23.9	27.8	25.5	..

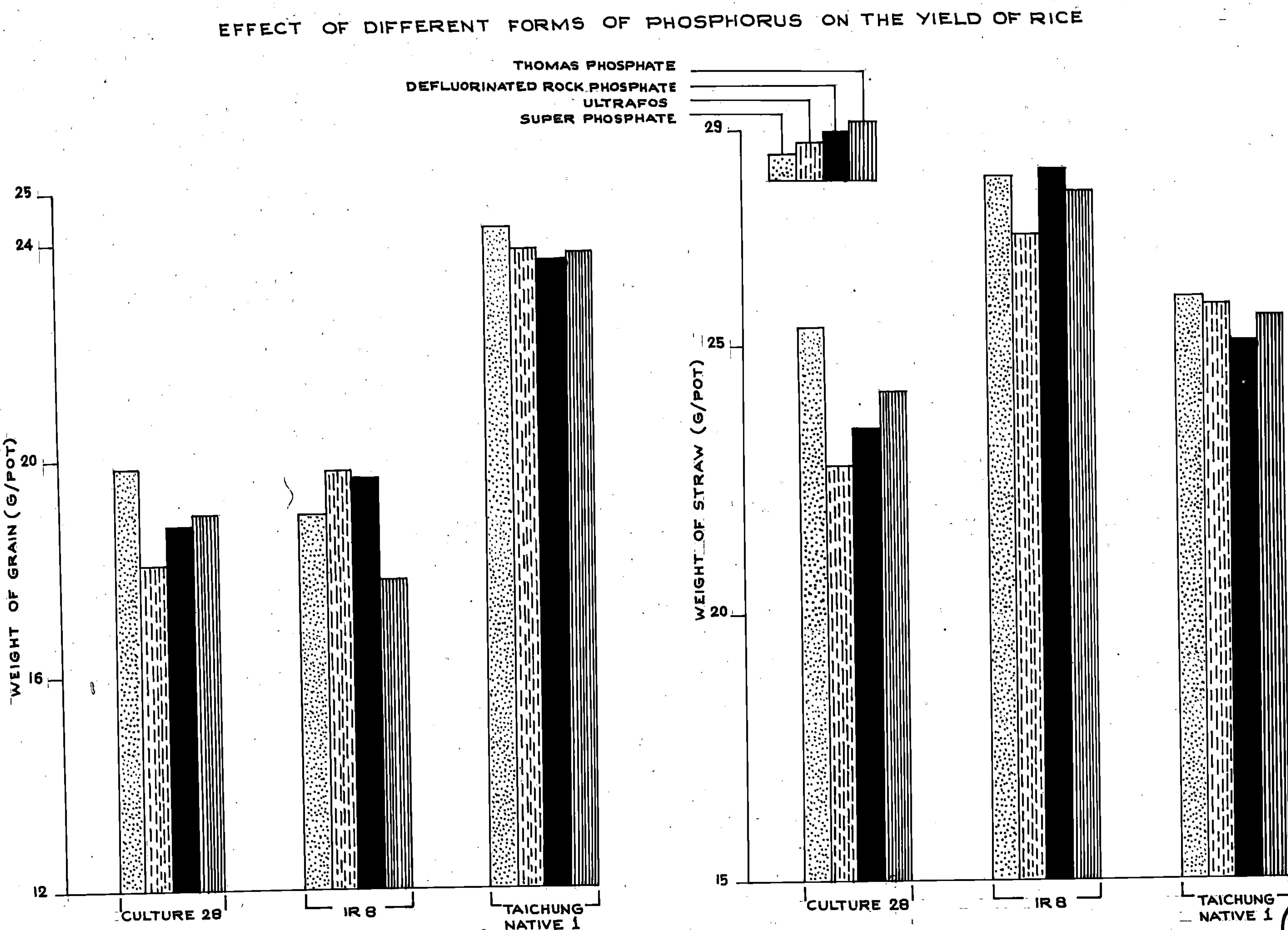
EFFECT OF DIFFERENT FORMS OF PHOSPHORUS ON THE YIELD OF RICE
THOMAS PHOSPHATE
DEFLUORINATED ROCK PHOSPHATE
ULTRAFOS
SUPER PHOSPHATE
WEIGHT OF GRAIN (G/POT)
25
24
20
16
12
CULTURE 28
IR 8
TAICHUNG NATIVE 1
WEIGHT OF STRAW (G/POT)
29
25
20
15
CULTURE 28
IR 8
TAICHUNG NATIVE 1

FIG 1

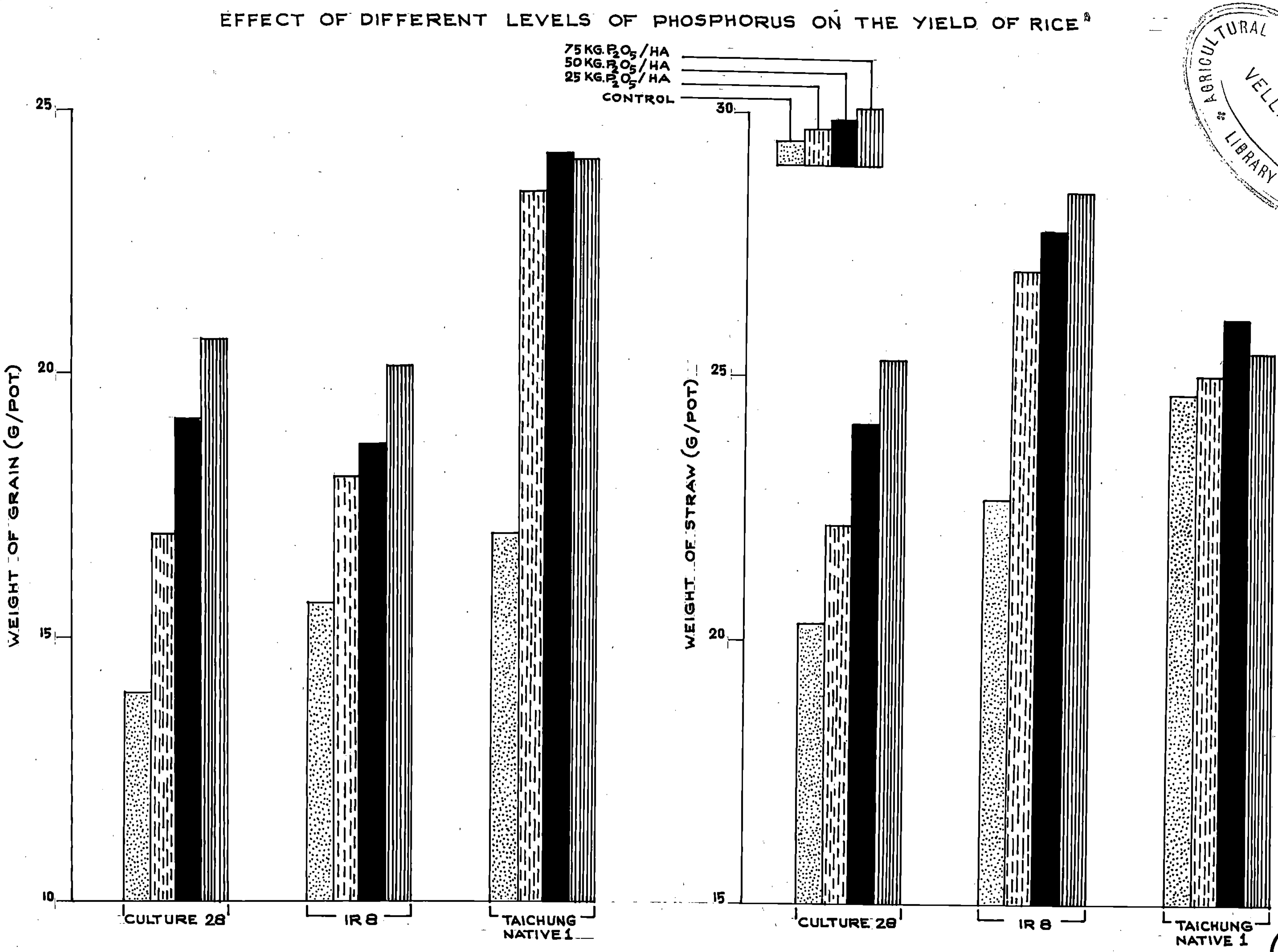
EFFECT OF DIFFERENT LEVELS OF PHOSPHORUS ON THE YIELD OF RICE
75 KG. P2O5/HA
50 KG. P2O5/HA
25 KG. P2O5/HA
CONTROL
WEIGHT OF GRAIN (G/POT)
25
20
15
10
CULTURE 28
IR 8
TAICHUNG NATIVE 1
WEIGHT OF STRAW (G/POT)
30
25
20
15
CULTURE 28
IR 8
TAICHUNG NATIVE 1

FIG 2

while Taichung Native 1 and Culture 28 gave an average yield of 25.5 and 23.9 g straw per pot respectively. Although there was no significant difference in the yield of straw for the different levels of phosphorus application, the general tendency for this yield character was to increase steadily with increasing levels of phosphorus.

