STUDIES ON THE LACK OF RESPONSE OF PHOSPHATIC FERTILIZERS TO RICE IN THE LATERITE SOILS OF KERALA

BY

A. AKBAR, B. Sc. (Ag.)

THESIS

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

DIVISION OF AGRICULTURAL CHEMISTRY
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
VELLAYANI, TRIVANDRUM

1970

CERTIFICATE

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

8.10.70

(J. SAM RAJ)
Principal.

(N. SUBRAMONEY)
Special Officer for the Establishment of the Agricultural University for Kerala

Agricultural College &
Research Institute,
Vellayani, Trivandrum,
19th September, 1970.

ACKNOWLEDGEMENTS

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

Dr. N. Subramoney, Special Officer for the Establishment of the Agricultural University for Kerala for suggesting and planning the present investigation and for his sagaceous guidance and encouragement,

Dr. J. Sam Raj, Principal, Agricultural College and Research Institute, Vellayani for providing necessary facilities for this study and for many other courtesies extended

Dr. M.M. Koshy, Professor of Agricultural Chemistry and State Agricultural Chemist, for the keen interest and critical suggestions during the course of this investigation

Dr. R. Subramonia Aiyer, Smt. T. Pankajakshi Amma and Shri. P. Ramasubramonian, Junior Professors of Agricultural Chemistry for their valuable suggestions,

Shri. N. Neelakantan Potty, Junior Professor of Agronomy, for his ever ready assistance and constructive criticisms during the course of this investigation and the preparation of manuscript,

Shri. N. Chittaranjan Nair, Research Officer, Pesticides Testing Laboratory for his immense and generous help in this investigation and in the preparation of thesis

Shri. E.J. Thomas, Professor in Agricultural Statistics for his help in the statistical layout of the experiment and analysis of the data,

Shri. T.V. Balakrishna Pillai, Assistant Soil Chemist and Kumari. S. Sreedevi Amma, Research Assistant of the Soil Testing Laboratory for rendering their valuable help in carrying out the investigation successfully,

and also for the unfailing help the author received from his friends whenever he has asked it of them.

The author is also thankful to the University of Kerala for providing him the University Merit Scholarship.

A. AKBAR.

C O N T E N T S

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	5
MATERIALS AND METHODS	38
RESULTS	46
DISCUSSION	77
SUMMARY AND CONCLUSIONS	91
REFERENCES	i - xxii
APPENDICES	I - XXVIII

INTRODUCTION

INTRODUCTION

The importance of phosphorus for crops is too well known to need special emphasis. However, the different aspects of phosphorus nutrition, such as its availability to plants and the response of crops to its application still deserve thorough investigation. More than anything else, the availability of this nutrient in the soil is governed by a large number of factors such as, soil particle size, soil reaction and the presence of soluble iron and aluminium in the soil. It would appear therefore, that the status of this element in the soil can hardly be considered as a criterion of plant response.

Indian soils, especially that of Kerala State though reported to be poor in total and available phosphorus, do not generally respond to application of phosphorus. Although this anomalous behaviour of fertilizer phosphorus has been sought to be explained as due to the fixation of this element by the sesquioxides present in these soils, fuller information as to the reasons for the lack of response to applied phosphorus are not available as yet.

A number of factors, it may be mentioned, contribute to the lack of response to applied phosphorus in soils. One such factor worthy of particular mention in this context, is the application of organic manures. Application of farm yard manure has been reported to enhance the efficacy of phosphorus utilisation and absorption by plants. This may be through the effects such as the action of carbondioxide in solubilising phosphorus compounds or by the formation of phosphohumic complexes which are more assimilable by plants or by the fixation of humus colloids which form a protective coating over the colloidal sesquioxides. Yet another factor that may influence the efficacy of applied phosphorus is the predominantly water logged conditions in which rice is grown. This condition may increase the availability of native phosphorus by reducing the insoluble ferriophosphate to soluble ferrous phosphate which is a more assimilable form. Form of phosphatic fertilizers used might also have some bearing on the response obtained. The possibility that plants may be able to attain the limiting levels of this nutrient from the limited supply of available phosphorus in the soil, thereby making the application of phosphorus ineffective, cannot also be ruled out.

The reasons for the lack of crop response to phosphorus application being so numerous, the need for an investigation on the influence of the aforesaid factors on the effect of applied phosphorus in a typical laterite soil of Kerala has been keenly felt.

