STUDIES ON THE EFFECT OF GRADED DOSES OF PHOSPHORUS IN CONJUNCTION WITH LIME ON GROWTH, YIELD & PHOSPHORUS UPTAKE IN RICE (*Oryza sativa* Linn.) Var. IR 8.

BY

P. SUSEELAN, B. Sc. (Ag.)

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)
OF THE UNIVERSITY OF KERALA

DIVISION OF AGRONOMY

AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE

VELLAYANI, TRIVANDRUM.

1969

CERTIFICATE

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Sri. P.Suseelan, under my supervision. No part of this thesis has been submitted earlier for the award of any degree.

(P.KUMARA PILLAI)
Principal

(C.M. GEORGE)
Professor of Agronomy

Agricultural College and
Research Institute,
Vellayani, Trivandrum.
8th August 1969

ACKNOWLEDGEMENTS

The author wishes to place on record his deep sense of gratitude to:

Sri. C.M.George, B.Sc.(Ag), M.S.A. (Toronto), Professor of Agronomy, Agricultural College and Research Institute, Vellayani for his valuable guidance, critical suggestions and encouragement during the course of the present investigation,

Sri. P. Kumara Pillai, M.Sc., M.S. (U.S.A.) Principal, Agricultural College and Research Institute, Vellayani, for the facilities provided for carrying out the present investigation, and

Sri. E.J.Thomas, M.Sc., M.S.(Iowa), Professor of Agricultural Statistics, Agricultural College and Research Institute, Vellayani, for the help rendered in the design of the experiment and analysis of the data.

The valuable help rendered by Sri.C.Sreedharan M.Sc.(Ag), Junior Professor of Agronomy, Sri.E.P.Nambiar, Ph.D. Scholar, Division of Agricultural Chemistry, Sri. N.Neelakantan Potti, M.Sc.(Ag), Senior Lecturer in Agronomy and the staff of the Division of Agronomy is gratefully acknowledged.

The author is also thankful to the Government of Kerala, for having deputed him for postgraduate course in Agronomy.

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INTRODUCTION

As a major food crop of India, rice claims a total cultivated area of 36 million hectares, out of which 802329 hectares is accounted for by Kerala State.

The per hectare production of rice in Kerala is low compared to that of advanced countries like Japan. The deficit of rice - the staple food of the people of the State, is estimated to be slightly over 50 percent. The scope for expanding the area under rice being limited, intensive cultivation through adequate fertilisation and introduction of high yielding varieties appear to be more feasible and promising to wipe out or narrow down the present food deficit. Therefore a thorough knowledge of the nutritional requirements of rice is a must, from the point of view of increasing production and economic and efficient use of fertilizers.

Of the vast number of manurial trials conducted previously, by and large, studies on nitrogen predominates, while experiments with phosphorus are relatively few. These few trials with phosphatic fertilizers either alone or in combination with organic or inorganic sources of nitrogen, indicate that unlike nitrogen; phosphorus generally gives little response in most of the places, except in parts of Maharashtra, Bihar, Andhra Pradesh and Madhya Pradesh. Elaborate experimental evidence is lacking in most of the states in India, with the possible exception of Bihar.

Though the utilisation of applied phosphorus by rice is comparatively less as evidenced by the results of many investigators the young paddy plant has to depend on external sources for its supply of phosphorus during the early stages of growth. Determination of the correct dose of phosphorus for optimum production is therefore an absolute necessity for the rational use of phosphatic fertilizers.

With the recent introduction of the high yielding varieties which have now covered an area of 143312 hectares (68-69) in the state, a thorough knowledge of the nutritional requirements of these varieties have became all the more important. Trials conducted elsewhere have fairly well established the high fertilizer response of these varieties for increased yields. Large number of experiments conducted on the nitrogen requirements of these varieties have shown the high response of these varieties to high doses of fertilizers under Kerala conditions. Eventhough there has not been much response to phosphorus for local varieties, recent experiments with high yielding varieties have shown positive response to phosphorus. Mahapatra (1969) has reported positive response even up to 120 Kg. P_2O_5 per hectare for the high yielding varieties. However data on the phosphorus requirements of these high yielding varieties under Kerala conditions is lacking. The present investigation is therefore, an attempt to study the response of IR.8 - a recently introduced high yielding variety of paddy - to graded doses of phosphorus under Vellayani conditions.

The nutrient availability is only one of the several factors which contribute to the productivity of the soil. For increasing production, the soil condition should be made more favourable for the efficient use of added fertilizers by the growing crop. Extensive soil test data available on the paddy soils of Kerala go to show that 82.8 percent of the soils are acidic in reaction. These soils, naturally are characterised by low pH, poor base status and poor availability of nutrients.

Liming has been reported to enhance the efficiency of utilisation of nutrients by plants, especially that of phosphorus. Application of lime has also been reported to influence the soil favourably, through its beneficial influence on soil reaction, nutrient availability and biological activity, besides its physical condition. In view of all these reported beneficial effects of liming it is felt desirable to study the role of lime also with special reference to its effect on better utilisation of phosphorus. The objectives of the present investigation, therefore are to study:-

1) The yield response of IR.8 to graded doses of phosphorus
2) Effect of lime on the yield of IR.8
3) The effect of lime on the efficiency of phosphorus utilisation in terms of yield and uptake.

Incidentally it is also attempted to study residual effect of liming on phosphorus availability.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

ROLE OF PHOSPHORUS IN PLANT GROWTH

Phosphorus is concerned with many vital growth processes in plants. It is an essential constituent of nucleic acids and the nuclei. It is involved in many of the biochemical reactions such as the metabolism of carbohydrates, fats and proteins in which phosphorylated compounds act as intermediaries; often in the role of conserves and suppliers of energy for specific reactions, in respiration and fermentation processes (Wallace 1961).

Low phosphorus supply suppresses early nitrogen uptake and prevents the synthesis of proteins from nitrogenous substances. A plentiful supply in the early stages promotes early growth because such a high supply increases the content of nucleic acid phosphorus and phospholipid phosphorus. Nucleic acid can actually promote heading in rice; as it controls the vegetative growth through protein bio-synthesis and reproductive growth through flower initiation (Fugiwara 1964).

Phosphorus increases the number of tillers as well as the number of productive tillers. It increases the ratio of grain to straw in cereals, resulting in greater yield of grain. Phosphorus is also reported to impart disease resistance to plants as it induces normal cell development resulting in vigorous growth. (Tamhane *et al*. 1965). Other beneficial effects of phosphorus are the formation of new cells, promotion of root growth (particularly the development of fibrous roots) formation of seeds and grain and improvement in the quality of grain. It also helps to strengthen the stem of cereals; thus reducing their tendency to lodge (Anonymous 1961).

THE UPTAKE OF PHOSPHORUS FROM NATIVE AND APPLIED FORMS

Information on the behaviour of native and applied phosphorus as well as the stage of growth of the plant at which uptake of this element is maximum is useful in evaluating the best time for applying phosphatic fertilizers to low land rice.

According to Davide (1964) when a soil is flooded and reduction occurs, there is a gradual increase in the concentration of available phosphorus. He found that early application of phosphorus was desirable to ensure adequate supply of this element to the plant at the early stages when the quantum of available native phosphorus may not be sufficient to meet the requirements of the crop.

Maung-mya-thueng (1960) from his studies on the effect of time of application and relative absorption of phosphorus from native and additive sources using radioactive phosphorus, found that with early application (ie. 9 days after transplanting) the plants absorbed more of the added phosphorus during the first seven to nine weeks of growth. From this time onwards the relative absorption from added and native sources was almost similar. He concluded that during the early stages of growth, when the level of available phosphorus in the soil is still low, because of its gradual release, the young plants used more of the applied phosphorus. He also concluded that with the application of phosphorus either mid way between transplanting and flower primordia initiation (54 days after transplanting) or at the flower primordia initiation (60 days to 80 days after transplanting) the plant absorbed phosphorus from both native and applied forms.

The studies also disclosed that, of the total phosphorus content of the plant, more phosphorus came from the soil phosphorus.

Nishigaki et al. (1958) arrived at similar conclusions and reported that during the first and second months plants used mostly the applied phosphorus, while more of soil phosphorus was utilised during the later stages of growth. Experimental evidences reported from the International Rice Research Institute, Manila (Anonymous 1964) showed that the percentage of phosphorus in the plant increased with an increase in phosphorus content of the soil. De Datta (1966) from his experiments with an indica variety of rice (Milfer 6(2) reported that only 8 to 27 percent of the total phosphorus in the plant was derived from the applied phosphorus.

ABSORPTION OF PHOSPHORUS AT DIFFERENT STAGES OF GROWTH

Ishizuka (1964) from his studies on the relative uptake of native and applied phosphorus at different stages of plant growth reported that the absorption of nutrients was noticed fifteen days after germination. He found that the percentage of phosphorus in the plant was high in the seedling stage, decreased rapidly after transplanting, then increased gradually corresponding to the recovery from the shock of transplanting and reached a high percentage at the time of initiation of flower primordia. According to this investigator the high level of phosphorus continued up to the flowering stage and then decreased towards the dough stage.

Patnaik (1965) from his studies with short duration varieties found that in the case of phosphorus there was a tendency for lesser absorption during the initial twenty to forty days after which there was vigorous uptake which continued up to flowering or a little later. In medium and long duration varieties, there was an increase in the rate of absorption of phosphorus till the maximum tillering phase only and slowed down considerably during the vegetative lag phase.

Kasai and Asada (1960) from their studies observed that phosphorus absorbed by the plant after flowering tended to accumulate in the roots. The investigations of Patnaik (1965) however, did not indicate any such accumulation in the roots. According to him the phosphorus absorbed after flowering tended to accumulate in all parts of the plant viz. grain, straw and roots.

PHOSPHORUS UPTAKE AT DIFFERENT STAGES OF GROWTH IN RELATION TO YIELD

Many workers have attempted to evaluate the efficiency of phosphorus absorbed at different stages of growth for grain production for devicing a suitable schedule for phosphate application.

Mitsui (1954) has recommended the application of phosphorus exclusively as basal dressing giving emphasis to its placement in the root zone, in order to facilitate early absorption of phosphorus by the crop. Nagai (1959) observed that phosphorus absorbed during the first forty two days after transplanting alone was utilised in grain production.

Kasai and Asada (1964) reported that at maturity 80 percent of the phosphorus in the entire plant was present in the grain. Using isotope P^{32} these workers were able to conclude that 60 to 80 percent of the total phosphorus absorbed at each stage of growth was translocated to the grains. They also found that most of the phosphorus brought to the grains from milky stage to maturity was translocated from the stem and leaves.

Ishizuka (1964) from his studies observed that after flowering the phosphorus content in the leaves and culm began to move to the grains. He concluded that the translocation of phosphorus from the leaves and culms to the panicles continued upto the dough stage and this coincided with the translocation and accumulation of starch in the grain, showing a close relationship between carbohydrate metabolism and phosphorus uptake.

Patnaik et al. (1965) from their solution culture studies on a short and a medium duration variety (PTB.10 and T.141) concluded that with adequate supply, the phosphorus absorbed during the tillering stage is most efficiently utilised for grain production and is adequate to give an optimal yield. They have also found that phosphorus absorbed beyond this period tended to accumulate in the grains, straw and roots with no advantage to grain production.

CROP RESPONSE TO PHOSPHORUS

The importance of crop response to phosphorus has been stressed by many workers.

Sethi et al. (1952) stated that most of the Indian soils did not give response to phosphorus except at a few places in Madhya Pradesh, Bihar and Bombay. These workers have stressed the importance of studies on crop response to phosphorus with reference to soil types.

Earlier experiments, conducted from 1936 to 1941 at the different Agricultural Research Stations in Mysore State did not show any significant response to phosphorus application (Raheja 1966).