3. Number of grains per panicle (Table XIII)

The number of grains per panicle differed significantly with variety. Significant interaction was also obtained for variety and level of phosphorus. The maximum number of grains per panicle (77.9) was produced by Taichung Native 1 for an application of Thomas phosphate at 25 kg P_2O_5/ha. In the case of IR 8 the largest number of grain per panicle (77.3) was obtained for an application of superphosphate at 25 kg P_2O_5/ha and in Culture 28 superphosphate at 50 kg P_2O_5/ha produced the highest number of grain per panicle (72.7). The average number of grains per panicle was also higher for Taichung Native 1, viz., 70.3 while, IR 8 and Culture 28 gave values of 68.9 and 59.8 grains per panicle respectively. Though the differences between the forms were insignificant, superphosphate showed a better efficiency over all the other forms.

4. Grain: Chaff ratio (Table XIV)

The grain: chaff ratio was influenced by variety and form of phosphorus, while the different levels of phosphorus showed only very

TABLE XIII

Effect of different forms and levels of phosphorus on the number of grains per panicle of three varieties of rice

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	56.0	68.7	60.8	61.8
Superphosphate	25	58.3	77.3	76.4	..
	50	72.7	73.1	68.1	..
	75	64.8	65.5	66.7	..
	Mean	65.3	72.0	70.4	69.2
Ultrafos	25	51.2	68.1	66.5	..
	50	59.7	69.3	75.6	..
	75	68.8	60.2	67.0	..
	Mean	59.9	68.9	70.4	66.3
Defluorinated rock phosphate	25	55.3	71.5	67.7	..
	50	53.0	63.5	59.0	..
	75	56.2	67.4	74.0	..
	Mean	54.8	67.5	66.9	63.1
Thomas phosphate	25	54.8	69.7	77.9	..
	50	62.7	68.0	72.2	..
	75	59.5	63.3	70.3	..
	Mean	59.0	67.0	73.5	66.5
All forms	25	54.9	71.7	72.6	66.4
	50	62.0	68.5	68.7	66.4
	75	62.3	66.4	69.5	66.1
Mean for variety	..	59.8	68.9	70.3	..

C.D. (0.05) between:

Varieties 3.67.

TABLE XIV

Effect of different forms and levels of phosphorus on the grain: chaff ratio of three varieties of rice

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	4.8	5.9	6.0	5.6
Superphosphate	25	6.1	11.7	14.6	..
	50	9.2	8.2	11.4	..
	75	7.0	12.0	19.7	..
	Mean	7.4	10.6	15.2	11.1
Ultrafos	25	5.0	9.0	7.7	..
	50	5.7	8.4	11.8	..
	75	7.2	11.2	10.7	..
	Mean	6.0	9.5	10.3	8.7
Defluorinated rock phosphate	25	8.1	8.0	10.0	..
	50	11.1	11.6	10.5	..
	75	8.2	12.4	16.3	..
	Mean	9.1	10.7	12.0	10.6
Thomas phosphate	25	6.8	6.3	9.2	..
	50	6.6	9.1	11.0	..
	75	8.2	9.6	7.2	..
	Mean	7.1	8.3	9.1	8.2
All forms	25	6.5	8.8	10.4	8.6
	50	8.2	9.3	10.9	9.5
	75	7.7	11.3	13.5	10.8
Mean for variety	..	7.5	9.8	11.9	..

C.D.(0.05) between:

1. Forms in a variety	3.95
2. Varieties	1.07
3. Forms	2.28

little influence. In the case of Taichung Native 1 the average grain: chaff ratio was 11.9 while for IR 8 and Culture 28 the ratios were 9.8 and 7.8 respectively. The highest ratio obtained was for the application of superphosphate (11.1) and the lowest ratio (8.2) for Thomas phosphate, the other two forms giving intermediate results. The increase in the level of phosphorus increased the ratio and wider ratios were obtained for higher levels of application but the differences were not significant.

C. NUTRIENT CONTENT

The data relating to the influence of phosphorus treatments on the nutrient content of rice grain and straw are presented in Tables XV to XX.

1. Nutrient content of grain (Fig.3)

(a) Nitrogen (Table XV)

The data show that both variety and form of phosphorus influenced appreciably the nitrogen content of grain. The results were significant at 1 per cent level. The highest nitrogen content of 1.44 per cent was obtained for IR 8 for an application of ultrafos at 25 kg P_2O_5/ha. The corresponding values for Taichung Native 1 and Culture 28 were 1.27 per cent and 1.09 per cent for application of superphosphate at 75 kg P_2O_5/ha and 50 kg P_2O_5/ha respectively. The average value for IR 8 was 1.24 per cent as against 1.05 per cent for Taichung Native 1 and 0.99 per cent for Culture 28.

TABLE XV

Effect of different forms and levels of phosphorus on the nitrogen content of rice grain (per cent)

Forms	Level kg P_2O_5/ha	Rice variety: Culture 28	IR 8	Taichung Native 1	Mean
Control	0	0.88	1.14	1.24	1.09
Superphosphate	25	1.04	1.08	1.24	..
	50	1.09	1.30	1.03	..
	75	1.04	1.41	1.27	..
	Mean	1.06	1.27	1.18	1.17
Ultrafos	25	0.95	1.44	1.05	..
	50	0.93	1.25	1.02	..
	75	1.02	1.30	1.25	..
	Mean	0.97	1.33	1.11	1.14
Defluorinated rock phosphate	25	0.95	1.23	0.97	..
	50	1.03	1.16	0.99	..
	75	0.99	1.35	1.00	..
	Mean	0.90	1.23	0.99	1.08
Thomas phosphate	25	0.91	1.03	0.76	..
	50	0.99	1.12	0.92	..
	75	0.98	1.14	1.08	..
	Mean	0.95	1.10	0.92	0.99
All forms	25	0.96	1.21	1.01	1.06
	50	1.01	1.21	0.99	1.07
	75	1.00	1.30	1.15	1.15
Mean for variety	..	0.99	1.24	1.05	..

C.D.(0.05) between:

1.	Forms in a variety	0.16
2.	Varieties	0.08
3.	Forms	0.09

Among the different forms of phosphorus tried superphosphate gave the highest value (1.17 per cent) followed by ultrafos (1.14 per cent) and defluorinated rock phosphate (1.08 per cent). The lowest value was obtained for Thomas phosphate (0.99 per cent). Although the nitrogen content of grain for the different levels of phosphorus application varied within insignificant levels the general tendency was for this element to increase with increase in the application of phosphorus.

(b) Phosphorus (Table XVI)

The phosphorus content of grain as influenced by variety was significant at 1 per cent level. The interaction between variety and form was also highly significant. Among the different varieties studied IR 8 gave the maximum P_2O_5 content (0.47 per cent) and Culture 28 the minimum (0.39 per cent).

The influence of form and level of phosphorus was also significant at 1 per cent level. The maximum P_2O_5 content was obtained for a phosphorus application of 75 kg P_2O_5/ha followed by applications of 50 kg and 25 kg P_2O_5/ha. Superphosphate and defluorinated rock phosphate tended to give the maximum P_2O_5 content (0.46 per cent) whereas Thomas phosphate gave the minimum (0.37 per cent).

(c) Potassium (Table XVII)

Both level and form of phosphorus were found to have significant influence on the K_2O content of grain at 1 per cent level. Significant differences were also obtained for varieties.

TABLE XVI

Effect of different forms and levels of phosphorus on the P_2O_5 content of rice grain (per cent)

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	0.15	0.29	0.33	0.26
Superphosphate	25	0.29	0.41	0.41	..
	50	0.45	0.50	0.52	..
	75	0.49	0.51	0.54	..
	Mean	0.41	0.47	0.49	0.46
Ultrafos	25	0.31	0.45	0.35	..
	50	0.37	0.41	0.44	..
	75	0.44	0.49	0.46	..
	Mean	0.37	0.45	0.42	0.41
Defluorinated rock phosphate	25	0.32	0.40	0.27	..
	50	0.41	0.56	0.48	..
	75	0.52	0.54	0.50	..
	Mean	0.42	0.53	0.43	0.46
Thomas phosphate	25	0.27	0.35	0.38	..
	50	0.37	0.42	0.46	..
	75	0.45	0.48	0.41	..
	Mean	0.36	0.42	0.42	0.37
All forms	25	0.30	0.43	0.35	0.36
	50	0.43	0.47	0.48	0.46
	75	0.47	0.51	0.48	0.49
Mean for variety	..	0.39	0.47	0.44	..