To have a better assessment of these factors, the experiment was simultaneously conducted in sand culture also.

The main aims set forth in this study are to investigate

1. The factors contributing to the lack of response to applied phosphorus for rice grown in laterite soil.

2. The role of Farm yard manure in influencing the availability of phosphorus in the soil.

3. Comparative performance of superphosphate and ultraphos as regards their availability and absorption of phosphorus by the rice plant.

4. The influence of applied phosphorus on the uptake of major nutrients.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

ROLE OF PHOSPHORUS IN PLANT GROWTH

Phosphorus is one of the 3 major nutrients required by plants. It is concerned with many vital growth processes in plants and is an essential constituent of nucleic acids and the nuclei. Its active role in conservation and energy in the metabolism of carbohydrates, fats and proteins is well established. Phosphorus also helps to strengthen the stem of cereals, thus reducing their tendency to lodge (Wallace 1961, Anonymous 1961).

An abundant supply of phosphorus in the early stages promotes rapid growth because such a high supply increases the content of nucleic acid phosphorus and phospholipid phosphorus. According to Fujiwara et al (1961) nucleic acids can actually promote heading in rice, as it controls vegetative growth through protein biosynthesis and reproductive growth through flower initiation.

Tamhane *et al* (1965) has reported that phosphorus imparts disease resistence to plant as it induces normal cell development resulting in vigorous growth. 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.

CHANGES TAKING PLACE TO THE APPLIED PHOSPHORUS

Even in soils containing large amounts of total phosphorus plants may frequently exhibit a deficiency of this element. This anomalous behaviour of unavailability of even available phosphorus after its application in the soil is due to phosphate fixation. Factors responsible for such unavailability of phosphorus are numerous such as the presence of hydrous oxides of iron and aluminium, high acidity of the soil, adsorption on the clay surfaces and depletion of calcium.

Warrington (1866) was apparently the first to observe the reaction of phosphate ions with hydrated oxides of iron and aluminium. After further study in

1868 he concluded that these reactions were chemical in nature and resulted in iron and aluminium phosphates citing a contemporary paper by Peters (1867) which mentioned similar results.

Conversion of soluble forms of phosphorus into sparingly soluble compounds with cations of the soil solution like iron, aluminium and calcium has been suggested by various workers like Gaarder (1930) Metzger (1940).

Scarseth and Tidmore (1934) found retention of phosphate by several clays which had been purified by electrodialysis and found that clays with low silica Sesquioxide ratio held more phosphate against extractions with dilute acids.

Hibbard (1935) stated that the soils had no definite "fixing power" but that fixation was a function of the concentration in the solution at equilibrium.

Toth (1937) showed that the removal of iron oxides reduced phosphate retention. Murphy (1939) explained retentions and low availability of phosphate retained by kaolinite and kaolinitic soils by an exchange of added phosphate with hydroxyl ions of the hydroxyl layers in the kaolinite crystal lattice. This explanation was supported by Stout (1939) Black (1941).

Coleman (1942) concluded that failure of crops to respond to added phosphate often attributed to the rapid fixation by the soil was due to the sufficiency of phosphorus already in the soil and that large amount of phosphorus formerly "considered fixed are available to plants".

Ghani and Aleem (1943) and Kurtz (1946) have found that in acid soils phosphorus became unavailable due to the formation of iron and aluminium phosphates and the accumulation of organic compounds.

Coleman (1944) and Perkin and King (1944) observed that phosphate adsorption increases with decreasing particle size and finer clay fractions have appreciably greater anion adsorption capacities than coarser fractions.

The reduction or apparent reduction in the availability of added fertilizer phosphorus had led to the term phosphorus fixation which implies only very slight availability to plants. According to Tisdale and Nelson (1956) phosphorus retention in soils are not entirely irreversible and the term fixation may be some what of an exhaggeration.

Chang and Jackson (1968) investigated the occurrence of the various forms of soil phosphorus in relation to fertilizer practices and found that the phosphorus added to the soil was converted to calcium, aluminium and iron phosphates. These transformations were observed in acid as well as in neutral soils.

Wright and Peach (1960) reported that under low pH range phosphorus was converted into iron phosphate. Analysis of soil from long term manurial plots also have confirmed this view.

Yuvan et al (1960), Bapal and Badekar (1965) investigated the rate of fixation of applied phosphorus and they found that more than 80 per cent of the applied phosphorus was fixed as iron and aluminium phosphates and only 10 per cent of the applied phosphorus will remain in the available form in the soil.