Experiments conducted at forty centres in the country in the cultivators fields under the fertilizer use project from 1953-54 to 1955-56 recorded an average increase of 2.2 and 3.5 maunds per acre respectively for 20 and 40 pounds P_2O_5. Moderate to high response to phosphorus was recorded only at Darrang (Assam), Kalahandi (Orissa), Samalkota and Bodhan (Andhra Pradesh) Pusa and Raneshwar (Bihar) and

Raipur (Madhya Pradesh) (Anonymous 1959). Dabin (1951) reported significant response to P_2O_5 when applied along with nitrogen and potash. Parthasarathy (1953) reported an increase in yield due to the application of 150 pounds of super phosphate along with 4000 to 5000 pounds of green manure. Desai et al.(1954) recorded significant increase in grain yield when phosphorus was applied in combination with nitrogen. Chavan et al.(1957) reported increased yields and better growth of plants by the application of phosphatic fertilizers. Ishizuka and Tanaka (1950) observed increased grain yield in solution cultures when phosphorus was applied at the rate of 20 ppm. Varma (1960) noticed marked increase in grain yield when phosphorus was applied along with nitrogen. He also found that phosphorus, when applied alone, has increased the yields but the difference was not significant.

In an experiment at chinsura, with graded doses of bonemeal, conducted for a period of ten years, in the clayey gangetic alluvium (pH 6.7). Digar and Mandal (1957) did not find any significant increase in yield for the first three years, but from the fourth year onwards significant increase in yield was recorded. From the analysis of the pooled data for ten years, these investigators obtained a linear response upto 60 pounds P_2O_5 per acre.

Kanwar (1961) from ninety seven experiments in Punjab, reported that the average response to one Kg. of P_2O_5 was 12.72 Kg. of grain. Daji (1965) after reviewing the fertilizer demonstration trials conducted in Trivandrum, Quilon and Trichur Districts of Kerala State reported that the average response to phosphorus was only half of that of nitrogen.

In a study of the sources and rates of fertilizer phosphorus for flooded rice soils, conducted at the International Rice Research Institute, Manila, (Philippines) addition of phosphorus has given sufficient increase in yield only in phosphorus deficient soil (Anonymous 1966).

Reviewing the experiments conducted in Madras State, where P_2O_5 levels upto 67.2 Kg. per hectare were used, Mariakulandai (1957) observed no response to phosphorus, when applied alone, but concluded that phosphorus when applied along with other nutrients like nitrogen, there was an enhanced response to these nutrients, producing greater yields of rice. Takajima *et al.*(1959) reported that an increased rate of phosphorus accelerated tillering, but inhibited panicle growth. Davide (1964) found that application of nitrogen and potassium would be of little use under conditions of phosphorus deficiency. Russel (1961) remarked that an excess of phosphorus over the actual requirement may depress crop yields while Buckman and Brady (1957) opined that heavy doses of phosphorus may adversely affect the uptake of iron and zinc by plants.

Ariyanayagom (1953) reported that phosphorus at 30 pounds per acre had no direct cumulative or residual effects on grain yield even in the presence of higher levels of nitrogen. Absence of direct or cumulative effect of phosphorus was also reported by Kalam *et al.*(1966) from their experiments conducted in the Model Agronomic Research Station, Karamana.

Siregar (1955) reported no response to phosphorus from his experiments at Bogor (Indonesia) with twenty varieties (ten japonicas and ten indicas) at two levels of nitrogen and two levels of phosphorus.

Chandranatna (1957) from the trials conducted in Ceylon with two levels of phosphorus, five levels of nitrogen and three varieties, did not find any response to phosphorus.

Mahapatra (1961) also reported no response to phosphorus by eight indica varieties during the main season at Orissa.

Tomy (1963) recorded a progressive decrease in grain yield at the rate of 6.45 pounds for every pound P_2O_5 applied, beyond 20 pounds. Potti (1964) reviewing fertilizer experiments at the various Rice Research Stations in Kerala reported nil response to phosphorus.

Reviewing the results of trials conducted in Madras State from 1959 to 1963 Mariakulandai and Chamy (1967) reported no significant response to phosphorus when applied through legumes, at Aduthurai, Tirukuppam, Chinglepet and Coimbatore. Mariakulandai and Thyagarajan (1965) also reported a nil to non-significant response to phosphorus at the rate of forty pounds of P_2O_5 per acre for Kuruvai crop in the cultivator's fields at Aduthurai, Tanjore, Chinglepet and Madurai.

Srinivasulu and Pawar (1965) from their studies on the influence of nitrogen, phosphorus and potash on some of the quantitative characters of two indica x japonica hybrids concluded that phosphorus has no significant influence on the number of tillers, length of panicle, percentage of filled grains, weight of one thousand grains, yield of grain and straw.

Reviewing the phosphorus fertilization of paddy, Davide (1964) concluded that unless a soil is deficient in phosphate yield response to the addition of phosphatic fertilizers in field experiments could not be detected.

ROLE OF CALCIUM AS A PLANT NUTRIENT

In the plant calcium is chiefly present in the leaves. It is an essential constituent of the middle lamella and cell wall which, consists largely of calcium pectate. This function appears to be of fundamental importance since, if calcium is replaced by any other of the essential elements such as magnesium or potassium the organic materials and mineral salts in the cells are readily leached through the walls. Calcium is intimately concerned with the activities of the growing points and is of special importance in root development. It has been shown to exercise 3 fold functions; cell division, cell elongation and detoxication of hydrogen ions in wheat roots. It also provides a base for neutralising organic acids (Wallace 1964).

Being a constituent of the cell wall calcium helps to increase the stiffness of straw. It also encourages seed production (Tamhane _et al_. 1965).

LIME AS A SOIL AMENDMENT

Soil reaction is an important factor in successful crop production. When the soil is too acidic the productivity is considerably impaired. According to Gardner and Gardner (1953) a soil reaction in the neutral or slightly alkaline range is the most optimum for majority of crops.

pH has a positive influence on the chemical and biological activities in the soil. A low pH retards nitrification, sulphate reduction and ammonification, but favours the accumulation of organic acids. The main effect of a low pH is therefore to reduce the supply of available nitrogen for the crop. According to Ponnamperuma (1955) for this reason alone a pH slightly above neutrality is better for rice than a low pH.

Another important change associated with pH in a flooded soil is the decrease in oxidation reduction potential in the soil. An important effect of low pH especially in a soil containing more of iron and manganese is the concentration of their reduced products in the soil solution. Since considerable amounts of Fe^{+2} and Mn^{+2} may be present even at pH values near neutrality, under the anaerobic conditions of a submerged soil, any deleterious effect high concentrations of Fe^{+2} and Mn^{+2} may have on rice will be aggravated at low pH values. Therefore it suggests that a low pH should be unfavourable for rice. Application of lime helps to decrease the concentration of reduced products thereby making the soil more congenial for plant growth (Ponnamperuma loc.cit). Significant increase in yield reported due to liming acidic paddy soils render added support to this.

PHOSPHATE AVAILABILITY IN RELATION TO CALCIUM

The concept of liming acid soils to induce beneficial effects on the availability and utilisation of both native and applied phosphates is a widely accepted corner stone of good soil management.

Studies of Wheeler and Adams (1906) show that base saturation of soil colloids is necessary for the availability of added phosphatic fertilizers. Ford (1934) concluded from his studies that increase in base saturation and consequent decrease in acidity played an important role in increasing the availability of soil phosphorus.

Ghani and Aleem (1942) studied the effect of liming on the transformation of phosphorus in acid soils. They found that available phosphorus regularly increased with lime in all treatments at all doses. These authors concluded that the greater availability of phosphorus by liming was due to the decomposition of organic phosphorus brought about by a change of reaction favourable for some kind of microbial activity and not due to chemical interaction of liming materials upon phosphates of iron and aluminium.

Bewer (1949) suggested that the fixation and availability of phytin derivatives in acid soils was due to their absorption by iron and aluminium compounds and that liming favoured the utilisation of phytin phosphorus by crops.

Venkatachalam and Mariakulandai (1954) observed that the effect of lime application on phosphorus availability may be attributed to the stimulating action of lime on the microbial activity in the soil.

Ekman (1955) from his studies on the effect of lime on the nutrient status of soils concluded that liming stimulated mineralisation of organic phosphorus compounds and reduced the fixation of phosphorus.

Dhar and Singh (1955) from their pot culture studies found that treatment of the soil with lime increased the availability of phosphorus. They obtained a positive correlation between the exchangeable calcium and available phosphorus levels in soils.

Gokhale et al.(1954) reported that liming increased the soluble phosphorus fraction and decreased the percentage of added phosphorus unavailable to plants in laterite soils.

Balks (1956) from his studies on the behaviour of soil phosphorus reported fixation of phosphorus in the form of iron and aluminium compounds in soils having a pH of 5. He also found that easily available calcium phosphates are formed under favourable conditions of soil reaction.

Robertson et al.(1954) studied the response of crops to different fertility levels and concluded that the requirements of phosphorus by crops for maximum yield was less in limed, than in unlimed soils.

Thorp and Hobbs (1956) found that the uptake of phosphorus by plants was greater from the limed soil, compared to that from the unlimed soils.

Doring's (1956) investigations on phosphorus sorbed on colloids indicated that with increasing acidity, sorption of phosphorus also increased. He concluded that this was probably due to the formation of insoluble tertiary iron phosphates. According to this investigator addition of small amounts of lime increased the availability of sorbed phosphorus, while heavy application might lead to the formation of difficultly soluble calcium phosphate.

The investigations of Alakseeva (1958) showed that liming resulted in increased utilisation of phosphatic fertilizers. He found that the plant recovery of phosphorus from superphosphate in limed soil increased from 17 to 25 percent.

Pearson (1958) in his discussion on liming and fertilizer efficiency observed that the highly soluble forms of phosphorus in commercial fertilizers when added to the soil, reacted with calcium, magnesium, iron and aluminium; resulting in depression in availability which was only temporary, as these are released subsequently as seen from the observed residual effects.

Mandal (1964) studied the transformation of inorganic phosphorus in waterlogged rice soils and found considerable decrease in the ferric phosphate and slight decrease in aluminium phosphate content in the soil due to liming. Calcium phosphate increased appreciably and some of the ferric phosphate was found to be converted to calcium phosphate. From his studies Mandal concluded that the use of lime followed by organic matter might increase the availability of soil phosphorus under water logged conditions.

Rai et al. (1963) studied the effect of lime on the production of upland crops (ground nut, soy bean and jowar) in the acidic red loam soils of Kanke farm (Chotanagapur) from 1956 to 1961. These authors found that liming increased the uptake of P_2O_5 by the plants and the absorption was still higher when lime was applied in conjunction with phosphatic fertilizers.

Hamilton et al. (1966) from their studies on liming a virgin gray wooded soil, noted a decrease in the organic matter content and increase in the acid soluble (Bray) P_2O_5 in the surface soil.

Tayler and Gurney (1965) noted an increase in the phosphorus extractable with an anion exchange resin, in five acid soils due to liming. They concluded that liming apparently caused more phosphorus to be adsorbed in a readily available form.

Kaila (1967) while studying the effect of lime on the fate of applied superphosphate in samples of silt, loam and sandy loam soils (pH. 3.9 to 5.1) noted an increase in soil pH from 6.1 to 7.3 and an increase in the soluble forms of phosphorus due to liming.

Mathen and Durai Raj (1967) from their studies on the availability of phosphorus in Nilgiri soil also reported an increase in the available phosphorus due to liming.

Patnaik _et al_.(1968) from their studies using different liming and phosphorus materials on rice yields in an acidic lateritic soil (ph 4.8) concluded that addition of liming materials increased the availability of applied phosphorus as measured from soil content and plant uptake.

PHOSPHORUS AVAILABILITY UNDER FLOODED CONDITIONS

Many workers have reported that the

behaviour of phosphorus in flooded soils was remarkably different from that in the uplands. Increased availability of phosphorus, judged both by plant response as well as by chemical tests as a result of flooding has been reported.