C.D.(0.05) between:

1. Levels of the same form in a variety	0.087
2. Levels in a variety over all forms	0.043
3. Forms in a variety	0.050
4. Varieties	0.025
5. Forms	0.029
6. Levels	0.025

TABLE XVII

Effect of different forms and levels of phosphorus on the K_2O content of rice grain (per cent)

Forms	Level kg P_2O_5	Rice variety: Culture 28	IR 8	Taichung Native 1	Mean
Control	0	0.27	0.32	0.54	0.38
Superphosphate	25	0.48	0.40	0.56	..
	50	0.59	0.54	0.53	..
	75	0.57	0.35	0.61	..
	Mean	0.55	0.43	0.57	0.52
Ultrafos	25	0.37	0.31	0.44	..
	50	0.38	0.52	0.54	..
	75	0.39	0.46	0.61	..
	Mean	0.38	0.43	0.53	0.45
Defluorinated rock phosphate	25	0.57	0.24	0.47	..
	50	0.49	0.33	0.57	..
	75	0.61	0.47	0.68	..
	Mean	0.56	0.35	0.57	0.49
Thomas phosphate	25	0.25	0.20	0.55	..
	50	0.30	0.29	0.57	..
	75	0.47	0.33	0.50	..
	Mean	0.34	0.30	0.54	0.39
All forms	25	0.42	0.31	0.51	0.41
	50	0.44	0.42	0.55	0.47
	75	0.51	0.40	0.60	0.50
Mean for variety	..	0.45	0.38	0.55	..

C.D.(0.05) between:

1. Levels of the same form in a variety	0.104
2. Levels in a variety over all forms	0.052
3. Forms in a variety	0.060
4. Varieties	0.030
5. Forms	0.034
6. Levels	0.030

Of the four forms of phosphorus tried the highest potassium content obtained was 0.52 per cent for the application of superphosphate. Thomas phosphate gave the lowest value (0.39 per cent), the effect of the other forms being intermediate. Variety Taichung Native 1 gave the highest K_2O content of 0.55 per cent as against 0.46 per cent for Culture 28 and 0.38 per cent for IR 8. The tendency of this element in the grain was to increase with the increase in the level of phosphorus application.

2. <u>Nutrient content of straw</u> (Fig.4)

(a) <u>Nitrogen</u> (Table XVIII)

The data reveal that variety, and form and level of phosphorus had significant effect on the nitrogen content of straw.

When the mean values for varieties were compared Culture 28 was found to contain the highest per cent (0.56) and Taichung Native 1 the lowest (0.38) per cent of nitrogen. As in the case of the nitrogen content of grain, the nitrogen content of straw was also found to vary significantly and the general tendency was for this element to increase with increasing levels of phosphorus application. In this case also the maximum nitrogen content (0.51 per cent) was obtained for phosphorus applied in the form of superphosphate. The lowest value (0.44 per cent) was obtained for defluorinated rock phosphate.

TABLE XVIII

Effect of different forms and levels of phosphorus on the nitrogen content of rice straw (per cent)

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	0.42	0.37	0.32	0.37
Superphosphate	25	0.58	0.54	0.37	..
	50	0.60	0.55	0.40	..
	75	0.67	0.57	0.33	..
	Mean	0.62	0.55	0.37	0.51
Ultrafos	25	0.62	0.38	0.42	..
	50	0.70	0.48	0.35	..
	75	0.50	0.57	0.42	..
	Mean	0.61	0.48	0.40	0.49
Defluorinated rock phosphate	25	0.57	0.37	0.35	..
	50	0.48	0.46	0.38	..
	75	0.48	0.52	0.37	..
	Mean	0.51	0.45	0.37	0.44
Thomas phosphate	25	0.52	0.55	0.27	..
	50	0.58	0.64	0.33	..
	75	0.40	0.58	0.57	..
	Mean	0.50	0.59	0.39	0.47
All forms	25	0.57	0.46	0.35	0.46
	50	0.59	0.53	0.37	0.50
	75	0.51	0.56	0.42	0.50
Mean for variety	..	0.56	0.52	0.38	..

C.D. (0.05) between:

1. Levels of the same form in a variety	0.102
2. Levels in a variety over all forms	0.051
3. Forms in a variety	0.059
4. Varieties	0.028
5. Forms	0.034
6. Levels	0.028

(b) Phosphorus (Table XIX)

The data given in the table show that phosphorus treatments and variety had no significant influence on the phosphorus content of straw. However, there was a general tendency for the P_2O_5 content to increase with increasing applications of phosphorus. When the average values for the different varieties were compared IR 8 gave the maximum P_2O_5 content (0.068 per cent) followed by Culture 28 (0.057 per cent) and Taichung Native 1 (0.05 per cent). However the differences were not significant statistically.

(c) Potassium (Table XX)

The K_2O content of straw presented in the table shows that variety and form of phosphorus had only very little influence on the K_2O content of straw. But level of phosphorus significantly influenced this component. Thus the maximum content of K_2O was obtained for an application of phosphorus at 75 kg P_2O_5/ha. The minimum value was obtained for the zero application. When the mean values for the varieties were compared the highest value (2.1 per cent) was given by Culture 28. The average values for Taichung Native 1 and IR 8 were 2.12 per cent and 1.71 per cent respectively. The differences between the varieties were, however, not significant. Although form of phosphorus had only very little influence on the K_2O content of straw, superphosphate and defluorinated rock phosphate tended to give higher values as compared to the other forms.

TABLE XIX

Effect of different forms and levels of phosphorus on the P_2O_5 content of rice straw (per cent)

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	0.034	0.031	0.038	0.034
Superphosphate	25	0.044	0.053	0.045	..
	50	0.055	0.082	0.053	..
	75	0.064	0.099	0.054	..
	Mean	0.054	0.078	0.051	0.061
Ultrafos	25	0.039	0.043	0.031	..
	50	0.072	0.065	0.050	..
	75	0.081	0.099	0.071	..
	Mean	0.064	0.069	0.051	0.061
Defluorinated rock phosphate	25	0.038	0.045	0.043	..
	50	0.059	0.074	0.063	..
	75	0.100	0.083	0.047	..
	Mean	0.069	0.067	0.051	0.062
Thomas phosphate	25	0.039	0.034	0.047	..
	50	0.042	0.067	0.034	..
	75	0.044	0.068	0.056	..
	Mean	0.041	0.056	0.046	0.044
All forms	25	0.040	0.044	0.042	0.042
	50	0.057	0.057	0.050	0.055
	75	0.072	0.087	0.057	0.072
Mean for variety	..	0.057	0.068	0.050	..

TABLE XX

Effect of different forms and levels of phosphorus on the K_2O content of rice straw (per cent)

Forms	Level kg P_2O_5/ha	Rice variety: Culture 28	IR 8	Taichung Native 1	Mean
Control	0	1.32	1.76	2.17	1.75
Superphosphate	25	2.48	1.93	2.38	..
	50	3.03	2.11	2.13	..
	75	3.01	2.11	2.29	..
	Mean	2.84	2.05	2.27	2.38
Ultrafos	25	2.22	1.38	1.62	..
	50	1.91	1.45	1.74	..
	75	2.04	1.45	1.99	..
	Mean	2.06	1.49	1.78	1.77
Defluorinated rock phosphate	25	1.80	1.34	2.08	..
	50	1.65	2.05	2.08	..
	75	2.21	2.11	2.78	..
	Mean	1.89	1.83	2.31	2.01
Thomas phosphate	25	1.71	1.14	2.05	..
	50	2.13	1.62	2.01	..
	75	1.99	1.60	2.34	..
	Mean	1.94	1.45	2.13	1.84
All forms	0	1.32	1.76	2.17	..
	25	2.05	1.49	2.03	1.89
	50	2.18	1.80	1.99	1.99
	75	2.31	1.81	2.35	2.16
Mean for variety	..	2.18	1.71	2.12	..

C.D. (0.05) between:

1. Levels of the same form in a variety	0.82
2. Levels in a variety overall forms	0.41
3. Levels	0.24

EFFECT OF DIFFERENT LEVELS OF PHOSPHORUS ON THE COMPOSITION OF RICE GRAIN

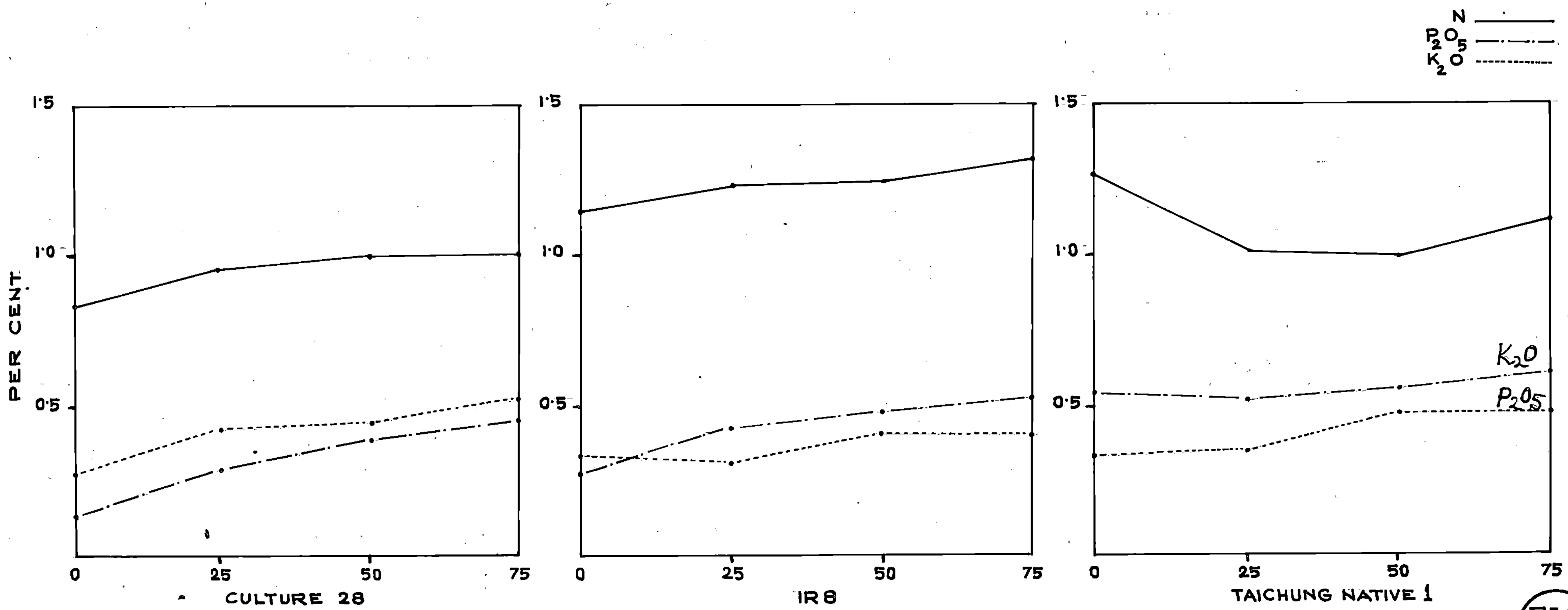

FIG 3

EFFECT OF DIFFERENT LEVELS OF PHOSPHORUS ON THE COMPOSITION OF RICE STRAW

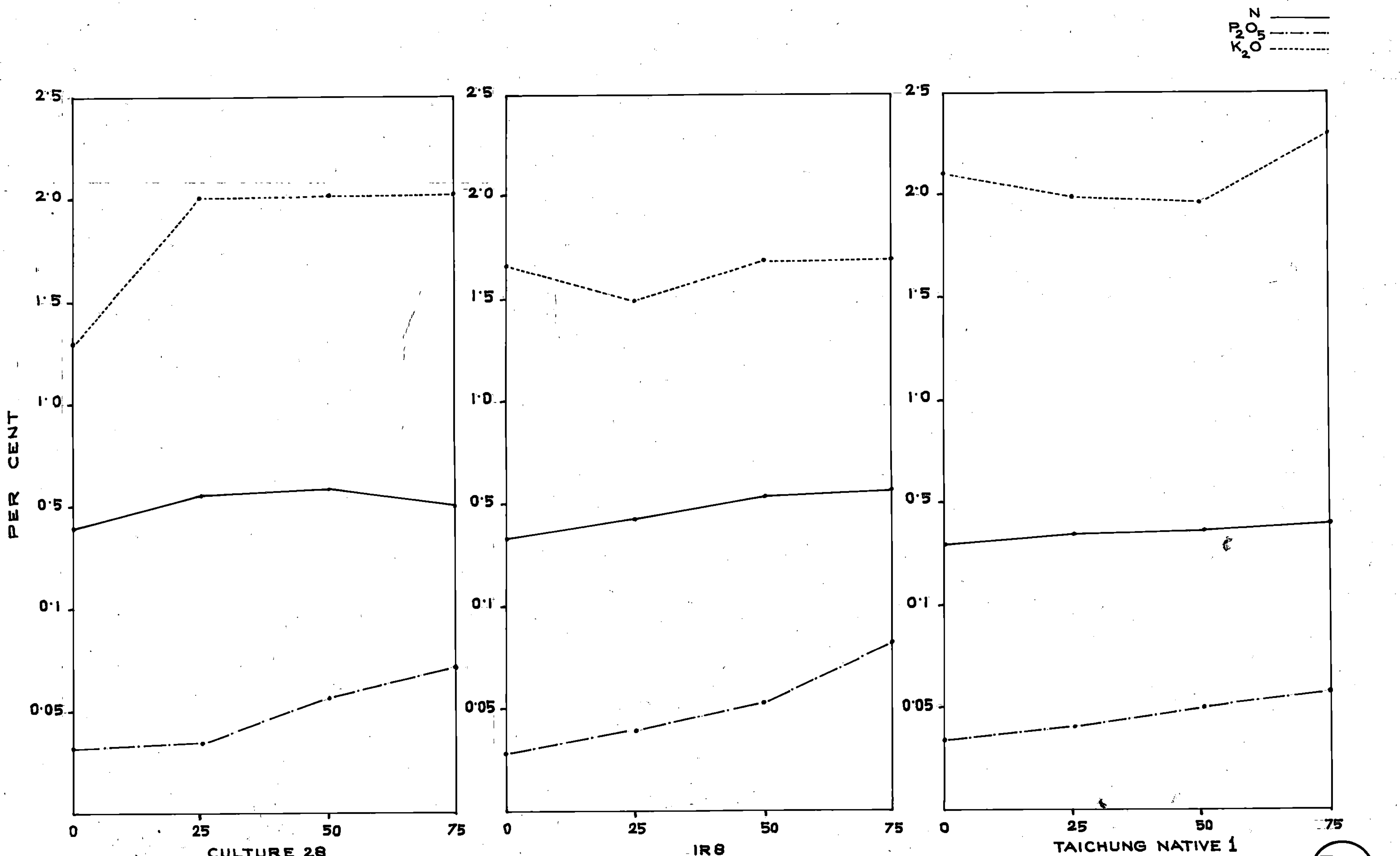

FIG 4

D. NUTRIENT REMOVAL

The data relating to the removal of nutrients by the three varieties of rice are furnished in Tables XXI to XXV.

1. Nutrient removal in grain

(a) Nitrogen (Table XXI)

Removal of nitrogen in grain was influenced by variety and form of phosphorus. Variety IR 8 removed the maximum amount (0.24 g/pot) and Culture 28 the least (0.188 g/pot). Of the different forms of phosphorus used, the maximum removal of nitrogen was noted for the application of superphosphate (0.244 g/pot) followed by defluorinated rock phosphate (0.223 g/pot), ultrafos (0.211 g/pot) and Thomas phosphate (0.200 g/pot).

(b) Phosphorus (Table XXII)

In the study of the effect of different forms and levels of phosphorus on the P_2O_5 content of grain, it was seen that the highest amount of P_2O_5/pot (0.105 g) was removed by Taichung Native 1 followed by IR 8 (0.090 g) and Culture 28 (0.077 g). As regards the influence of form, the plants supplied with superphosphate removed the maximum quantity of P_2O_5 in grain (0.09 g/pot) followed by those treated with defluorinated rock phosphate (0.005 g/pot), ultrafos (0.086 g/pot) and Thomas phosphate (0.080 g/pot). Plants receiving higher levels of phosphorus application removed the maximum amount of P_2O_5/pot compared to the lower levels of application.

TABLE XXI

Removal of nitrogen in grain by three varieties of rice (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	0.123	0.179	0.211	0.171
Superphosphate	25	0.177	0.207	0.284	..
	50	0.229	0.234	0.260	..
	75	0.226	0.282	0.314	..
	Mean	0.207	0.241	0.286	0.244
Ultrafos	25	0.155	0.259	0.147	..
	50	0.165	0.254	0.146	..
	75	0.207	0.273	0.291	..
	Mean	0.176	0.262	0.195	0.211
Defluorinated rock phosphate	25	0.162	0.231	0.220	..
	50	0.196	0.220	0.235	..
	75	0.203	0.294	0.247	..
	Mean	0.187	0.248	0.234	0.223
Thomas phosphate	25	0.161	0.175	0.177	..
	50	0.188	0.194	0.224	..
	75	0.195	0.217	0.259	..
	Mean	0.181	0.199	0.220	0.200
All forms	25	0.163	0.218	0.209	0.197
	50	0.194	0.225	0.213	0.211
	75	0.207	0.266	0.277	0.250
Mean for variety	..	0.188	0.240	0.234	..

TABLE XXII

Removal of P_2O_5 in grain by three varieties of rice (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	0.021	0.045	0.056	0.041
Superphosphate	25	0.049	0.078	0.098	..
	50	0.095	0.090	0.126	..
	75	0.104	0.102	0.143	..
	Mean	0.083	0.090	0.122	0.098
Ultrafos	25	0.051	0.081	0.084	..
	50	0.066	0.083	0.107	..
	75	0.089	0.103	0.107	..
	Mean	0.069	0.089	0.099	0.086
Defluorinated rock phosphate	25	0.054	0.090	0.061	..
	50	0.078	0.106	0.114	..
	75	0.107	0.117	0.124	..
	Mean	0.080	0.104	0.100	0.095
Thomas phosphate	25	0.038	0.060	0.089	..
	50	0.070	0.073	0.112	..
	75	0.091	0.091	0.098	..
	Mean	0.066	0.075	0.100	0.080
All forms	25	0.048	0.077	0.083	0.069
	50	0.077	0.088	0.115	0.093
	75	0.098	0.103	0.118	0.106
Mean for variety	..	0.077	0.090	0.105	..