Nayakam and Koshy (1961) in their study on fixation and availability of phosphorus in Kerala soils found that soils differ widely in their capacities to fix phosphorus and they also found that acid soils with high silica sesquioxide content have high capacities for fixation.

Phosphorus fixation has been reported by Ghani and Aleem (1943) and Nayakam and Koshy (1965) to be a function of soil reaction.

According to Bapal (1965), Chai Moochu and Gladwell (1959) and Nayakam and Koshy (1965) fixation by iron and aluminium compounds dominate in the acid range and by calcium in the alkaline range.

Khar and Chakravarthy (1969) in their study in five West Bengal acid soils pH varying from 4.3 - 6.3 observed that about 30 to 50 per cent of the added soluble phosphates was found to get fixed during the crop growth and analysis showed appreciable increase in aluminium phosphate, iron phosphate and to lesser degree occluded aluminium phosphate. Calcium phosphate was unaffected except with soils having pH 6.18.

THE UPTAKE OF NATIVE AND APPLIED PHOSPHORUS

A first approach to the subject of phosphorus nutrition of plants leads to a consideration of the amounts and rates of absorption. Such studies will indicate something of the requirements imposed upon the soil as a source of supply. Coleman (1942) observed that failure of crops to respond to added phosphate often attributed to rapid fixation by the soil was due to sufficiency of phosphorus already in the soil and that large amounts of phosphorus formerly "considered fixed are available to plants".

A multitude of compounds both organic and inorganic in nature could conceivebly exist under soil conditions. But usually the bulk of the soil phosphorus in many soils is in the organic form. Pierre (1948) reported the existence of organic forms as well as the inorganic forms of phosphorus in soils.

Bear (1949) using radio active isotope of phosphorus has shown that plants obtain an unusually high proportion of phosphate from that already present in the soil.

Stanford and Nelson (1949) in their studies on the effect of phosphatic fertilizers on absorption rates observed an initial increase in utilisation of applied phosphorus by the corn plants but later the absorption rate from soil phosphorus increased.

Fried and Dean (1952) observed that a plant presented with two sources of phosphorus, namely the soil and fertilizer will absorb phosphorus from each in direct proportion to the amounts of their respective supplies.

In the early stages of growth seedlings absorb phosphorus at a faster rate from the fertilizer than from the soil the net result being that in young plants a high proportion of the total phosphorus absorbed is that derived from the fertilizer. As the plants develop the enlarging root system continuously increases the amount of soil phosphorus as compared with that of fertilizer phosphorus (Dean and Murice Fried (1953)). They also observed in a green house experiment with millet that the amounts of total and fertilizer phosphorus absorbed increased with increasing application of fertilizer.

Nishgaki <u>et al</u> (1958) reported that during the first and second month, plants used mostly the applied phosphorus while more of soil phosphorus was utilised during the later stages of growth.

Maung-mya-thuang (1960) from his studies on the effect of time of application and relative absorption of phosphorus from native and additive sources using radio active phosphorus observed that during 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 midway between transplanting and flower primordia initiation, the plants absorbed phosphorus from both native and applied forms. The studies also disclosed that of the total phosphorus content of the plant more phosphorus come from the soil phosphorus.

De Datta et al (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.

Goswami et al (1969) in their study on the uptake and utilisation of soil and fertilizer phosphorus by jute observed that fertilizer phosphorus was maximum at the early stages of growth while 'A' values reached the maximum at the later stages of growth. They also concluded that the phosphorus uptake from the fertilizer was very low as compared to that from the soil.

FACTORS GOVERNING THE AVAILABILITY OF PHOSPHORUS

Most soil management practices like liming, application of manures and crop residues, cultural operations application and availability of other nutrients, nature of crops, irrigation and drainage, either directly or indirectly affect the availability and utilisation of phosphorus by plants.

Hilgard (1907) stressed the highly favourable influence of lime on the availability of soil phosphorus.

Salter and Schollenberger (1939) concluded that the availability to plants of phosphorus in farm yard manure is equal to or in some instances exceeds that applied in chemical fertilizers.

Investigations have revealed that organic materials like green manures, crop residues and farm yard manure exert considerable influence in increasing the availability of both native as well as applied phosphorus. Fuller and Dean (1949) found that green manure phosphorus from wheat tops and roots was about

70 per cent efficient as superphosphate where these materials were mixed with the soil under green house conditions.