Aoki (1941) reported that rice grown under low land conditions gave no response to phosphatic fertilizers while Barley grown on the same soil as a winter crop did, and attributed this to the reduction of insoluble ferric phosphate to the more soluble ferrous phosphate. Increase in the solubility of phosphorus under flooded conditions has also been reported by Islam and Elahi (1954); Ponnemperuma (1955); Mitsui (1960) and these authors have attributed the reason for increased solubility of phosphorus to the reduction of insoluble ferric phosphate to soluble ferrous phosphate brought about by the anaerobic condition due to flooding. Shapiro (1958) evaluated the effect of submergence on phosphate availability and concluded that flooding increased the uptake by the plant and availability of soil phosphorus as measured by 'A' value. Mang-mya-thaung (1960) reported a high 'A' value for Burmese paddy soils thirteen weeks after transplanting. Datta and Datta (1963) from their studies with isotope P^{32} reported increased availability of soil phosphorus as measured by 'A' value due to flooding. Basak and Bhattacharya (1962) reported increase in available phosphorus in the unmanured paddy soils in West Bengal. They found that the available phosphorus increased by 64 percent from the original value of 44 pounds per acre, from planting to flowering, remained fairly constant from tillering to preflowering and decreased towards the post harvest time.

OTHER BENEFICIAL EFFECTS OF LIMING

Nitrogen in relation to calcium

Soil reaction plays an important role in the volatilisation loss of nitrogen that can occur in the biological oxidation of ammonia to nitrate. The investigations of Gerretsen and Dehoop (1957) showed that loss of nitrogen from acid sandy soils amounted to as high as 74 percent of the added ammoniacal nitrogen and the loss ceased when sufficient $CaCo_3$

was added to maintain the pH above 5.5. According to Aslander (1952) liming induced a rapid mineralisation of organic matter resulting in increased nitrate production. The experimental study by Cornfield (1953) indicated that nitrate accumulation was inhibited under acid conditions when no lime was added. Blue et al. (1957) found that liming resulted in better and efficient utilisation of nitrogenous fertilizers. The studies of Papalvi (1958) on the effect of addition of different rates of lime in a calcium deficient soil indicated that application of lime progressively decreased the organic matter content and increased the levels of nitrate and ammoniacal nitrogen. Abichandani and Patnaik (1955) at Central Rice Research Institute, Cuttack found that application of lime @ 2000 lbs per acre gave an additional yield response of 395 lbs paddy per acre on an average for two years. They estimated that liming resulted in the release of 30 lbs nitrogen. Remarkable increase in mineralisation of nitrogen due to liming has also been reported by Mitsui (1960), Abichandani and Patnaik (1961) and Gardner et al (1965).

Liming in relation to potash availability

Several workers have reported on the efficiency of liming practice in increasing the solubility of potash in soils. York and Rogers (1947) who experimented on the solubility of K in soils and its availability to plants found that addition of calcium resulted in an increased availability of potash in all the soils studied. According to these investigators the addition of lime to a soil could result in an increase or decrease in the available potash depending upon the ability of the soil to fix the applied potash and on the nature, amount and solubility of potash bearing minerals in the soil. Maclean (1956) in his investigations on the influence of lime application on the availability of potash and other cations did not find any appreciable effect on the exchangeable potash due to liming. According to him increased yields could be got if potassic fertilizers were also applied in conjunction with lime. The study of Pratt *et al.* (1956) indicated that liming increased the release of potash from non-exchangeable forms. Incubation studies made by these authors with various cations in the exchange complex indicated higher release of K from non-exchangeable forms with calcium as exchangeable cation.

Liming in relation to biological activities in the soil

Waksman and Starkey (1924) found that limed soils produced more Co_2 as compared to unlimed soils and observed that addition of lime to an acid soil made the soil conditions more favourable for the micro-flora and resulted in an increase in the respiratory power of the soil. Lysenko (1957) observed that considerable improvement in plant growth could be achieved if the vital activity of micro organisms was made possible in acid soils by neutralising the acidity by application of lime. Nambiar (1960) reported a significant positive correlation between nitrate accumulation and Co_2 evolution by liming acidic laterite soil of the west coast. This was also reflected in crop yields in pot culture studies.

Liming and physical condition of the soil

Liming influences the physical properties of the soil that are of vital importance to plant growth and crop yields. Ghani *et al.* (1955) while studying the effect of lime on soil aggregates found that liming promoted soil aggregation and stability of aggregates. Bekhari *et al.* (1957) found that liming increased the porosity of the soil and decreased resistance to ploughing.

CROP RESPONSE TO LIMING

Divergent findings have been reported regarding the role of lime in increasing crop yields.

Mitsui (1954) reported that liming of acid soils, especially the paddy fields is a common practice in Japan. From more than two hundred field experiments conducted on the acid soils of Taiwan (pH 4.0 to 6.0) Chang and Huang (1951) reported that ninety five percent of the experiments recorded increased yields of rice, when lime was applied at the rate of three tons per hectare. In another series of experiments, also in Formosa, Chang and Puh (1951) observed that on acid soils of pH 4.5 to 6.3 the response to a basal application of fertilizer increased progressively as the rate of lime application was increased from one to three tons per hectare.

Experiments conducted in the highly acidic areas of Kuttanad (pH 3.5 to 4.5) have recorded significant increase in yield due to liming. In an experiment conducted in marshy land in the Agricultural Research Station, Ambalavayal (pH 4.2 to 5.6) application of slaked lime at the rate of 1121, 2242 and 3362 kilogrammes per hectare respectively, have not shown any beneficial effects due to liming. But in the sandy loam soils of the same station, application of lime at the rate of 3362 kilogrammes has given significant increase in grain yield. Experiments conducted at Pattambi in both crop seasons with 3362 kilogrammes per hectare of slaked lime, showed an increase of about 370 kilogrammes of grain (Anonymous 1959).

The experiments conducted under the fertilizer use project from 1954 to 1956, by the Indian Council of Agricultural Research on the acid soils of Shimoga and Ponnampet, showed good response to the application of one ton of lime per acre. At Shimoga, there was significant response in both the years; the response increasing with the increasing levels of lime (Chakraborty et al.(1961). Subramoniam and Varadarajan (1957) from trials conducted in cultivator's fields in Coorg reported significant response in the yield of paddy due to liming in two zones lying in the 70" to 100" rainfall belt. In all other zones, these workers found that paddy crop in the lime applied plots were much greener in appearance, flowered earlier and had more percentage of well filled grains. In an experiment conducted for five years in the Agricultural Research Station at Mangalore, in South Kanara District, application of staked lime at the rate of 2242 kilogrammes per hectare significantly increased the yield of rice (Anonymous 1959).

From the fertilizer trials conducted in cultivator's fields in Ceylon from 1955 to 1959, Ponnamperuma (1960) concluded that the mean response to six tons per acre of slaked lime was 920 pounds of paddy in a strongly acid lateritic soil in the first season and a residual response of 322 pounds per acre during the next season.

Abichandani and Patnaik (1961) also recorded significant increase in grain yield due to the application of 2000 pounds of lime per acre.

Tamhane *et al.*(1965) reported significant increase in the yield of paddy by applying lime in conjunction with 20 pounds of nitrogen, in the acid soils of Bastar (Madhya Pradesh).

While reviewing the experiments on liming of rice soils in Madras, West Bengal and Bihar, Abraham and Kathuria (1967) concluded that rice crop responds to liming in strongly acid soils.

MATERIAL AND METHODS

MATERIAL AND METHODS

Object:- This investigation was designed to study the response of a high yielding exotic variety of rice viz. IR.8 to graded doses of phosphorus, applied alone and in conjunction with lime.

Location:- The experiment was laid out at the Agricultural College Farm, Vellayani in the wet land with facilities for controlled irrigation and drainage.

Season:- The trial was conducted during the first crop season (Viruppu) of 1968.

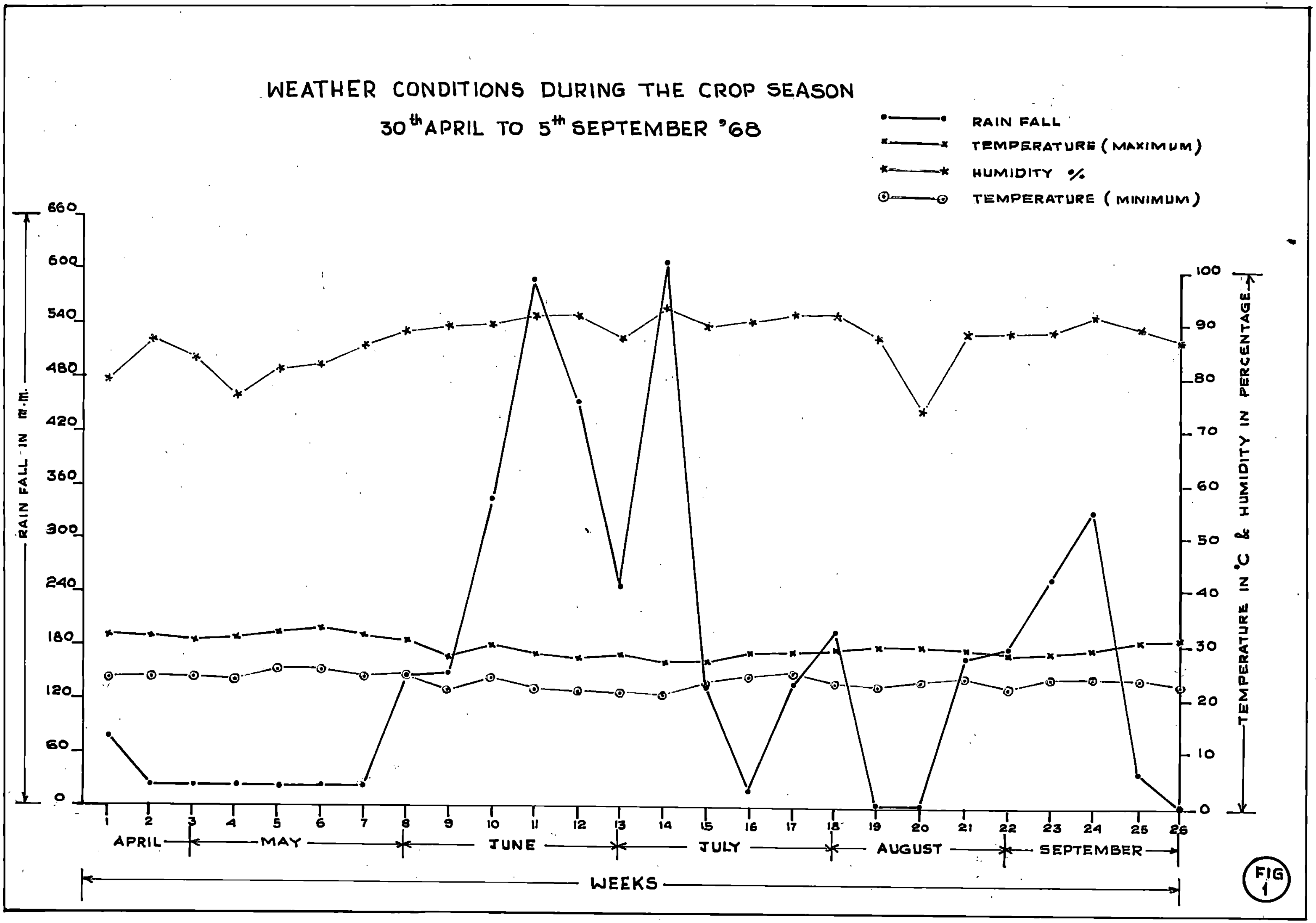
Cropping history.

The area was under a bulk crop of paddy during the previous season.

Soil:- The soil belonged to the textural group of sandy clay loam, the chemical and mechanical analysis of which are presented in Appendix I.

Weather conditions.

Meteorological data for the crop period is presented in Appendix II.



WEATHER CONDITIONS DURING THE CROP SEASON
30th APRIL TO 5th SEPTEMBER '68
RAIN FALL
TEMPERATURE (MAXIMUM)
HUMIDITY %
TEMPERATURE (MINIMUM)
RAIN FALL IN m.m.
TEMPERATURE IN °C & HUMIDITY IN PERCENTAGE
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
WEEKS

FIG 1

MATERIAL

The variety used in the present study was IR.8 - 288-3; popularly known as IR.8, a high yielding photo insensitive variety of about 130 days duration developed at the International Rice Research Institute, Philippines and recently released and popularised in India.