TABLE XXIII

Removal of K_2O in grain by three varieties of rice (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety: Culture 28	IR 8	Taichung Native 1	Mean
Control	0	0.038	0.050	0.091	0.060
Superphosphate	25	0.082	0.075	0.135	..
	50	0.123	0.098	0.128	..
	75	0.124	0.070	0.151	..
	Mean	0.110	0.081	0.138	0.109
Ultrafos	25	0.061	0.055	0.106	..
	50	0.067	0.105	0.131	..
	75	0.079	0.096	0.141	..
	Mean	0.069	0.085	0.126	0.093
Defluorinated rock phosphate	25	0.096	0.045	0.106	..
	50	0.093	0.063	0.136	..
	75	0.124	0.101	0.167	..
	Mean	0.104	0.070	0.136	0.103
Thomas phosphate	25	0.044	0.034	0.120	..
	50	0.058	0.051	0.130	..
	75	0.107	0.062	0.119	..
	Mean	0.103	0.049	0.129	0.094
All forms	25	0.071	0.052	0.119	0.081
	50	0.085	0.079	0.133	0.099
	75	0.109	0.088	0.144	0.114
Mean for variety	..	0.099	0.071	0.132	..

(c) Potassium (Table XXIII)

When the weight of K_2O/pot removed by grain was calculated the highest value was obtained for Taichung Native 1 (0.132 g) followed in order by Culture 28 (0.099 g) and IR 8 (0.071 g). Of the different forms of phosphorus used the plants supplied with superphosphate and defluorinated rock phosphate removed the maximum quantity of K_2O/pot while those under the other treatments removed only lesser quantities. As regards the influence of the rate of phosphorus application, it was noted that the total uptake of K_2O by grain increased with increase in the level of phosphorus applied.

2. Nutrient removal in straw

(a) Nitrogen (Table XXIV)

As in the case of the uptake of nitrogen by grain the removal of this element in straw was also a maximum for variety IR 8. Of the different forms of phosphorus applied, the plants supplied with superphosphate absorbed the maximum quantity of nitrogen (0.149 g/pot) followed by those receiving the Thomas phosphate (0.129 g/pot), ultrafos (0.123 g/pot) and defluorinated rock phosphate (0.113 g/pot). It may also be noted that the quantity of nitrogen in the straw increased with increase in the level of phosphorus application.

(b) Phosphorus (Table XXV)

When the uptake of phosphorus in straw was considered it was seen that IR 8 removed the maximum quantity (0.02 g/pot). The

TABLE XXIV

Removal of nitrogen in straw by three varieties of rice (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety: Culture 28	IR 8	Taichung Native 1	Mean
Control	0	0.085	0.084	0.070	0.083
Superphosphate	25	0.130	0.147	0.094	..
	50	0.150	0.154	0.105	..
	75	0.181	0.181	0.085	..
	Mean	0.157	0.161	0.128	0.149
Ultrafos	25	0.126	0.098	0.108	..
	50	0.194	0.099	0.092	..
	75	0.120	0.160	0.106	..
	Mean	0.147	0.119	0.102	0.123
Defluorinated rock phosphate	25	0.121	0.099	0.084	..
	50	0.114	0.133	0.096	..
	75	0.122	0.151	0.095	..
	Mean	0.119	0.128	0.092	0.113
Thomas phosphate	25	0.121	0.154	0.068	..
	50	0.130	0.165	0.087	..
	75	0.100	0.162	0.144	..
	Mean	0.120	0.167	0.100	0.129
All forms	25	0.127	0.125	0.089	0.114
	50	0.149	0.143	0.095	0.120
	75	0.137	0.164	0.108	0.136
Mean for variety	..	0.130	0.144	0.106	..

TABLE XXV

Removal of P_2O_5 in straw by three varieties of rice (g per pot)

Forms	Levels kg P_2O_5/ha	Rice variety: Culture 28	Rice variety: IR 8	Rice variety: Taichung Native 1	Mean
Control	0	0.007	0.007	0.009	0.008
Superphosphate	25	0.011	0.015	0.011	..
	50	0.014	0.023	0.014	..
	75	0.018	0.028	0.014	..
	Mean	0.014	0.022	0.013	0.016
Ultrafos	25	0.008	0.011	0.008	..
	50	0.020	0.018	0.013	..
	75	0.010	0.028	0.018	..
	Mean	0.016	0.019	0.013	0.016
Defluorinated rock phosphate	25	0.008	0.012	0.010	..
	50	0.014	0.025	0.016	..
	75	0.025	0.024	0.012	..
	Mean	0.016	0.021	0.013	0.017
Thomas phosphate	25	0.009	0.010	0.012	..
	50	0.010	0.018	0.009	..
	75	0.011	0.019	0.014	..
	Mean	0.010	0.016	0.012	0.013
All forms	25	0.009	0.012	0.010	0.010
	50	0.015	0.021	0.013	0.016
	75	0.018	0.025	0.015	0.019
Mean for variety	..	0.014	0.020	0.013	..

TABLE XXVI

Removal of K_2O in straw by three varieties of rice (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety: Culture 28	IR 8	Taichung Native 1	Mean
Control	0	0.268	0.400	0.536	0.401
Superphosphate	25	0.595	0.533	0.602	..
	50	0.758	0.591	0.560	..
	75	0.813	0.606	0.588	..
	Mean	0.722	0.577	0.583	0.627
Ultrafos	25	0.451	0.406	0.416	..
	50	0.520	0.392	0.458	..
	75	0.490	0.410	0.504	..
	Mean	0.487	0.403	0.459	0.449
Defluorinated rock phosphate	25	0.383	0.358	0.499	..
	50	0.391	0.595	0.526	..
	75	0.559	0.612	0.715	..
	Mean	0.444	0.522	0.580	0.515
Thomas phosphate	25	0.398	0.319	0.513	..
	50	0.511	0.442	0.580	..
	75	0.498	0.448	0.590	..
	Mean	0.469	0.403	0.561	0.477
All forms	25	0.456	0.404	0.507	0.456
	50	0.545	0.505	0.531	0.527
	75	0.590	0.519	0.599	0.569
Mean for variety	..	0.530	0.476	0.546	..

quantities of phosphorus removed by Culture 28 and Taichung Native 1 were 0.014 g/pot and 0.013 g/pot respectively. When the mean values for the different forms were examined it was found that the quantities of phosphorus removed by plants treated with superphosphate, ultrafos and defluorinated rock phosphate were more or less equal and higher than those removed by plants under Thomas phosphate treatment.

(c) Potassium (Table XXVI)

The data presented in the table for the K_2O removal in straw, reveal that variety and phosphorus treatment had marked influence on the uptake of this nutrient. The maximum quantity removed was for the application of superphosphate (0.637 g/pot) followed in order by defluorinated rock phosphate (0.515 g/pot), Thomas phosphate (0.477 g/pot) and ultrafos (0.449 g/pot). The highest amount of K_2O removed by Taichung Native 1 was 0.699 g/pot for an application of 75 kg P_2O_5/ha. For Culture 28 and IR 8 the corresponding values were 0.590 g/pot and 0.519 g/pot for the same level viz., 75 kg P_2O_5/ha.

3. Total nutrient removal in grain and straw

The data relating to the effect of phosphorus on the total nutrient removal by grain and straw are presented in Tables XXVII, XXVIII and XXIX.

(a) Nitrogen (Table XXVII)

It may be seen that plants treated with superphosphate removed the maximum quantities of nitrogen (0.383 g/pot) followed in order by defluorinated rock phosphate (0.336 g/pot), ultrafos (0.334 g/pot) and Thomas phosphate (0.327 g/pot). When the mean values for the different varieties were compared it was found that IR 8 removed the highest amount of nitrogen (0.38 g/pot) while Culture 28 removed the lowest (0.324 g/pot). Level of phosphorus also showed a marked influence on the absorption of this nutrient by the plants and the general tendency was for this element to increase with increase in the level of phosphorus application.

2. Phosphorus (Table XXVIII)

Variety Taichung Native 1 removed more P_2O_5 (0.118 g/pot) than IR 8 (0.105 g/pot) and Culture 28 (0.087 g/pot). Of the different sources of phosphorus used in this investigation, superphosphate was found to be superior to other forms and an average of 0.115 g/pot was removed by plants receiving this treatment. Plants supplied with Thomas phosphate removed the minimum quantity of P_2O_5 (0.092 g/pot) and the other two forms were found to give intermediate results. As regards the effect of level, an increase in the rate of phosphorus application increased the uptake of this nutrient by plants.