Mc Lean and Hoelscher (1954) noted that the application of fertilizer phosphorus in the soil reduced the availability of soil phosphorus to plants.

Srivastava (1955) found significant increase in availability of phosphorus when superphosphate was applied either alone or in combination with farm yard manure rather than farm yard manure alone.

The soil reaction is another important factor which influences the availability of phosphorus. Availability of phosphorus according to Collings (1955) is maximum between pH 6 and 7 in the majority of soils.

Venkita Rao and Govindaraju (1956) found an interrelationship between the nitrogen content and phosphorus availability.

Mehta and Patel (1963) on their studies of some aspects of phosphorus availability in Gujarat soils observed no correlation between any single factor such as organic matter, finer fractions or pH and available phosphorus.

Singh and Pancholy (1967) observed that application of nitrogen increased the availability of native as well as applied phosphorus.

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.

CROP RESPONSE TO PHOSPHORUS

Although phosphorus is a major essential nutrient for plant growth, the crop response to applied phosphorus is very often inconsistent. Many investigators have revealed that the low land rice fails to respond to phosphatic fertilization when upland crops grown on the same soil show greater response.

Ishizuka and Tanaka (1950) found an increase in grain yield in solution cultures when phosphorus was applied at the rate of 20 ppm.

Sethi et al (1952) observed that it was paradoxical that while rice soils in many tracts were deficient in phosphorus, its addition had not given appreciable responses.

Desai et al (1954) have recorded significant response to phosphorus when applied along with nitrogen and potash.

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

That phosphorus is an important a nutrient to paddy as nitrogen is well established. But compared to nitrogen and potash the phosphate requirement of paddy is low (Ghose et al 1956).

Chavan et al (1957) reported increased yields and better growth of plants by the application of phosphatic fertilizers.

Trials conducted in Ceylon with 2 levels of phosphorus, five levels of nitrogen and 3 varieties Chandraratna (1957) did not find any response to phosphorus.

Buckman and Brady (1957) opined that heavy doses of phosphorus may adversely affect the uptake of iron and zinc by plants.

Reviewing the experiments conducted in Madras where phosphorus levels upto 67.2 kg per hectare were used no response to phosphorus by Mariakulandai (1957) when applied alone but concluded that phosphorus when applied along with nutrients like nitrogen there was an enhanced response to these nutrients producing greater yields of rice.

Diger and Mandal (1957) did not find any significant increase in yield for the first 3 years after application of phosphorus 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 to 60 pounds of phosphorus per acre.

Relwani (1959) observed that application of phosphorus was generally uneconomic.

Basak et al (1960) failed to get any response for phosphates under wet land conditions in 25 trials conducted in the cultivators field in Bihar. This was in general agreement with the results reported by him earlier (Basak, 1956).

However increase in grain yield was noted when phosphorus was applied along with nitrogen by Varma (1960). He also found that phosphorus, when applied alone, had increased the yields but the difference was not significant.

Russel (1961) remarked that an excess of phosphorus over the actual requirement may depress crop yields. But Tomy (1963) recorded a progressive increase in grain yield at the rate of 6.4 pounds for every pound of phosphorus applied beyond 20 pounds.

Potty (1964) reviewing fertilizer experiments at the various Rice Research Stations in Kerala reported that there is no response to phosphorus application.

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.

Mariakulandai and Thyagarajan (1965) also reported a nil to nonsignificant response to phosphorus at the rate of 40 pounds of phosphorus 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.

Absence of direct or cumulative effect for phosphorus application was reported by Kalam <u>et al</u> (1966) from their experiments in the Model Agronomic Research Station, Karamana.

Suseelan (1969) in his study on the effect of graded doses of phosphorus in conjunction with lime on growth, yield and phosphorus uptake in rice found that though the grain yield was significantly increased by the application of lime, phosphorus or calcium phosphorus interaction did not show any significant effect on the yield of grain.

EFFECT OF PHOSPHORUS ON THE UPTAKE OF MAJOR NUTRIENTS

Much emphasis is being laid on the yield of grain alone and not on the uptake of nutrients as a criterion for the studies on the application of fertilizers. Evidences are numerous to show that application of higher doses of phosphorus enhance the uptake of many nutrients especially nitrogen, phosphorus and potassium.