Seeds.

The seeds of IR.8 were obtained from the Central Rice Research Station, Pattambi. The seeds were tested for viability and were found to give 97.8% germination.

Manures.

Farm yard manure with the following analysis was used.

N	0.46%
P_2O_5	0.23%
K_2O	0.43%

Fertilizers.

Fertilizers with the following analysis were used in the experiment.

Nitrogen	-	Ammonium sulphate analysing 20.0% N
P_2O_5	-	Superphosphate analysing 16.2% P_2O_5
K_2O	-	Muriate of potash analysing 50% K_2O

Lime.

Slaked lime analysing 71.2% CaO

METHODS.

The levels of nitrogen and potash were fixed according to the recommendations of Department of Agriculture, Kerala (136 Kgs.Nitrogen and 90 Kgs. K_2O per hectare).

Levels of P_2O_5.

The recommendation of the Department of Agriculture, Kerala State for IR.8 is 36 Kgs. P_2O_5 per acre (90 Kgs. P_2O_5 per hectare). Aim of the present investigation was to determine the optimum P_2O_5 requirements of IR.8 under Vellayani conditions. In this study the levels of P_2O_5 were fixed at 0, 50, 100 and 150 Kgs. P_2O_5 per hectare.

Levels of lime.

The lime requirement of the soil was

determined by Hutchinson Maclenan method as 3900 pounds $CaCo_3$ per acre (3273.00 Kgs. slaked lime per hectare). Lime requirement was determined based on the analysis of pooled soil sample.

DESIGN AND LAYOUT

The experiment was laid out as per Randomised block design and replicated four times.

Treatments.

Levels of P_2O_5

1) P_0 = 0 No P_2O_5.
2) P_1 = 50 Kgs. P_2O_5 per hectare
3) P_2 = 100 Kgs. P_2O_5 per hectare
4) P_3 = 150 Kgs. P_2O_5 per hectare

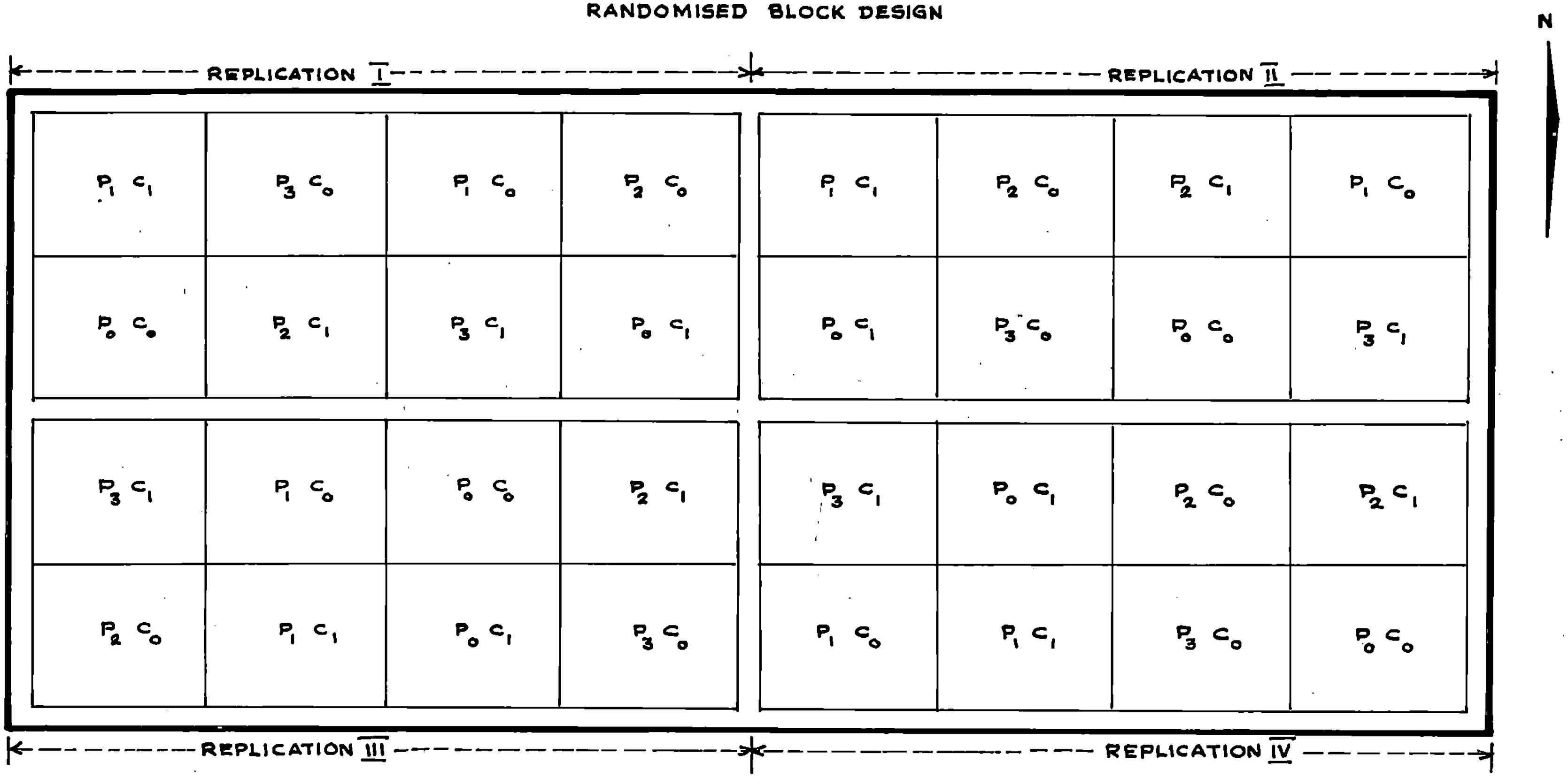
Levels of lime.

1) C_0 = No lime
2) C_1 = 3273.00 Kgs. slaked lime per hectare.

Total number of treatments per block	8
Number of blocks	4
Total number of plots	32

LAY OUT PLAN

RANDOMISED BLOCK DESIGN



TRETMENTS

- P_0 .. NO P_2O_5
- P_1 .. 50 Kg: P_2O_5 PER HECTARE
- P_2 .. 100 Kg: P_2O_5 PER HECTARE
- P_3 .. 150 Kg: P_2O_5 PER HECTARE
- C_0 .. NO LIME
- C_1 .. 2900 Kg: SLAKED LIME PER HECTARE

SIZE OF PLOTS — 7·5 METRES x 5·4 METRES

GROSS AREA PER PLOT — 40.50 SQUARE METRES

NET AREA PER PLOT — 7·05 METRES x 5.10 METRES (35.955 SQUARE METRES)

SPACING :— 10 Cm BETWEEN PLANTS; 15 Cm BETWEEN LINES

FIG 2

Size of plots	7.5 metres x 5.4 metres
Gross area per plot	40.50 Square metres
Net area per plot	7.05 metres x 5.10 metres
	(35.955 Square metres)
Spacing	10 cms. between plants
	15 cms. between lines.

FIELD CULTURE.

Nursery.

8 Kgs. of seeds were sown to get sufficient number of healthy seedlings. A basal dressing of 500 Kgs. farm yard manure, 2 Kgs. of ammonium sulphate, 6 Kgs. of super phosphate and 2.5 Kgs. of muriate of potash were applied to the nursery. The seeds were soaked for 24 hours in water and kept for sprouting after treating with Agrosan. G.N. Sprouted seeds were sown in the nursery beds, in an area of 8 cents on 30-4-1968.

Growth performance in the nursery.

Germination was over in about 5 days. Two protective sprayings were given with Folidol and Blitox (60 mls. Folidol and 120 gms Blitox in 40 litres of water) one 15 days after sowing and the second

2 days before transplanting.

Main field.

The experimental site was ploughed twice with wooden plough. Plots of size 7.5 metres x 5.4 metres were laid out with 8 plots per block and spaded well. The plots were separated with bunds 30 cms. in width and individual blocks were given an outer bund 50 cms. in width.

Basal dressing.

Farm yard manure was applied to each plot at the rate of 20.25 Kgs. as basal dressing which worked out to 5000 Kgs. per hectare.

Application of lime.

Lime was applied 3 days prior to transplanting and was well mixed with the soil. 13.25 Kgs. of slaked lime was applied per plot for the plots receiving lime as treatment.

C_0 No lime

C_1 3273.00 Kgs. slaked lime per hectare

Fertilizers.

1.377 Kgs. Ammonium sulphate and 0.729 Kgs. of muriate of potash were applied as basal dressing per plot. Super phosphate was applied as basal dressing as per the schedule of treatments fixed.

P_0	No super phosphate
P_1	1.25 Kgs. super phosphate per plot
P_2	2.50 Kgs. super phosphate per plot
P_3	3.75 Kgs. super phosphate per plot.

Transplanting.

The seedlings were uprooted and transplanted with two seedlings per hill, on 23-5-1968.

AFTERCARE

Irrigation and drainage.

Excess water was drained off seven days after transplanting. Controlled irrigation and drainage were given thereafter.

Gap filling.

Gap filling was done whenever required with seedlings from the nursery.

Weeding.

The plots were hand weeded twice, fifteen days and forty five days after transplanting.

Plant protection.

Two protective sprayings were given with a mixture of folidol and blitox one 22 days after transplanting and the other 41 days after transplanting. A dusting with B.H.C. 10% was given at the ear filling stage @ 25 Kgs. per hectare as a prophylactic measure against rice bug.

Top dressing.

Top dressing with ammonium sulphate was given on 20-6-1968 and 13-7-1968 so as to coincide with the maximum tillering and initiation of ear primordia.

General stand of the crop.

The stand of the crop in general was good. There was no lodging.

Harvest.

The crop was harvested and threshed on 5-9-1968. Wet weight of grain and straw were recorded plot wise. The grain was cleaned off chaff and weighed separately. Weight of straw was also recorded plot wise.

OBSERVATIONS

Sampling technique.

After eliminating the guard rows a sampling unit of one square metre was measured from each plot adopting random sampling technique. Sampling unit had 77 hills each. The tiller counts and other observations were recorded for all the plants in the sampling unit. Height of the plants were recorded only for the 4 corner plants of the sampling unit.

Observations on growth performance.

The observations were recorded at an interval of 20 days. ie. on 21st, 41st and 61st days after transplanting and 3 days prior to harvest.

Height.

Height of plants at the 4 corners of the sampling unit were recorded on each of the above dates.

Number of tillers.

The number of tillers on each hill within the observational unit were recorded on the above dates.

Observations on yield attributes.

Panicles from the 4 corner plants of the observational units were separately collected before harvest for recording the panicle characteristics and post harvest observations. The following observations were also recorded.

1) Percentage of productive tillers.

2) Length of panicles.

3) Percentage of filled grains.

4) Weight of one thousand grains.

Observations on yield.

1) Yield of grain.

2) Yield of straw.

Each plot was harvested separately, leaving the guard rows, threshed and cleaned. Wet-weight and dry weight of the grain was also recorded plot wise.

3) The grain/straw ratio was also worked out.

Chemical analysis of plant and soil samples.

The plants (excluding roots) were analysed for the uptake of P_2O_5 at the following growth phases.

1) Active tillering stage — 45th day ~~after transplanting~~

2) Ear primordia initiation stage — 74th day ~~after transplanting~~

3) Stem elongation stage — 89th day ~~after transplanting~~

4) Flowering stage — 96th day ~~after transplanting~~

5) Milky stage — 110th day ~~after transplanting~~

The estimations were done colorimetrically following standard A.O.A.C. methods. P_2O_5 content of grain and straw were also estimated following the same method.

<u>Post harvest soil analysis.</u>

Estimation of available phosphorus in each plot was done immediately after harvest of the crop in order to assess the residual effect of the treatments.

RESULTS

RESULTS

Results of the present investigation are presented in Tables I to XIV and the analysis of variance in Appendices III to VIII.