3. Potassium (Table XXIX)

In the case of potassium the total quantity of K_2O removed in the grain and straw was highest for Taichung Native 1 (0.678 g/pot) followed by Culture 28 (0.619 g/pot) and IR 8 (0.547 g/pot). When the

TABLE XXVII

Removal of nitrogen in grain and straw (total) by three varieties of rice (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culturo 28	IR 8	Taichung Native 1	
Control	0	0.209	0.203	0.290	0.137
Superphosphate	25	0.316	0.356	0.387	..
	50	0.379	0.388	0.355	..
	75	0.407	0.463	0.399	..
	Mean	0.367	0.402	0.380	0.383
Ultrafos	25	0.281	0.357	0.254	..
	50	0.350	0.353	0.238	..
	75	0.327	0.433	0.398	..
	Mean	0.322	0.381	0.300	0.334
Defluorinated rock phosphate	25	0.283	0.329	0.304	..
	50	0.310	0.354	0.331	..
	75	0.325	0.445	0.342	..
	Mean	0.306	0.376	0.326	0.336
Thomas phosphate	25	0.280	0.329	0.245	..
	50	0.327	0.379	0.310	..
	75	0.295	0.379	0.303	..
	Mean	0.301	0.362	0.319	0.327
All forms	25	0.290	0.342	0.297	0.310
	50	0.343	0.368	0.308	0.340
	75	0.338	0.430	0.382	0.383
Mean for variety	..	0.324	0.380	0.331	..

TABLE XXVIII

Removal of P_2O_5 in grain and straw (total) by three varieties of rice (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety			Mean
		Culture 28	IR 8	Taichung Native 1	
Control	0	0.028	0.052	0.066	0.050
Superphosphate	25	0.060	0.093	0.110	..
	50	0.108	0.113	0.140	..
	75	0.122	0.130	0.157	..
	Mean	0.097	0.112	0.136	0.115
Ultrafos	25	0.058	0.092	0.092	..
	50	0.075	0.101	0.120	..
	75	0.108	0.131	0.125	..
	Mean	0.080	0.081	0.112	0.091
Defluorinated rock phosphate	25	0.063	0.102	0.072	..
	50	0.092	0.132	0.130	..
	75	0.132	0.141	0.136	..
	Mean	0.096	0.125	0.113	0.111
Thomas phosphate	25	0.047	0.069	0.100	..
	50	0.080	0.091	0.121	..
	75	0.102	0.110	0.112	..
	Mean	0.076	0.090	0.111	0.092
All forms	25	0.057	0.080	0.093	0.080
	50	0.088	0.100	0.127	0.108
	75	0.116	0.128	0.132	0.125
Mean for variety	..	0.087	0.105	0.118	..

TABLE XXIX

Removal of K_2O in grain and straw (total) by three varieties of rice (g per pot)

Forms	Level kg P_2O_5/ha	Rice variety: Culture 28	IR 8	Taichung Native 1	Mean
Control	0	0.306	0.449	0.627	0.461
Superphosphate	25	0.677	0.610	0.737	..
	50	0.881	0.689	0.688	..
	75	0.937	0.676	0.740	..
	Mean	0.832	0.658	0.722	0.737
Ultrafos	25	0.512	0.462	0.523	..
	50	0.587	0.497	0.588	..
	75	0.569	0.506	0.645	..
	Mean	0.556	0.488	0.585	0.543
Defluorinated rock phosphate	25	0.480	0.401	0.605	..
	50	0.484	0.659	0.662	..
	75	0.684	0.713	0.881	..
	Mean	0.549	0.591	0.716	0.618
Thomas phosphate	25	0.443	0.353	0.641	..
	50	0.569	0.493	0.710	..
	75	0.605	0.510	0.709	..
	Mean	0.539	0.452	0.690	0.560
All forms	25	0.528	0.456	0.626	0.533
	50	0.630	0.584	0.604	0.626
	75	0.608	0.600	0.743	0.680
Mean for variety	..	0.619	0.547	0.678	..

influence of source of phosphorus on the total uptake of K_2O was considered it was seen that the highest amount of K_2O was removed by the plants treated with superphosphate (0.737 g/pot). The application of ultrafos, defluorinated rock phosphate and Thomas phosphate resulted in the removal of 0.543 g, 0.618 g and 0.660 g K_2O/pot respectively. When the effect of the level of phosphorus on the removal of K_2O was considered it was seen that the total quantity of K_2O removed per pot increased steadily with increase in the rate of phosphorus application.

VARIATION IN AVAILABLE P_2O_5 AND pH OF THE SOIL DURING THE GROWTH PERIOD OF PLANTS

The data relating to the influence of form and level of phosphorus on the available P_2O_5 content and pH of the soil are furnished in Table XXX.

Available P_2O_5

The analysis of the soil at all the three stages of growth revealed that form of phosphorus had no effect in increasing the available P_2O_5 content of the soil. However, it increased with increase in levels of phosphorus application. Thus the pots receiving 75 kg P_2O_5/ha gave higher values than control. The general tendency for this element was to increase with increase in time and the maximum amount was observed on the 60th day after application. After this period it tended to decrease towards the time of harvest of the crop.

TABLE XXX

Available P_2O_5 (per cent) and pH of the soil at three stages of plant growth

Form of phosphorus	Level kg P_2O_5/ha	30th day		60th day		After harvest	
		Available P_2O_5	pH	Available P_2O_5	pH	Available P_2O_5	pH
Control	0	0.0003	4.6	0.0003	4.9	0.0003	5.0
Superphosphate	25	0.0002	4.2	0.0005	4.8	0.0003	5.0
	50	0.0003	4.3	0.0004	4.7	0.0004	4.9
	75	0.0003	4.4	0.0007	5.0	0.0005	5.2
	Mean	0.0003	4.3	0.0005	4.8	0.0004	5.0
Ultrafos	25	0.0002	4.3	0.0004	4.9	0.0003	4.9
	50	0.0004	4.3	0.0004	5.0	0.0004	5.3
	75	0.0004	4.3	0.0007	4.8	0.0004	4.9
	Mean	0.0003	4.3	0.0005	5.0	0.0004	5.0
Defluorinated rock phosphate	25	0.0002	4.5	0.0004	4.6	0.0004	4.7
	50	0.0003	4.5	0.0007	4.9	0.0005	5.0
	75	0.0004	4.8	0.0006	4.9	0.0006	5.1
	Mean	0.0003	4.6	0.0006	4.8	0.0005	4.9
Thomas phosphate	25	0.0002	4.4	0.0003	5.0	0.0004	5.1
	50	0.0003	4.4	0.0004	4.8	0.0004	5.0
	75	0.0004	4.5	0.0005	4.8	0.0005	4.9
	Mean	0.0003	4.4	0.0004	4.9	0.0004	5.0
All forms	25	0.0002	4.4	0.0004	4.8	0.0004	4.9
	50	0.0003	4.4	0.0005	4.9	0.0004	5.1
	75	0.0004	4.5	0.0006	5.0	0.0005	5.1

pH

The pH of the soil was not very much influenced by form or level of phosphorus. In this case also a gradual increase in pH was noted with increase in time and it was found to be a maximum immediately after the crop was harvested.

DISCUSSION

DISCUSSION

The results obtained in the present investigation reveal the role of variety and the influence of applied phosphatic fertilizers on the growth, yield and uptake of nutrients by the rice plant.

The growth characters studied in this investigation were the height of plant, the number of vegetative and productive tillers and the length of the panicle. All these are predominantly varietal characters, but are also influenced to different extents by phosphorus treatments. The height of the plant varied rather irregularly during the early stages of growth but at the time of harvest IR 8 was significantly taller than Culture 28. The different forms of phosphorus studied had no effect on this character. However, the plant height increased significantly with increase in the level of phosphorus applied. A favourable effect for phosphorus on plant height has been reported by Chavan et al (1957), and Moriya and Sato (1958).

The number of vegetative and productive tillers is a character which was influenced, not only by variety, but also by the source and level of phosphorus. Tillering was more or less similar for Taichung Native 1 and Culture 28, both these varieties being superior to IR 8 in this character. The influence of superphosphate and defluorinated rock phosphate was remarkably more than that of ultrafos and Thomas phosphate. Increased levels of phosphorus application have resulted in an increased number of tillers, both vegetative and productive. Similar findings have been reported by Cassidy et al (1956), Yoshida (1958) and Takijima et al (1959).

In contrast to tillering and plant height, the length of the panicle was found to be almost entirely a varietal character which was little influenced by phosphorus treatments. This result is in accordance with the findings of Takijima et al (1959), and Sreenivasulu and Pawar (1965), who did not notice any significant effect for phosphorus on panicle length. Of the different varieties studied, IR 8 produced significantly longer panicles than Taichung Native 1 and Culture 28, but this was not reflected in any increase in the yield of grain because of a lower number of productive tillers for this variety.