Williams (1948) found that phosphorus deficiency greatly depressed nitrogen uptake in the early stages of growth of roots and shoots. Thomas et al (1951) demonstrated a direct phosphorus nitrogen relation in plants.

According to Larson (1952) phosphorus content of Oats straw was an indication of the quantity of phosphorus applied.

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

Sanyasiraju et al (1954) have observed that increased application of phosphorus to soil increased the phosphorus content of paddy grain in laterite soil of Pattambi.

Significant results were obtained by many workers (Srivastava et al 1955) on the total phosphorus content of grain when superphosphate alone and in combination with organic manure were applied. But they found that organic matter alone had no appreciable effect on the total phosphorus content of the grain.

Coulter and Locakard (1955) observed that phosphorus content of grains was increased by the application of phosphatic fertilizers.

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 maximum levels of phosphorus and vice versa. At two levels of fertilizer application nitrogen and phosphorus exchanged their effects.

Chaves Sandrez and Gozalez Gracia (1956) found that the increasing of phosphorus level decreased the nitrogen content but rapidly increased the potash and phosphorus content in wheat grain.

Mc Lean (1956) found increased uptake of phosphorus by increasing the supply of phosphorus in the soil.

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

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

Sreeramulu et al (1959) observed that an increased application of phosphorus to soil increased the total phosphorus in the grains.

Digar (1960) reported that a combination of 30 pounds of nitrogen and 60 pounds of phosphorus was the optimum for the maximisation of crop yields. In their study of the nutritive value of rice Basak et al (1961) found that application of phosphorus along with calcium had a negative influence on the protein, phosphorus and calcium content of grain. Kanwar and

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

Sreeramulu and Mariakulandai (1964) while working on the composition of Ragi grain and straw observed that application of phosphatic manures increased the nitrogen, phosphorus and potash content but depressed the calcium content of the grain.

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

Mohan Kumar (1967) observed a decrease in nitrogen content and an increase in the phosphorus content with increase in the rate of phosphate application. Similar conclusions were also drawn by Nair (1968).

RELATIVE MERITS OF DIFFERENT PHOSPHATIC FERTILIZERS

Some of the generally recognized factors which determine the apparent relative efficiency of a particular phosphorus fertilizer are soil reaction, degree of soil phosphorus deficiency, rate of application, method of application, needs of the specific crop and certain pedological factors.

Paave 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.

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

In Java Chandraratna (1951) found that rock phosphate was satisfactory although less effective in increasing yields than double superphosphate.

Trials conducted in Thailand by Owens (1953) especially in the phosphate deficient regions showed better results with ordinary superphosphate than with rock phosphate.

Cheng and Chiang (1953) studied the availability of phosphorus in calcium superphosphate, magnesium superphosphate 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.

De Geus (1954) in a five year experiments in some Burmese soils found that superphosphate was somewhat superior to bonemeal.

In Ceylon 6 season experiments in a few areas Chandraratna and Fernando (1954) found no significant yield variation with the use of soft rock phosphate, ordinary superphosphate, con. superphosphate, bonemeal and basic slag.

Chandani and Obhria (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 phosphorus recovery was 59.25 per cent. The other fertilizer gave recovery values of 20 to 40 per cent.

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

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.

By using different sources of phosphorus the results obtained varied with the types of soil and it was concluded that superphosphate was more suited to both black and red soils of the country (Seetha Rama Rao and Krishna Rao 1961, Sinha and Bhattacharya 1962).

Mattingly (1963) reported from the recent reports of Rothamsted Experimental Station that none of the newer fertilizers were significantly and consistently better than superphosphate.

Motiramani *et al* (1964) found that maximum availability for superphosphate on black soils and for dicalcium phosphate on alluvial soils.

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

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

ROLE OF FARM YARD MANURE IN THE PHOSPHORUS NUTRITION OF RICE

The phosphorus nutrition of rice is influenced in various ways by the addition of organic materials like Farm Yard Manure to the soil. The relative rates of immobilisation of inorganic phosphorus and mineralisation of organic forms undoubtedly exert considerable influence on the amount of phosphorus available to the plant at various stages of the decomposition of the added materials.

Many investigators like Jensen (1917) Midgley and Dunklee (1945) have observed that organic matter increased the availability of soil phosphates and rockphosphates applied as a fertilizer.

Salter and Schollenberger (1939) concluded that the availability to plants of phosphorus in farm yard manure is equal to or in some instances exceeds that applied in chemical fertilizers.