GROWTH CHARACTERS

Height of plants.

Data on the mean height of plants recorded at different stages of growth is presented in Table No.I and the analysis of variance in Appendix III. The results do not reveal any significant influence of phosphorus, calcium or their interaction at any stage of growth.

Tiller numbers.

The tiller counts recorded at periodical intervals were analysed and the analysis of variance is presented in Appendix IV and summary in Table No.II. The result shows that phosphorus has significantly influenced the number of tillers only during the first twenty days of transplanting. Between levels P_3 is significantly superior to P_2, P_1 and P_0. However at all other stages of observation the number of tillers

TABLE No. I

Mean height of plants at different stages of growth

	20th day			40th day			60th day			Harvest		
	C_0	C_1	Mean	C_0	C_1	Mean	C_0	C_1	Mean	C_0	C_1	Mean
P_0	42.68	42.62	42.65	77.18	76.31	76.75	83.68	85.37	84.53	98.81	99.81	99.31
P_1	41.87	45.75	43.81	79.06	81.31	80.18	88.31	88.19	88.25	100.50	102.12	101.31
P_2	43.68	45.00	44.34	77.12	79.37	78.25	86.50	90.00	88.25	99.50	102.18	106.61
P_3	46.25	45.00	45.84	83.18	81.00	82.09	87.12	89.69	88.41	101.81	101.93	101.87
Mean	43.62	45.43		79.14	79.50		86.43	88.31		100.16	101.21	

Sl. No.	Treatment Comparisons	C.D.	S.E. of mean	C.D.	S.E. of mean	C.D.	S.E. of mean	C.D.	S.E. of mean
1.	Between levels of phosphorus	N.S.	1.170	N.S.	1.438	N.S.	1.341	N.S.	1.65
2.	Between levels of lime	N.S.	0.828	N.S.	1.010	N.S.	0.950	N.S.	1.17
3.	Between levels of lime with different doses of phosphorus	N.S.	1.650	N.S.	2.002	N.S.	1.913	N.S.	2.34

TABLE No. II

Mean number of tillers at different stages of growth

	20th day			40th day			60th day		
	C_0	C_1	Mean	C_0	C_1	Mean	C_0	C_1	Mean
P_0	4.22	4.53	4.38	7.67	7.64	7.66	7.12	6.79	6.95
P_1	4.24	4.17	4.21	7.64	7.35	7.23	6.42	6.37	6.39
P_2	4.54	4.56	4.55	8.00	7.84	7.92	7.46	6.71	7.08
P_3	4.44	5.33	4.89	7.88	8.27	8.08	6.84	7.71	7.28
Mean	4.36	4.65		7.68	7.78		6.96	6.89	

Sl. No.	Treatment comparisons	C.D.	S.E. of mean	C.D.	S.E. of mean	C.D.	S.E. of mean
1.	Between levels of phosphorus	0.435		N.S.	0.782	N.S.	0.830
2.	Between levels of lime	N.S.	0.334	N.S.	0.553	N.S.	0.591
3.	Between levels of lime with different doses of phosphorus	N.S.	0.670	N.S.	0.349	N.S.	0.374

was not significantly influenced by the treatments or their interactions.

Percentage of productive tillers.

The analysis of variance table for the percentage of productive tillers is presented in Appendix IV and summary in Table No. III.

The treatment P_3 C_1 shows 8.98 percent increase over control. However the data do not reveal any significant effect of phosphorus, calcium or their interaction on this yield attribute.

TABLE No. III

Percentage of productive tillers

	P_0	P_1	P_2	P_3	Mean
C_0	74.61	70.68	71.87	72.79	72.67
C_1	72.12	70.71	71.29	78.82	73.24
Mean	73.27	70.69	71.58	75.81	

Sl.No.	Treatment comparisons	C.D.	S.E. of mean
1.	Between levels of phosphorus	N.S.	1.51
2.	Between levels of lime	N.S.	1.07
3.	Between levels of lime with different doses of phosphorus	N.S.	2.14

<u>Length of panicle.</u>

Analysis of varience table for the length of panicle is presented in Appendix V and summary in Table No.IV. The results do not indicate any significant influence of phosphorus, calcium or their interaction on the length of panicle.

TABLE No.IV

Length of panicle

	P_0	P_1	P_2	P_3	Mean
C_0	21.81	22.29	21.36	21.42	21.72
C_1	21.92	21.59	21.89	22.63	22.00
Mean	21.86	21.99	21.67	22.02	

Sl.No.	Treatment comparisons	C.D.	S.E.of mean
1.	Between levels of phosphorus	N.S.	0.507
2.	Between levels of lime	N.S.	0.350
3.	Between levels of lime with different doses of phosphorus	N.S.	0.710

Percentage of filled grains.

The analysis of variance table is presented in Appendix V and the summary in Table No.V. The results reveal highly significant influence of calcium on this yield attribute. However the effect of phosphorus or calcium, phosphorus interaction is not significant.

TABLE No.V

Percentage of filled grains

	P_0	P_1	P_2	P_3	Mean
C_0	92.05	92.46	93.64	93.32	92.86
C_1	94.97	95.31	95.84	95.07	95.29
Mean	93.51	93.88	94.74	94.19	94.07

S.No.	Treatment comparisons	C.D.	S.E.of Mean
1.	Between levels of phosphorus	N.S.	0.580
2.	Between levels of lime	~~N.S.~~ 1.28	0.401
3.	Between levels of lime with different doses of phosphorus	N.S.	0.807

Weight of thousand grains.

The analysis of variance table is presented in Appendix V and the summary in Table No.VI. The result reveals significant influence of calcium on thousand grain weight. The effect of phosphorus or the interaction between phosphorus and calcium are not significant.

TABLE No.VI

Weight of thousand grains

	P_0	P_1	P_2	P_3	Mean
C_0	31.10	32.09	31.66	31.90	31.69
C_1	31.99	32.07	32.39	31.87	32.08
Mean	31.55	32.08	32.03	31.89	

Sl.No.	Treatment comparisons	C.D.	S.E.of mean
1.	Between levels of phosphorus	N.S.	0.18
2.	Between levels of lime	0.312	-
3.	Between levels of lime with different doses of phosphorus	N.S.	0.25

Yield of grain.

Analysis of variance table for the yield of grain is presented in Appendix V and summary in Table No.VII. Application of phosphorus has not significantly influenced the grain yield as revealed by the data. Calcium has significantly influenced the grain yield, but calcium, phosphorus interaction is not significant.

TABLE No.VII

Yield of grain

	P_0	P_1	P_2	P_3	Mean
C_0	17.80	18.30	18.75	17.75	18.15
C_1	19.52	2.00	20.25	20.07	19.96
Mean	18.66	19.15	19.50	18.91	

Sl.No.	Treatment comparisons	C.D.	S.E.of mean
1.	Between levels of phosphorus	N.S.	0.49
2.	Between levels of lime	1.0108	-
3.	Between levels of lime with different doses of phosphorus	N.S.	0.69

GRAIN AND STRAW YIELD AND REMOVAL OF P_2O_5 BY GRAIN AND STRAW

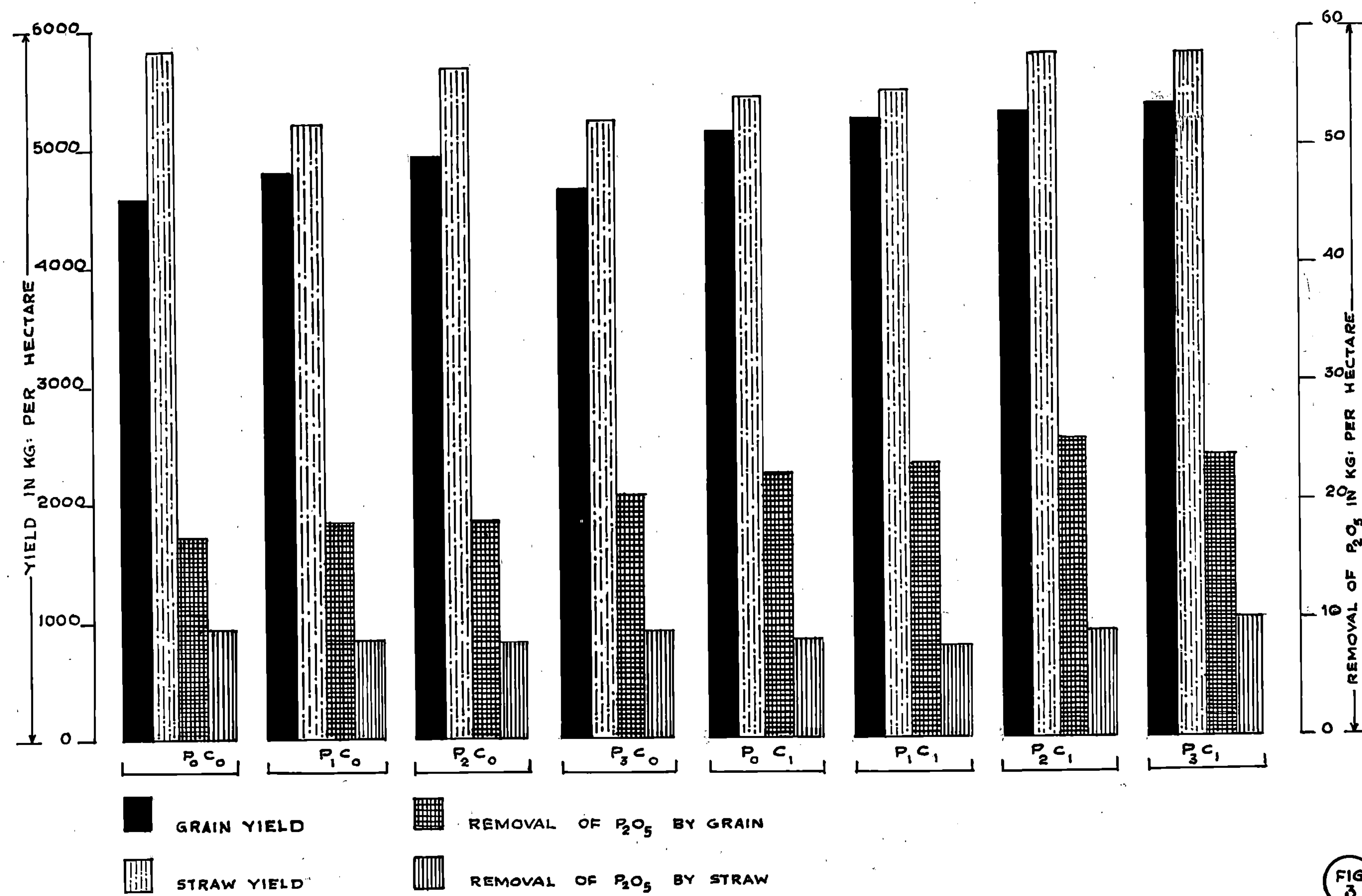


FIG 3

Yield of straw.

Analysis of variance table is presented in Appendix VIII and summary in Table No.VIII. The results do not reveal any significant influence of phosphorus on straw yield.

Effect of calcium and calcium phosphorus interaction are also not significant.

TABLE No.VIII

Yield of straw

	P_0	P_1	P_2	P_3	Mean
C_0	22.24	19.90	21.68	19.88	20.93
C_1	20.58	20.85	22.19	21.67	21.32
Mean	21.41	20.38	21.94	20.78	

Sl.No.	Treatment comparisons	C.D.	S.E. of mean
1.	Between levels of phosphorus	N.S.	0.904
2.	Between levels of lime	N.S.	0.640
3.	Between levels of lime with different doses of phosphorus	N.S.	1.28

Grain/Straw ratio.

Analysis of variance table is presented in Appendix VIII and the summary in Table No.IX. The data do not reveal any significant influence of phosphorus, calcium or calcium phosphorus interaction on grain/straw ratio. In the case of phosphorus eventhough the effect is not significant there is a tendency to increase the grain/straw ratio.