The yield characters investigated in the present study were the total yield of grain and straw per pot, number of grains per earhead and the grain: chaff ratio. The total grain yield varied significantly, not only from variety to variety, but also with the different phosphorus treatments. Taichung Native 1 produced significantly higher yields than Culture 28 at every level of phosphorus application. Of the different forms of phosphorus applied superphosphate produced significantly higher yields than the other forms. This may be attributed to the presence of water soluble and easily available P_2O_5 present in this material as compared to the less available forms of P_2O_5 present in ultrafos, Thomas phosphate and defluorinated rock phosphate. Similar findings have been reported by Choudhury (1967) who obtained higher yields of rice by the application of superphosphate. For the different levels of phosphorus applied, the yield of grain was found to increase with the rate of phosphorus application. This is in agreement with the findings of Rhind et al (1949), Raychoudhuri (1953) Chavan et al (1957), Mariakulandai and Sreenivasan (1959) and many other workers.

The yield of straw varied within small limits for the different varieties, as well as for the various phosphorus treatments, but the differences were not statistically significant. Thus the straw yield was more for IR 8 than for Taichung Native 1 and Culture 28, but IR 8 was not statistically superior to the other varieties in this regard. The application of phosphorus resulted in increased yields of straw in all the varieties. The beneficial effect of phosphorus on straw yield has been reported by Paul (1953) and Digar (1960). As in the case of grain yield, the yield of straw also tended to be more for the treatment with superphosphate which contains water soluble P_2O_5.

The number of grains per panicle is also predominantly a varietal character and it was seen that Taichung Native 1 was superior to IR 8 and Culture 28 in this respect. The mean number of grains per panicle was more for this variety and the differences were also significant. The application of phosphorus had resulted in a larger number of grains per panicle as compared to the no phosphorus treatment but the differences were not statistically significant. The source of phosphorus had practically no influence on the number of grains per earhead.

The grain: chaff ratio was influenced both by variety and form of phosphorus. Taichung Native 1 had a higher grain: chaff ratio than IR 8 and Culture 28. Similarly, superphosphate and defluorinated rock phosphate significantly reduced the proportion of the chaff in relation to grain. The better availability of phosphorus from these carriers may be responsible for the beneficial influence of superphosphate and defluorinated rock phosphate on the grain: chaff ratio.

The mineral composition of the grain and straw was found to be influenced by variety, as well as phosphorus treatments. The highest amount of nitrogen and phosphorus in grain was found in IR 8 which was statistically superior to the other two varieties in the matter of these two elements. But in the case of potassium, Taichung Native 1 was superior to IR 8 and Culture 28. The percentage of N, P_2O_5 and K_2O in the three varieties was significantly influenced by the form of phosphorus used. Superphosphate was found to have the most beneficial effect in increasing the levels of N, P_2O_5 and K_2O in the rice grain. The rate of phosphorus application increased the P_2O_5 and K_2O content of grain but it had no significant influence on the percentage of nitrogen. This result is in conformity with the findings of Unnikrishnan (1961), and of Chin and Li (1960) who have reported increased levels of P_2O_5 and K_2O in rice for increased applications of phosphatic fertilizers.

In the case of straw the largest amount of N was found in Culture 28 while IR 8 contained the maximum amount of P_2O_5 and Taichung Native 1 the highest amount of K_2O. Of the different forms of phosphorus applied superphosphate produced the highest level of N, P_2O_5 and K_2O in all the varieties. The levels of these elements in straw increased with increase in the rate of phosphorus application. This is in agreement with the findings of William (1948), Thomas et al (1951), Satyanarayana (1958) and Tanaka et al (1964) who observed that the level of nitrogen and P_2O_5 in the rice plant increased with increase in the rate of application of phosphorus.

The total quantities of nutrients removed by the plant in each pot was influenced both by the form and level of phosphorus applied. The largest amount of nitrogen per pot was removed by IR 8 followed, in order by Taichung Native 1 and Culture 28. But the maximum removal of P_2O_5 and K_2O/pot was by Taichung Native 1. The second largest amount of P_2O_5 was removed by IR 8 and that of K_2O by Culture 28. When the effect of form of phosphorus on nutrient removal was considered it was seen that superphosphate closely followed by defluorinated rock phosphate was the most effective in the removal of N, P_2O_5 and K_2O. The better availability of P_2O_5 in these fertilizers are obviously responsible for this finding.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

To study the effect of different forms and levels of phosphorus on the growth, yield and composition of three high yielding varieties of rice, a pot culture experiment was carried out in the Agricultural College and Research Institute, Vellayani, in a randomised block design with 39 treatments and 3 replications. The different forms of phosphorus used were superphosphate, ultrafos, defluorinated rock phosphate and Thomas phosphate. The levels of application were 0, 25, 50 and 75 kg P_2O_5/ha. The rice varieties studied were Culture 28, IR 8 and Taichung Native 1. The main findings of the experiment are summarised below:

1 The height of plants was a maximum for IR 8. This growth character was not influenced by the form of phosphorus used, but it increased significantly with increase in the rate of phosphorus application.

2 In the matter of tillers, Taichung Native 1 was superior to IR 8 and Culture 28. Of the different forms of phosphorus applied, superphosphate and defluorinated rock phosphate produced the maximum number of tillers. As regards the effect of level, the number of tillers increased with increase in the level of phosphorus application.

3 The length of the panicle was found to be more for IR 8 than for the other varieties. The form and level of phosphorus had no significant effect on this character.

4 In the matter of grain yield Taichung Native 1 was superior to IR 8 and Culture 28. Even though the differences between the different forms of phosphorus were not significant, the grain yield tended to increase with increase in the level of phosphorus application. The straw yield was not found to be significant for the different phosphorus treatments.

5 The varietal influence was significant for the other yield characters, such as number of grain per panicle and grain: chaff ratio. Of the different forms of phosphorus used, superphosphate significantly increased the grain: chaff ratio, but the form and level of phosphorus had no significant role in increasing the number of grains per panicle.

6 The mineral composition grain was found to be influenced by variety. IR 8 contained the highest amount of N and P_2O_5 in grain, while Taichung Native 1 contained the maximum amount of K_2O. Among the different phosphatic fertilizers applied, superphosphate significantly increased the P_2O_5 and K_2O contents of grain, but it had no significant influence on the N content.

7 Variety Culture 28 contained the maximum amount of N in the straw, while IR 8 contained maximum amount of P_2O_5 and Taichung Native 1 the highest amount of K_2O. Of the different forms of phosphorus used, superphosphate significantly increased the N, P_2O_5 and K_2O content of the straw. The levels of these nutrients in the straw also increased with increase in the rate of phosphorus application.

8 The highest amount of P_2O_5 and K_2O/pot was removed by Taichung Native 1, whereas IR 8 removed the maximum amount of N/pot. Among the different sources of phosphorus used, superphosphate, closely followed by defluorinated rock phosphate, was most effective in the removal of these nutrients. The nutrient removal increased with increase in the rate of phosphorus application.

The results obtained in the present study emphasise the influence of phosphorus in the fertilizer schedule for rice for ensuring luxurious and healthy growth, higher yields and better utilisation of other nutrients like nitrogen and potassium.

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APPENDICES

Appendix I

Analysis of variance for plant height: 20th day

Source	S.S.	Df	M.S.	F ratio
Total	1495.33	116	..	..
Block	50.89	2	25.45	3.17 *
Treatment	833.01	38	21.93	2.72 **
Form	31.16	3	10.39	1.29
Level	75.28	2	37.64	4.69 *
Variety	26.19	2	13.09	1.63
F x L	75.28	6	12.55	1.56
F x V	12.86	6	2.14	1
L x V	57.83	4	14.46	1.80
F x L x V	555.01	12	46.25	5.76 **
Error	610.83	76	8.04	..

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Appendix II

Analysis of variance for plant height: 40th day

Source	S.S.	Df	M.S.	F ratio
Total	2283.98	116	..	..
Block	42.97	2	21.39	3.40 *
Treatment	1724.98	38	45.39	7.40 **
Form	108.66	3	36.22	5.90 **
Level	386.30	2	193.15	31.50 **
Variety	30.52	2	15.26	2.49
F x L	70.64	6	11.77	1.92
F x V	6.42	6	1.07	1
L x V	28.60	4	14.30	2.33
F x L x V	1093.84	12	91.15	14.87 **
Error	466.23	76	6.13	..

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Appendix III

Analysis of variance for plant height: 60th day

Source	S.S.	Df	M.S.	F ratio
Total	1014.02	116	..	..
Block	81.97	2	40.99	6.20**
Treatment	1034.58	38	27.22	4.22 **
Form	47.42	3	15.80	2.41
Level	113.06	2	56.53	8.64 **
Variety	73.10	2	36.55	5.58 **
F x L	30.36	6	6.56	1.00
F x V	9.32	6	1.55	0.23
L x V	49.49	4	12.37	1.80
F x L x V	702.83	12	58.57	8.96 **
Error	497.46	76	6.54	..