Humus extracts of soils or composts have been reported by a number of workers to increase the solubility of phosphorus in soils (Bischot and Sylvester 1949, Swenson et al 1949) or to increase its availability to plants (Chaminde and Blanchet, 1952). The latter authors have ascribed the beneficial action of organic matter in phosphorus nutrition to formation of humic complexes, the phosphorus in these complexes is regarded as being more assimilable by plants than that of difficultly soluble soil phosphorus compounds.

Certain studies using plant residues tagged with radiophosphorus also shown that utilization of soil phosphorus was increased by incorporation of green manures (Fuller and Dean 1949, Nielsen 1952), while others have shown no such effect. (Mc Auliffe et al 1949, Fuller and Rogers 1951).

Aslander (1950) in Sweden observed that liberal applications of phosphorus may eliminate the need for liming.

The aspect of action of decomposition of organic matter in increasing the availability of mineral nutrients particularly soil phosphate and the phosphate supplied through fertilizers are being stressed by Dalton et al (1952).

Mc Auliffe and Bradfield (1952) found in a study that the two sources of phosphorus were same in the first 30 days while the availability of phosphorus in the farm yard manure exceeded that of superphosphate afterwards is governed by pH, moisture level, salt content, temperature, organic ions, biological activity and CO_2 production.

Georgestanford and Pierre (1953) observed that application of organic matter not only enhance the solubility of native soil phosphorus but also reduction in fixation of applied phosphorus.

Parthasarathy (1953) reported an increase in yield due to the application of 150 pounds of superphosphate along with 4000 to 5000 pounds of green manure per acre.

Venkitasubramonian and Durairaj (1954) abscribed the beneficial influence of green manure to its physical effects on soils, in improving the aeration and movement of oxygen in the soil.

Basak (1956) reported that no beneficial effect was obtained due to the phosphatic fertilizers even when it was combined with organic matter.

Srivastava et al (1956) reported significant increase in the total uptake of phosphorus treatments receiving superphosphate or combination of superphosphate and farm yard manures had no appreciable effect on the phosphorus content of the grain.

Allen and Coulter (1956) Kanapathy and Thampoo (1960) in a set of pot experiments as much as 50 per cent increase in yield was obtained with the use of rockphosphate with organic matter.

Sreeramulu and Mariakulandai (1962) found that combination of both superphosphates and farm yard manure gave higher amounts of available phosphorus compared to the treatments which receive superphosphate or farm yard manure individually. They also found that superphosphate was preferable to farm yard manure at equal phosphorus level when applied individually. The same authors in (1964) on their study of the influence of phosphorus as present in farm yard manure and superphosphate on the ragi crop observed that superphosphate was more effective in raising the phosphorus content of the grain and straw, than farm yard manure on equal phosphorus basis. Increasing amounts of farm yard manure had dipressing effect of phosphorus content of the straw.

CHANGES BROUGHT ABOUT BY THE APPLIED PHOSPHORUS ON THE SOIL pH AND ORGANIC CARBON DURING CROP GROWTH

It has long been recognized that carbondioxide production in soils may bring about the increased availability of soil phosphorus. Mc George and Greene (1935) and Mc George (1939) believed that the beneficial effect of applying organic materials to calcareous soils could be explained to a considerable extent by the action of carbondioxide liberated and the accompanying reduction in pH value of the soil. Stephenson (1938) also concluded that carbonic acid is of considerable significance in neutral or calcareous soils, but that exerts little solvent action on soil minerals in acid soils.

Williams (1952) pointed out that the supply of available phosphorus in soil is governed by pH, moisture level, salt content, temperature, organic ions, biological activity and CO_2 production.

Black and Goring (1953) and others pointed out that the content of organic phosphates in the soil was positively correlated with organic carbon and pH.

Saurlandt and Grietzner (1953) recorded a significant increase in organic carbon content to exist in fallow soils.

Chandrasekharan <u>et al</u> (1953) found that application of phosphatic manures and fertilizers influence the available nitrogen and also organic carbon content of the soil.

Thompson <u>et al</u> (1954) had given an equation showing the relationship between organic phosphorus, organic carbon and pH.

Long term experiments with phosphatic fertilizers in West Bengal have indicated that higher the dose of phosphatic fertilizer in the form of bonemeal or superphosphate higher is the yield of paddy. Total nitrogen and available phosphate, carbon exchangeable calcium and bases in soil have gone up by continuous application of bonemeal but no marked change in chemical composition or pH has taken place due to application of superphosphate for 6 years Ghosh (1963).