TABLE No.IX

Grain/straw ratio

	P_0	P_1	P_2	P_3	Mean
C_0	0.79	0.89	0.83	0.88	0.84
C_1	0.89	0.92	0.91	0.92	0.91
Mean	0.81	0.90	0.87	0.90	

Sl.No.	Treatment comparisons	C.D.	S.E. of mean
1.	Between levels of phosphorus	N.S.	0.258
2.	Between levels of lime	N.S.	0.182
3.	Between levels of lime with different doses of phosphorus	N.S.	0.365

Uptake of phosphorus at different stages of growth.

The phosphorus content of the plant samples at different stages of growth and at maturity was determined and the data statistically analysed. The analysis of variance tables are presented in Appendices VI and VII and summary in Table No.X.

The data reveals highly significant influence of phosphorus and calcium on the uptake of phosphorus by the plant at the tillering stage. Calcium phosphorus interaction is also found to be significant. Between levels of phosphorus, treatment P_2 is superior to P_3 while there is no significant difference between the treatments P_1 and P_0. Regarding the effect of lime C_1 is significantly superior to C_0. However when the interaction effect is considered, the treatment C_1 P_3 shows its significant superiority over all the other treatments.

At the primordia initiation stage the effect of phosphorus and calcium are highly significant. Calcium phosphorus interaction also followed the same trend as that at the tillering stage. Between levels of phosphorus, P_3 is superior to all other treatments.

P_2O_5 CONTENT OF THE PLANT AT DIFFERENT STAGES OF GROWTH

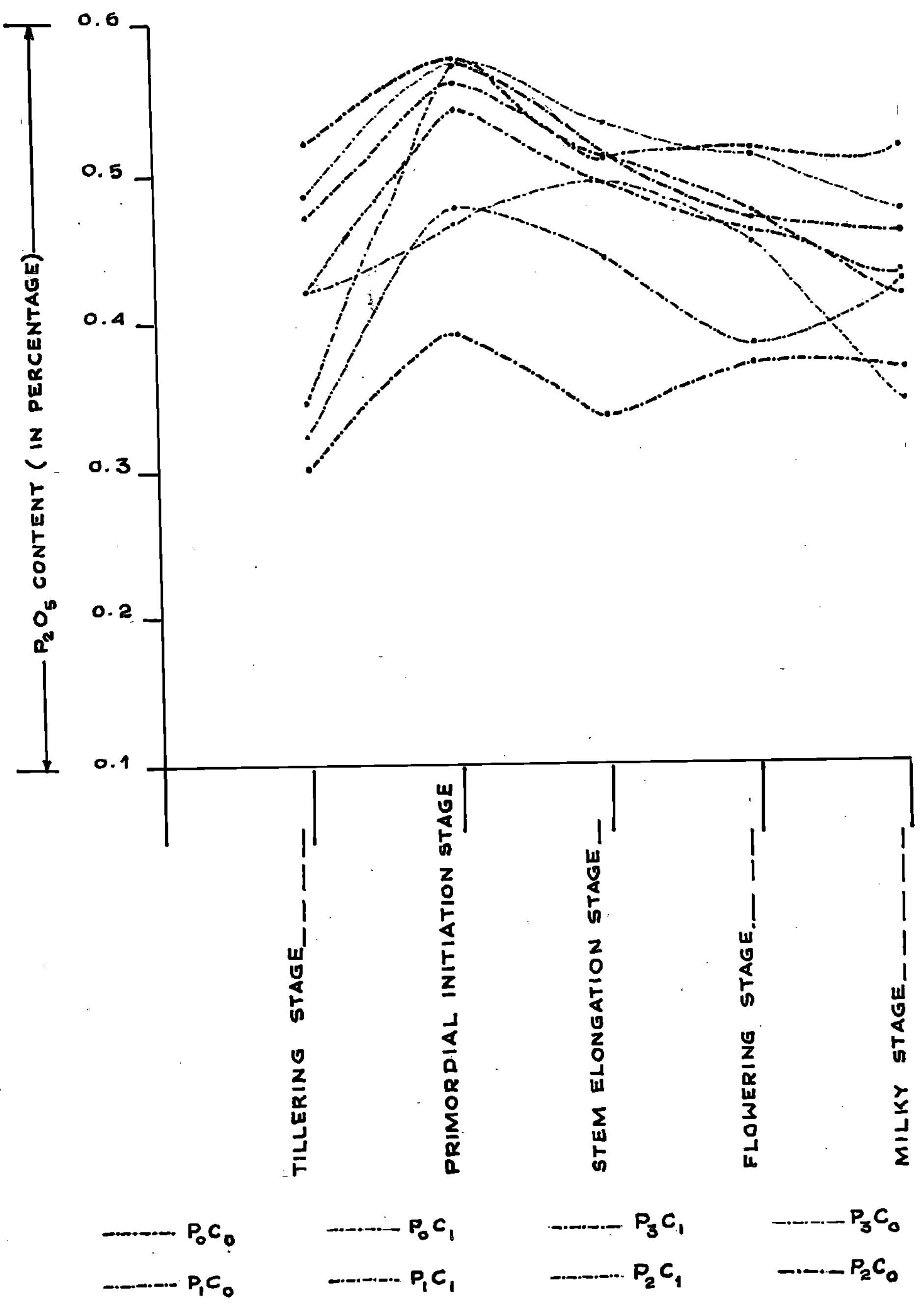


FIG 4

Regarding treatment combinations, there is no significant difference between $C_1 P_3$, $C_0 P_2$, $C_0 P_3$, $C_1 P_2$ and $C_1 P_1$. There is also no significant difference between $C_0 P_1$ and $C_1 P_0$. However it is seen that $C_0 P_0$ is significantly inferior to all other treatments.

At the stem elongation stage, the treatment P_3 is found to be superior to all other treatments eventhough there is no significant difference between P_3 and P_2. Regarding calcium phosphorus interaction all the treatment combinations are found to be significantly superior to $C_0 P_0$.

At the heading stage, the treatment P_3 is significantly superior to P_2, P_1 and P_0. P_2 is superior to P_1 and P_0 eventhough the difference is not significant.

Regarding calcium phosphorus interaction the data do not reveal any significant difference between $C_1 P_3$ and $C_0 P_3$ eventhough they are found to be superior to all other treatment combinations. There is also no significant difference between $C_0 P_1$ and $C_0 P_0$. However they are found to be inferior to all other treatment combinations.

At the milky stage, between levels of phosphorus, P_3 is significantly superior to P_2 and P_1. P_0 shows its inferiority to all other levels. It is also seen that the effect of calcium is not significant. However calcium phosphorus interaction is significant. Between treatment combinations $C_1 P_3$ is superior to $C_0 P_3$ and $C_0 P_2$. There is no significant difference between $C_1 P_1$, $C_0 P_1$ and $C_1 P_2$. $C_0 P_0$ and $C_1 P_0$ are significantly inferior to all other treatment combinations.

P_2O_5 content of grain.

The analysis of variance table is presented in Appendix VI and summary in Table No.XI. The data reveals highly significant influence of calcium and phosphorus on the P_2O_5 content of grain. Between levels of phosphorus, P_3 is superior to P_1, P_2 and P_0. The difference between the treatments P_1 and P_2 is not significant. The data also reveals that P_0 is inferior to all other treatments. Eventhough the individual effects of phosphorus and calcium are highly significant. Their interaction is not significant.

TABLE No. X

P_2O_5 content of the plant at different stages of growth

	Tillering stage			Primordial initiation stage			Stem elongation stage			Heading stage			Milky stage		
	C_0	C_1	Mean	C_0	C_1	Mean	C_0	C_1	Mean	C_0	C_1	Mean	C_0	C_1	Mean
P_0	0.309	0.427	0.368	0.399	0.463	0.431	0.336	0.496	0.416	0.373	0.454	0.414	0.379	0.345	0.362
P_1	0.327	0.427	0.377	0.473	0.546	0.505	0.441	0.518	0.479	0.374	0.463	0.419	0.418	0.435	0.427
P_2	0.482	0.473	0.478	0.575	0.561	0.569	0.515	0.518	0.517	0.473	0.454	0.464	0.454	0.418	0.436
P_3	0.345	0.527	0.436	0.570	0.577	0.574	0.536	0.454	0.517	0.517	0.518	0.518	0.473	0.515	0.439
Mean	0.366	0.464		0.504	0.536		0.457	0.508		0.434	0.472		0.431	0.428	

Sl. No. Treatment comparisons	C.D.	S.E. of mean	C.D.	S.E. of mean	C.D.	S.E. of mean	C.D.	S.E. of mean	C.D.	S.E. of mean
1. Between levels of phosphorus	0.0314	-	0.0312	-	0.0353	-	0.0208	-	0.0015	-
2. Between levels of lime	0.0291	-	0.0291	-	0.0270	-	0.0146	-	N.S.	0.001
3. Between levels of lime with different doses of phosphorus	0.0449	-	0.0416	-	0.0549	-	0.0290	-	0.0187	-

TABLE No.XI

P_2O_5 content of grain

	P_0	P_1	P_2	P_3	Mean
C_0	0.386	0.409	0.405	0.449	0.412
C_1	0.424	0.445	0.436	0.473	0.445
Mean	0.405	0.427	0.421	0.461	

Sl.No.	Treatment comparisons	C.D.	S.E.of mean
1.	Between levels of phosphorus	0.0081	-
2.	Between levels of lime	0.0054	-
3.	Between levels of lime with different doses of phosphorus	N.S.	0.0121

P_2O_5 content of straw.

The analysis of variance table is presented in Table No. VI and summary in Table No.XII. The data reveals significant influence of phosphorus and calcium phosphorus interaction on the P_2O_5 content of straw. Between levels of phosphorus P_3 is significantly superior to P_0, P_1 and P_2.

Regarding treatment combinations C_1 P_1 and C_1 P_2 are found to be inferior to all other treatments which are on par.

TABLE No.XII

P_2O_5 content of straw

	P_0	P_1	P_2	P_3	Mean
C_0	0.164	0.168	0.155	0.181	0.167
C_1	0.159	0.154	0.154	0.195	0.166
Mean	0.162	0.161	0.155	0.188	

Sl.No.	Treatment comparisons	C.D.	S.E.of mean
1.	Between levels of phosphorus	0.0145	-
2.	Between levels of lime	-	0.0036
3.	Between levels of lime with different doses of phosphorus	0.0208	-

Residual effect of lime on phosphorus availability.

Analysis of variance table is presented in Appendix VIII and summary in Table No.XIII. The data do not reveal any significant influence of treatments on the availability of phosphorus eventhough there was a positive trend noticed.

TABLE No.XIII

Available P_2O_5 status of the soil (post harvest)

	P_0	P_1	P_2	P_3	Mean
C_0	1.75	2.75	5.00	4.25	2.94
C_1	3.00	3.00	4.25	3.75	3.50
Mean	2.38	2.88	4.63	4.00	

Sl.No.	Treatment comparisons	C.D.	S.E.of mean
1.	Between levels of phosphorus	N.S.	0.860
2.	Between levels of lime	N.S.	0.608
3.	Between levels of lime with different doses of phosphorus	N.S.	1.216

DISCUSSION

DISCUSSION

The present study is an attempt to evaluate the response of the high yielding variety of rice viz. IR.8 - 288-3, to graded doses of phosphorus applied individually and in conjunction with lime. Since the absorption of phosphorus by the plant is a more reliable indication of the efficient utilisation of phosphatic fertilizers, an attempt has also been made to study the uptake of phosphorus at different stages of growth. The results are discussed in relation to the effect of treatments at various growth phases, on the biometric observations recorded, yield of grain and straw and plant and soil analysis.

<u>Height of plants.</u>

The results (Appendix III Table No.I) show that phosphorus has no significant influence on the height of the plants at any stage of growth. This is in agreement with the reported results of Srinivasulu and Pawar (1965). The results also do not reveal any significant influence of calcium on the height of the plant at any stage of growth studied. This is in agreement with the results of Muliyar (1965) who also found no significant effect of calcium on the height of the plant. Calcium phosphorus interaction is also not significant thereby showing that these nutrients do not exert much influence on the height of the plant.