** Significant at 1 per cent level.

Appendix IV

Analysis of variance for plant height at harvest

Source	S.S.	Df	M.S.	F ratio
Total	1035.07	116	..	..
Block	44.84	2	22.24	2.52
Treatment	1214.94	38	31.97	3.60 **
Form	34.12	3	11.37	1.28
Level	30.04	2	19.52	2.20
Variety	412.94	2	206.47	23.25 **
F x L	45.18	6	7.53	1
F x V	18.48	6	3.08	1
L x V	106.22	4	26.55	2.98**
F x L X V	558.96	12	46.58	5.23 **
Error	675.29	76	8.88	..

** Significant at 1 per cent level.

Appendix V

Analysis of variance for tiller count: 20th day

Source	S.S.	Df	M.S.	F ratio
Total	22.21	116	..	..
Block	0.46	2	0.228	2.89
Treatment	15.75	38	0.415	5.27 **
Form	3.09	3	1.029	13.02 **
Level	5.24	2	2.622	33.19 **
Variety	3.27	2	1.634	20.69 **
F x L	1.74	6	0.289	3.66 **
F x V	0.59	6	0.099	1.25
L x V	0.36	4	0.089	1.33
F x L x V	1.46	12	0.122	1.54
Error	6.01	76	0.079	..

** Significant at 1 per cent level.

Appendix VI

Analysis of variance for tiller count: 40th day

Source	S.S.	Df	M.S.	F ratio
Total	190.87	116	..	..
Block	4.07	2	2.04	3.24*
Treatment	138.93	36	3.66	5.82 **
Form	12.51	3	4.14	6.58 **
Level	28.80	2	14.40	22.89 **
Variety	2.63	2	1.31	2.09
F x L	3.56	6	0.59	1
F x V	8.20	6	1.37	2.17
L x V	4.80	4	1.20	1.91
F x L x V	78.43	12	6.54	10.39 **
Error	47.87	78	0.63	..

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Appendix VII

Analysis of variance for tiller count: 60th day

Source	S.S.	Df	M.S.	F ratio
Total	176.44	116	..	..
Block	1.81	2	0.91	1.61
Treatment	131.42	38	3.45	6.10 **
Form	9.21	3	3.07	5.40 **
Level	16.05	2	8.03	14.11 **
Variety	17.71	2	8.85	15.55 **
F x L	15.32	6	2.55	4.48 **
F x V	2.08	6	0.35	1
L x V	5.21	4	1.30	2.29
F x L x V	65.84	12	5.49	9.64 **
Error	43.21	76	0.57	..

** Significant at 1 per cent level.

Appendix VIII

Analysis of variance for productive tiller count at harvest

Source	S.S.	Df	M.S.	F ratio
Total	47.13	116	..	..
Block	0.69	2	0.345	1
Treatment	67.03	38	1.764	4.56 **
Form	4.73	3	1.580	4.09 **
Level	7.13	2	3.560	9.22 **
Variety	9.96	2	4.980	12.91 **
F x L	5.69	6	0.950	2.46 *
F x V	3.35	6	0.560	1.45
L x V	6.31	4	1.580	4.09 **
F x L x V	29.86	12	2.488	6.44 **
Error	29.40	76	0.386	..

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Appendix IX

Analysis of variance for panicle length

Source	S.S.	Df	M.S.	F ratio
Total	160.61	116	..	..
Block	1.10	2	0.55	1
Treatment	92.57	38	2.49	2.80
Form	5.34	3	1.78	2.00
Level	0.76	2	0.38	1
Variety	42.61	2	21.31	23.90 **
F x L	10.21	6	1.70	1.91
F x V	5.34	6	0.89	1.00
L x V	8.62	4	2.14	2.40
F x L x V	19.69	12	1.64	1.85
Error	66.94	76	0.89	..

** Significant at 1 per cent level.

Appendix X

Analysis of variance for grain yield

Source	S.S.	Df	M.S.	F ratio
Total	1231.70	110	..	..
Block	20.98	2	10.49	6.24 **
Treatment	1083.03	38	28.50	16.96 **
Form	10.54	3	3.51	2.09
Level	95.68	2	47.84	27.83 **
Variety	576.91	2	288.41	136.50 **
F x L	6.77	6	1.13	1
F x V	28.65	6	4.78	2.78 *
L x V	35.28	4	8.82	5.25 **
F x L x V	329.20	12	27.43	16.32 **
Error	127.69	76	1.68	..

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Appendix XI

Analysis of variance for straw yield

Source	S.S.	Df	M.S.	F ratio
Total	6887.12	116	..	..
Block	48.22	2	24.11	1
Treatment	583.46	38	15.35	1
Error	6225.00	76	82.30	..

Appendix XII

Analysis of variance for number of grains per panicle

Source	S.S.	Df	M.S.	F ratio
Total	11369.00	116	..	..
Block	120.44	2	60.22	1
Treatment	5566.64	38	146.49	2.37 **
Form	502.18	3	167.39	2.71
Level	3.10	2	1.55	1
Variety	2364.70	2	1182.35	19.19 **
F x L	695.58	6	115.93	1.88
F x V	314.00	6	52.33	1
L x V	686.23	4	171.58	2.79
F x L x V	1000.85	12	83.40	1.35
Error	4681.92	76	61.60	..

** Significant at 1 per cent level.

Appendix XIII

Analysis of variance for grain: chaff ratio

Source	S.S.	Df	M.S.	F ratio
Total	2482.77	116	..	..
Block	33.56	2	16.78	1
Treatment	1092.08	38	28.74	1.61 **
Form	179.21	3	59.74	3.34 *
Level	92.55	2	46.27	2.59
Variety	321.21	2	160.60	8.94**
F x L	53.78	6	8.97	1
F x V	104.49	6	17.41	1
L x V	19.24	4	4.81	1
F x L x V	321.60	12	26.80	1.50
Error	1357.13	76	17.86	..

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Appendix XIV

Analysis of variance for nitrogen content of grain

Source	S.S.	Df	M.S.	F ratio
Total	5.980	116	..	..
Block	0.020	2	0.010	1
Treatment	3.740	38	0.098	3.37 **
Form	0.544	3	0.181	6.24 **
Level	0.114	2	0.057	1.97
Variety	1.644	2	0.822	28.34 **
F x L	0.156	6	0.026	1
F x V	0.306	6	0.051	1.76
L x V	0.246	4	0.062	2.14
F x L x V	0.730	12	0.061	2.10 **
Error	2.220	76	0.029	..

** Significant at 1 per cent level.

Appendix XV

Analysis of variance for P_2O_5 content of grain

Source	S.S.	Df	M.S.	F ratio
Total	1.203	116	..	..
Block	0.003	2	0.0015	1
Treatment	0.978	38	0.0257	8.81 **
Form	0.074	3	0.0247	8.51 **
Level	0.304	2	0.1520	52.50 **
Variety	0.104	2	0.0520	17.90 **
F x L	0.026	6	0.0043	1.48
F x V	0.046	6	0.0077	2.65 *
L x V	0.043	4	0.0108	3.72 **
F x L x V	0.381	12	0.0318	10.95 **
Error	0.222	76	0.0029	..

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Appendix XVI

Analysis of variance for K_2O content of grain

Source	S.S.	Df	M.S.	F ratio
Total	2.09	113	..	..
Block	0.08	2	0.040	9.75 **
Treatment	1.70	35	0.045	10.98 **
Form	0.23	3	0.077	18.78 **
Level	0.16	2	0.080	19.51 **
Variety	0.56	2	0.280	68.29 **
F x L	0.07	6	0.010	2.44 *
F x V	0.22	6	0.037	9.00 **
L x V	0.03	4	0.007	1.71
F x L x V	0.43	12	0.035	8.73 **
Error	0.31	76	0.004	..

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Appendix XVII

Analysis of variance for nitrogen content of straw

Source	S.S.	Df	M.S.	F ratio
Total	1.759	116	..	..
Block	0.041	2	0.021	4.30 *
Treatment	1.433	38	0.037	9.25 **
Form	0.080	3	0.027	6.75 **
Level	0.039	2	0.019	4.75 *
Variety	0.650	2	0.325	81.25 **
F x L	0.014	6	0.002	1
F x V	0.153	6	0.026	6.50 **
L x V	0.121	4	0.030	7.50 **
F x L x V	0.376	12	0.031	7.82 **
Error	0.285	76	0.004	..

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Appendix XVIII

Analysis of variance for P_2O_5 content of straw

Source	S.S.	Df	M.S.	F ratio
Total	3.9335	116	••	••
Block	0.0004	2	0.0002	1
Treatment	0.0428	38	0.0011	1
Error	3.8903	76	0.0501	••

Appendix XIX

Analysis of variance for K_2O content of straw

Source	S.S.	Df	M.S.	F ratio
Total	37.36	110	..	..
Block	0.30	2	0.15	1
Treatment	17.50	38	0.46	1.79 **
Form	6.05	3	2.02	7.84 **
Level	1.62	2	0.81	3.14 *
Variety	4.81	2	0.24	1
F x L	1.14	6	0.19	1
F x V	3.05	6	0.51	1.07
L x V	0.51	4	0.13	1
F x L x V	0.32	12	0.03	1
Error	19.56	76	0.20	..