<u>Tiller number.</u>

It is seen that phosphorus has significantly influenced the number of tillers within 20 days of transplanting (Appendix IV, Table No.II). However no significant influence of phosphorus could be seen in the subsequent observations. Eventhough phosphorus do not seem to have exerted any significant influence on the number of tillers, there is an increase of 8.98 percent in the number of productive tillers at the highest level of phosphorus applied in conjunction with lime.

It is quite probable that the quantum of native phosphorus released as a result of submergence might not have been sufficient to meet the plant requirements in the early periods of submergence and as such, the significant response observed on the 21st day might be due to the abundant supply of available phosphorus from the added fertilizer during this period to satisfy the requirements of the crop. According to Mang-Mya-Thuang (1960) young paddy plant uses more of applied phosphorus during the early stages of growth (7 to 9 weeks) since the release of native phosphorus was slow and gradual during this period. He further observed that the plant made no distinction in the absorption of phosphorus from native and added phosphates after nine weeks. Rajaram (1964) in his study of a typical paddy soil of Vellayani also found that under submerged conditions peak values for available phosphorus reached between 30th and 60th days after flooding. The lack of significant response in the number of tillers in the subsequent growth phases of the crop can be further substantiated by the results reported by Hoyna (1963), who found that the critical content of phosphorus in the plant required for tillering was only 0.25 percent (P_2O_5). The analytical data on the phosphorus content of the plant (Appendices VI & VII Table No.X, Figure 4) shows a high content of phosphorus, well above the critical limit even in the control plot which again strengthens the above finding. The results also reveal that calcium or calcium phosphorus interaction has not exerted any significant influence on the number of tillers at any growth stage studied. This may be due to the fact that calcium is utilised more, by the plant towards the later stages of growth as reported by Ishizuka (1964) who noticed higher concentration of calcium in the leaves and culm after flowering.

<u>Length of panicle.</u>

Application of phosphorus or calcium has not significantly influenced the length of panicle. (Appendix V Table No.IV). Length of panicle therefore, seems to be a varietal character which can seldom be influenced significantly by the application of fertilizers. This is in agreement with the results obtained by Srinivasan and Rajagopalan (1956), Chamy (1960) and Tomy (1963).

<u>Percentage of filled grains.</u>

Data on the percentage of filled grains (Appendix V, Table No.V) show that applied phosphorus has not exerted any significant effect on the percentage of filled grains. It may be observed that, by the time setting of grains took place, the full requirement of phosphorus might have been satisfied by the native soil phosphorus solubilised under the reduced conditions that prevailed as discussed earlier and this can be attributed to the lack of response to added phosphorus on this yield attribute. The study of Srinivasulu and Pawar (1965) also indicate absence of significant influence of phosphorus on the percentage of filled grains.

The results also reveal that calcium has significantly influenced the percentage of filled grains. One of the roles attributed to calcium in the nutrition of cereals is its favourable effect on the setting percentage. Application of lime appears to have exerted significant influence in increasing the setting percentage, resulting in a higher percentage of filled grains. Similar results were reported by Subramonian and Varadarajan (1957), Murayama (1964) and Muliyar (1965).

Weight of thousand grains.

The results (Appendix V, Table No.VI) show that application of phosphorus has no significant influence on the thousand grain weight. This is in agreement with the findings of Srinivasulu and Pawar (1965). Calcium phosphorus interaction also has not influenced this yield attribute.

Application of lime has significantly increased the weight of thousand grains as evidenced by the results. This is in agreement with the results of Muliyar (1965) who also found increase in thousand grain weight due to lime application.

Yield of grain.

The data presented in Appendix V, Table No.VII Figure 3 on grain yield show that application of phosphorus has not given any significant response even at a dose as high as 150 Kgs. P_2O_5 per hectare.

The lack of response to added phosphorus noticed in the present study may be due to the fact that adequate amounts of available phosphorus was present in the soil to meet the crop requirements. Increased availability of phosphorus under flooded conditions reported by Islam and Elahi (1954) Ponnamperuma (1955), Shapiro (1958), Mang-Mya-Thuang (1960) and Datta and Datta (1963) can be taken as indirect evidence for the lack of response to added phosphorus recorded in the present investigation. The data presented in Appendices VI and VII, Table No.X, on the absorption of phosphorus at different stages of plant growth shows that the phosphorus content of the plant in the control plot ranged from 0.309 percent at the tillering stage to 0.379 percent at the primordia initiation stage while in the plants receiving 150 Kgs. P_2O_5 and 3273 Kgs. slaked lime per hectare, the phosphorus content at these stages were 0.527 percent and 0.577 percent respectively. According to Velley (1959) response to added phosphorus can be obtained only if the percentage of phosphorus as shown by leaf analysis is 0.28 percent P_2O_5 or less, but Krishnamurthy _et al._ (1963) puts this limit between 0.17 percent and 0.30 percent. Krishnamurthy _et al._ (loc.cit) further contents that the response is uneconomic if the P_2O_5 content is between 0.30 percent and 0.50 percent. The phosphorus content of the plant in terms of P_2O_5 at different stages of growth shows that the same was maintained well above the critical limit at all stages of growth studied, even in the control plots.

Analysing the reason for the lack of response to phosphorus based on the chemical analysis of the soil, it could be seen that the soil originally had a total and available phosphorus content of 720 Kgs. and 36 Kgs. respectively, on hectare basis. It is likely that flooding would have brought about solubility of more native phosphorus, bringing the available phosphorus status of the soil to a much higher level so as to exhibit any significant response to added phosphorus. The results of Basak and Bhattacharya (1962) who recorded 64 percent increase in available phosphorus content due to flooding strongly suggests such a possibility.

The results show that grain yield was significantly increased by the application of lime. The increased yield of grain observed may be attributed to the cumulative favourable influence of liming on major yield attributes studied viz. percentage of filled grains and weight of thousand grains. The importance of liming, especially in acid soils has been stressed by Gardner and Gardner (1953) and Ponnemperuma (1955). Liming has been reported to increase the efficiency of phosphatic fertilizers through its favourable influence on the availability, better absorption and utilisation by the crop as evidenced by Dhar and Singh (1955) Robertson _et al._(1956) Rai _et al._ (1963) and

Mandal (1964). Other beneficial effects attributed to liming are increased mineralisation of nitrogen (Papalvi 1958 and Mitsui 1954) increased potash availability (Maclean 1956) and enhanced biological activity (Ghani et al. 1955 and Nambiar 1961); besides improvement in the physical condition of the soil (Bekhari et al 1957).

Considering the major role played by calcium in the reported findings referred to above, the significant increase in yield obtained in the present investigation can be attributed to the favourable effects of lime on the physical condition of the soil, nutrient availability and biological activity. The increased yield of paddy reported by Bavappa and Rao (1956) Subramonian and Varadarajan (1957), Ponnamperuma (1960) and Chakraborty et al. (1961) can be cited as corroborative evidence in support of the results obtained in the present study.

Regarding calcium phosphorus interaction on yield, it is seen that there is no significant favourable interaction effect. According to Patnaik et al. (1965) the phosphorus absorbed at the active tillering phase is most efficiently utilised for grain production and is sufficient to give an optimal grain yield. It has to be pointed out in this connection, that the determination of phosphorus content of the plant at different growth phases (Appendices VI and VII, Table No.X) of the crop has shown significant effect of calcium, phosphorus and their interaction. Therefore, it is only logical to expect significant effect of phosphorus, calcium and calcium phosphorus interaction on grain yield. The results obtained shows only the effect of calcium, but not the effect of phosphorus or calcium phosphorus interaction. This apparent contradiction can be explained by the fact that there was enough amount of available phosphorus even in the control plots, brought about by the reduction of iron phosphate, which, according to Rajaram (1964) is the dominant phosphorus fraction present in Vellayani paddy soils. Eventhough calcium might have exerted a favourable influence and reflected in greater grain yield, the interaction as expected could not be got for the reason that the situation in the control plots receiving no phosphorus, as far as phosphorus availability during the active tillering phase of the crop is considered, was fairly comparable and well above the critical limits for optimum grain production.

Yield of straw.

The results of straw yield presented in Appendix VIII, Table No.VIII reveals absence of any significant effect of phosphorus calcium or their interaction. The number of tillers and height of plants are the two contributory factors which determine the yield of straw. Since these factors, as has been discussed earlier are unaffected by the treatments it is only reasonable to expect a similar relationship with respect to that of straw yield also. It may also be pointed out that Srinivasulu and Pawar (1965) also did not observe significant influence of phosphorus on any of the quantitative characters of rice.

Grain/Straw ratio.

The grain/straw ratio presented in Appendix VIII, Table No.IX indicates a trend to increase the ratio with increase in the level of phosphorus compared to control both in the presence and absence of lime. However the result is not significant. The increase in grain/straw ratio noted may be due to the slight increase in yield of grain obtained by phosphorus application as revealed in Table Nos. VII and XIV.

In the case of calcium also there was a slight increase in the grain/straw ratio eventhough it is not significant. The data on yield of grain and straw presented in Tables VII and VIII respectively show that application of calcium has influenced both grain and straw production and the increase in grain yield is significant. The slight increase in grain/straw ratio by calcium application must be due to the proportionately higher rate of increase in grain production consequent on liming. This clearly brings forth the beneficial effect of liming in increasing the setting percentage and thousand grain weight as discussed earlier.

Uptake of P_2O_5 at different stages of growth.

The P_2O_5 content of the plant at different stages of growth presented in Appendices VI and VII, Table No.X shows significant influence of phosphorus, calcium and their interaction on the absorption of P_2O_5 upto the folowering stage. At the milky stage though phosphorus and calcium phosphorus interaction are significant, the effect of calcium is not significant.

The pattern of P_2O_5 absorption followed an increasing trend upto the primordia initiation stage (Fig.4) followed by a gradual decrease thereafter at the stem elongation stage, flowering stage and milky stage. Consistantly higher phosphorus uptake was noted in all the plots under treatments compared to that of control at all stages of growth. This is in agreement with the findings of Ishizuka (1964) and Patnaik (1965).

The absence of significant influence of calcium on phosphorus uptake, observed at the milky stage may appear strange at first, especially in view of the consistantly significant effect of calcium and calcium phosphorus interaction on phosphorus uptake noted upto the flowering stage. But it may be noted that there is no inconsistancy in this result and the same will be apparent if a correct appreciation is made on the nature and trend of phosphorus absorption by the growing rice crop. As indicated before the pattern of phosphorus absorption is linear upto the primordial initiation stage; thereafter it showw a depressing trend. Kasai and Asada (1964) have experimentally proved that most of the phosphorus translocated to the grains from milky stage onwards is derived from the leaves and culm of the rice plant. In otherwords it is the metabolic uptake rather than physico-chemical that plays a dominant role in the absorption and translocation of phosphorus. The effect of calcium in its relation to phosphorus is that it enhances the solubilisation and better utilisation of added and native phosphorus in the soil. Since the plant requirements of phosphorus from milky stage onwards is mostly satisfied by the translocation from the leaves and stem the absence of significant effect of calcium on phosphorus uptake can be rightly expected especially in view of the fact that the absorption of phosphorus is a metabolic driven process from this phase of the crop growth.

The significant calcium phosphorus interaction obtained in this growth phase appears to be a continuation of the significant interaction effect noted in all the other growth phases and more so because of the fact that 60 to 80 percent of the phosphorus utilised during this growth phase is derived from the phosphorus already absorbed and present in the leaves and culm of the plant. This also accounts for the observed absence of individual effect of calcium.

P_2O_5 content of grain and straw.

The uptake of phosphorus as reflected by the composition of grain and straw presented in Appendix VI and Table Nos. XI and XII indicate significant influence of phosphorus. The phosphorus content of both grain and straw increases with increasing levels of phosphorus in the soil. Thus it is seen that eventhough the applied phosphorus has not significantly increased the yield, the quality of both grain and straw with regard to phosphorus content is enhanced as is observed by Patnaik (1968).

The results also reveal that calcium while increasing the P_2O_5 content of grain, has not exerted any direct influence on the P_2O_5 content of straw. Table No.X shows increased uptake of phosphorus by the plant with calcium application. This difference in the phosphorus content during vegetative growth period and at harvest can be attributed to the fact that 60 to 80 percent of the P_2O_5 absorbed at each growth phase of the crop is translocated to the grains. However it may be noted that there is significant calcium phosphorus interaction effect on the P_2O_5 content of straw.

Residual effect of lime on phosphorus availability.

Data on the available phosphorus status of the soil, immediately after harvest of the crop presented in Appendix VIII, Table No.XIII do not reveal any significant increase in the quantum of available phosphorus consequent on liming. The data presented, being that of the available P_2O_5 content of the soil, after harvest of the crop, it is evident that a greater fraction of the phosphorus solubilised as a result of liming was absorbed by the crop. Data on the phosphorus content of the plant at different stages of growth (Table No.X) also substantiates this fact. Similar observations were reported by Rai *et al.* (1963) and Mahapatra (1966).

Economics of phosphorus and lime application.

Results of the present investigation (Table No.XIV) indicate that liming has significantly increased the yield - the increase being 9.5 percent over control when lime alone was applied without phosphorus. Application of phosphorus in conjunction with lime has also resulted in increased yields - the increase being 12.3 percent and 13.7 percent respectively for the treatments P_1C_1 and P_2C_1. Thus it is clear that phosphorus at lower doses is more efficient and profitable, when applied in conjunction with lime. The results also reveal that liming alone without application of phosphorus has recorded maximum profit of Rs. 189.29 per hectare. The margin of profit has narrowed down to Rs. 138.63 and Rs. 54.75 each when 50 and 100 Kgs. P_2O_5 respectively were applied per hectare, in conjunction with lime. Hence liming can be considered as an economic practice in rice culture under Vellayani conditions.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A field experiment was laid out in the wet lands of the Agricultural College Farm, Vellayani, during the first crop season of 1968, to study the response of rice (variety IR.8) to graded doses of phosphorus (0, 50, 100 and 150 Kgs. P_2O_5) per hectare applied alone and in conjunction with lime. The experiment was laid out as per randomised block design with four replications. Uptake of phosphorus by the plant at different stages of growth was also studied, besides the residual effect of liming on available phosphorus content. Results of the investigation are summarised below.

1) Application of phosphorus either alone or in conjunction with lime did not influence the height of the plant, percentage of productive tillers or length of panicle.

2) Phosphorus has significantly increased the number of tillers within 20 days of transplanting. No significant effect of phosphorus, calcium or their interaction on tiller production was noted in the observations on 40th or 60th days.

3) Calcium has significantly increased the percentage of filled grains and thousand grain weight, while phosphorus or calcium phosphorus interaction did not show any favourable effect on both these yield attributes.

4) Grain yield is significantly increased by the application of lime while phosphorus or calcium phosphorus interaction did not show any significant effect on the yield of grain.

5) There was significant increase in the uptake of P_2O_5 by the plant, with increasing levels of phosphorus whether applied alone or in conjunction with lime.

6) Phosphorus content of grain and straw is significantly increased by increasing levels of phosphorus.

7) The pattern of phosphorus absorption showed an increasing trend upto the primordia initiation stage, followed by a gradual depression thereafter.

8) Application of lime has favourably influenced the uptake of phosphorus at all stages of growth.

9) The residual effect of lime seems to exert a favourable influence on the availability of phosphorus in the soil.

The lack of response to applied phosphorus noted in the present investigation cannot be taken as an indication of lesser importance of this nutrient in stepping up crop yields since the present study was undertaken under submerged conditions where native soil phosphorus was available due to the reduced conditions that prevailed. It would therefore be worthwhile to take up further investigations to study the behaviour of native as well as applied phosphorus in relation to crop production under varying soil conditions. The present study also indicate that the importance of phosphate manuring is more from the point of view of maintaining the soil status than its direct effect on the crop.

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*Original not seen.

APPENDICES

APPENDIX I

Data on soil analysis

Mechanical analysis

	% (Moisture free basis)
Coarse sand	35.8
Fine sand	15.6
Silt	10.2
Clay	36.2

Chemical analysis

		Available
Nitrogen	0.189	0.0210
Phosphorus	0.036	0.0018
Potash	0.178	0.0221
CaO	0.105	
MgO	0.030	
Al_2O_3	11.540	
Fe_2O_3	10.740	
Base exchange	5.3 m.e/100 gr.	
pH	5.1	
Lime requirement	3900 lbs. $CaCO_3$/acre	

APPENDIX II

Meteorological data for the crop period (30th April to 5th September 1968) at the Agricultural College Farm, Vellayani

No. of weeks	Period	Rainfall (in m.m) weekly total	No. of rainy days	Temperature °C Weekly average Maximum	Minimum	Relative humidity % Weekly average
1.	30-4-68 - 6-5-68	-	-	30.9	24.2	83.9
2.	7-5-68 - 13-5-68	-	-	31.7	23.5	76.3
3.	14-5-68 - 20-5-68	-	-	32.7	25.1	81.1
4.	21-5-68 - 27-5-68	-	-	33.1	25.3	81.7
5.	28-5-68 - 3-6-68	25.4	1	32.1	24.9	85.0
6.	4-6-68 - 10-6-68	145.2	3	31.0	24.4	88.6
7.	11-6-68 - 17-6-68	146.8	6	28.4	22.7	89.4
8.	18-6-68 - 24-6-68	341.0	4	29.7	23.7	89.1
9.	25-6-68 - 1-7-68	598.0	7	28.2	22.3	91.3
10.	2-7-68 - 8-7-68	451.0	5	28.2	22.3	92.3
11.	9-7-68 - 15-7-68	251.0	4	29.2	22.6	87.7
12.	16-7-68 - 22-7-68	616.0	7	27.4	22.0	93.3
13.	23-7-68 - 29-7-68	128.0	4	28.0	23.1	89.1
14.	30-7-68 - 5-8-68	20.0	1	29.1	23.4	90.3
15.	6-8-68 - 12-8-68	150.0	4	29.1	23.2	92.0
16.	13-8-68 - 19-8-68	196.0	6	29.2	22.4	92.0
17.	20-8-68 - 26-8-68	-	-	29.3	23.1	88.0
18.	27-8-68 - 2-9-68	-	-	29.6	23.2	74.0
19.	3-9-68 - 9-9-68	166.9	4	29.7	23.2	88.0

APPENDIX III

Analysis of variance

(Height of plants)

Source	D.F.	21st day		41st day		61st day		At harvest	
		Variance	F	Variance	F	Variance	F	Variance	F
Total	31								
Block	3	81.04	7.38*	204.90	12.75**	86.80	5.97*	38.36	1.75
Treatment	7								
P	3	14.00	1.27	43.17	2.68	28.47	1.96	9.66	<1
C	1	9.30	<1	1.03	<1	29.08	2.00	14.84	<1
P x C	3	8.50	<1	10.12	<1	4.77	<1	2.32	<1
Error	21	10.97		16.06		14.47		21.92	

*Significant at 5% level

**Significant at 1% level

APPENDIX IV

Analysis of variance
(Tiller counts)

Source	D.F.	21st day Variance	21st day F	41st day Variance	41st day F	61st day Variance	61st day F	Percentage of productive tillers Variance	Percentage of productive tillers F
Total	31								
Block	3	0.70	3.88*	2.72	5.55*	1.75	3.12	41.91	2.27
Treatment	7								
P	3	0.67	3.72*	1.05	2.14	1.15	2.05	40.74	2.21
C	1	0.66	3.66	0.09	<1	0.03	<1	4.43	<1
P x C	3	0.37	2.05	0.12	<1	0.94	1.67	27.20	1.47
Error	21	0.18		0.49		0.56		18.41	

*Significant at 5% level

APPENDIX V

Analysis of variance

(Length of panicle, percentage of filled grains, weight of thousand grains and yield of grain)

Source	D.F.	Length of panicle		Percentage of filled grains		weight of thousand grains		Yield of grain	
		Variance	F	Variance	F	Variance	F	Variance	F
Total	31								
Block	3	0.8366	<1	1.68	<1	0.93	3.57	20.13	10.48**
Treatment	7								
P	3	0.2400	<1	2.15	<1	0.46	1.76	1.02	<1
C	1	0.6700	<1	47.34	17.46**	1.24	4.76*	26.46	13.78**
P x C	3	1.2833	<1	0.62	<1	0.47	1.80	0.25	<1
Error	21	2.0604		2.71		0.26		1.92	

*Significant at 5% level
**Significant at 1% level

APPENDIX VI

Analysis of variance

(P_2O_5 content at milky stage, P_2O_5 content of grain and P_2O_5 content of straw)

Source	D.F.	P_2O_5 content at milky stage		P_2O_5 content of grain		P_2O_5 content of straw	
		Variance	F	Variance	F	Variance	F
Total	31						
Block	3	0.00050	3.12*	0.00013	2.16	0.0019	9.50**
Treatment	7						
P	3	0.02330	145.62**	0.00440	7.33**	0.0023	11.50**
C	1	0.00000	..	0.00830	13.33**	0.0004	2.00
P x C	3	0.00306	19.12**	0.00010	<1	0.0010	5.00**
Error	21	0.00016		0.00060		0.0002	

*Significant at 5% level

**Significant at 1% level

APPENDIX VII

Analysis of variance

(P_2O_5 content of the plant at various stages of growth)

Source	D.F.	P_2O_5 content at tillering stage		P_2O_5 content at primordia initiation stage		P_2O_5 content stem elongation stage		P_2O_5 content at flowering stage	
		Variance	F	Variance	F	Variance	F	Variance	F
Total	31								
Block	3	0.02760	29.05**	0		0		0.0030	7.5**
Treatment	7								
P	3	0.05770	60.73**	0.0330	36.60**	0.0200	14.28**	0.0200	50.00**
C	1	0.01330	10.28**	0.0100	11.11**	0.0200	14.28**	0.0200	50.00**
P x C	3	0.00420	4.42**	0.0030	3.33*	0.0133	9.50**	0.0030	7.50**
Error	21	0.00095		0.0009		0.0014		0.0004	

*Significant at 5% level

**Significant at 1% level

APPENDIX VIII

Analysis of variance

(Yield of straw, grain/straw ratio and P_2O_5 availability of the soil (post harvest)

		Yield of straw		Grain/straw ratio		P_2O_5 availability of the soil (post harvest)	
Source	D.F.	Variance	F	Variance	F	Variance	F
Total	31						
Block	3	12.40	1.89	0.0533	<1	5.86	<1
Treatment	7						
P	3	3.78	<1	0.7100	1.32	8.44	1.42
C	1	1.28	<1	0.0325	<1	0.03	<1
P x C	3	4.31	<1	0.0193	<1	1.61	<1
Error	21	6.54		0.0534		5.91	

TABLE No. XIV

Economics of phosphorus and lime application

Treatment	Yield obtained (Kgs.)	Difference in yield compared to control (Kgs.)	Yield increase %	Cost of 4423 of $CaCO_3$ @ Rs. 13.50 per ton Rs. Ps	Cost of P_2O_5 @ Rs. 2.40 per Kg. Rs. Ps	Total Rs. Ps	Cost of paddy @ Rs. 55/- per quintal Rs. Ps	Net returns Rs. Ps.
P_0C_0	4675.59							
P_1C_0	4806.93	131.34	2.8		120.00	120.00	72.23	-47.77
P_2C_0	4925.13	249.54	5.3		240.00	240.00	137.24	-102.76
P_3C_0	4662.46	-13.13	..		360.00	360.00	(-7.22)	-367.22
P_0C_1	5127.39	451.80	9.5	59.20	..	59.20	248.49	189.29
P_1C_1	5253.48	577.89	12.3	59.20	120.00	179.20	317.83	138.63
P_2C_1	5319.14	643.55	13.7	59.20	240.00	279.20	353.95	54.75
P_3C_1	5437.35	761.76	16.3	59.20	360.00	419.20	418.96	-0.24