Mehta and Patel (1963) in their study on the factors such as organic matter, finer fractions of soil and pH which are known to affect the availability of soil phosphorus found that there was no significant correlation between any single factor and available phosphates in Gujarat soils. They concluded that the integrated action of all these factors affects the availability of phosphorus.

Sreeramulu and Mariakulandai (1963) in their study on the influence of phosphatic manuring on the available nitrogen, pH and organic carbon of the soil observed that during the crop growth organic carbon content of the soil fluctuates showing maximum in the 15 - 40th day period and exhibited an increase afterwards. They also concluded that the phosphorus application also influence the available nitrogen but not pH.

Patel *et al* (1963) observed during their study on the effect of phosphate manuring of Berseem on the fertility status of Delhi soil that there had been significant increase in the organic carbon and nitrogen status of the soil by phosphate manuring at 72 kg/ha, lower doses of phosphorus being less effective. They also observed that the contents of total soluble salts and the soil reaction have not altered to any marked extent.

FLOODING AND ITS SIGNIFICANCE IN PHOSPHORUS NUTRITION OF RICE

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

Aoki (1941) reported that rice grown under low land conditions gave no responce 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 ferrous phosphate.

Fujiwara (1950) ascribed the increase in available phosphorus under paddy conditions to the hydrolysis of soil phosphates and increased solubility of ironphosphates.

Increase in solubility of phosphorus under flooded conditions has also been reported by Islam and Elahi (1954), Ponnamperuma (1955), Mitsui (1960) and these authors have attributed the reason for increased solubility of phosphorus to the reduction of insoluble ferric phosphate to the soluble ferrous phosphate brought about by the anaerobic condition due to flooding.

Some investigators (Shapiro 1958, Davide 1960) evaluated the effect of submergence in phosphorus availability by growing rice in the same soil flooded and nonflooded. They observed that flooding increases the phosphorus uptake by the plant and availability of soil phosphorus as measured by the A-value. In other words utilization of native and applied phosphorus is better in flooded soils than in well drained soils.

Fractionation studies of the inorganic phosphorus in paddy soils revealed the dominance of iron phosphate (Davide 1960, Chang and Chu 1961).

Maung Mya-Thaung (1960) also obtained a high A-value of Burmese paddy soils 13 weeks after transplanting.

Tyner and Davide (1962) concluded that the availability of phosphorus in paddy soils was a function of the magnitude and reactivity of the prevailing ironphosphate system.

Basak and Bhattacharya (1962) reported increase in available phosphorus in the unmanured paddy soils West Bengal. They found that the available phosphorus increased by 64 per cent from the original value of 44 pounds per acre from planting to flowering remained fairly constant from tillering to pre-flowering and decreased towards the post harvest time.

MATERIALS AND METHODS

MATERIALS AND METHODS

With a view to investigate the factors responsible for the lack of response to phosphatic fertilizers applied for rice in the laterite soils of Kerala, a pot culture trial was undertaken.

MATERIALS

1. Soils

Two types of soils were used to this study. These were (1) typical laterite soil collected from the Central Rice Research Station, Pattambi (2) River sand collected from Thiruvallam, near Agricultural College, Vellayani.

The details relating to the mechanical and chemical analysis of the soil are given below:-

Mechanical Analysis		
Coarse sand	(%)	42.3
Fine sand	(%)	10.1
Silt	(%)	15.9
Clay	(%)	20.7

Chemical Analysis		
pH		5.2
Nitrogen	(%)	0.17
Phosphorus	(%)	0.09
Av. phosphorus	(%)	0.0026
Av. potassium	(%)	0.0023
Organic carbon	(%)	0.92
Iron (Fe_2O_3)	(%)	9.50
Aluminium (Al_2O_3)	(%)	17.50
Calcium	(%)	0.07

The details relating to the mechanical and chemical analysis of the river sand are given below:-

Mechanical Analysis		
Coarse sand	(%)	91.6
Fine sand	(%)	9.4
Silt	(%)	1.2
Clay	(%)	0.9

Chemical Analysis		
pH		5.9
Nitrogen	(%)	0.012
Phosphorus	(%)	0.0090
Av. phosphorus	(%)	0.0006
Potassium	(%)	0.0050
Organic Carbon	(%)	0.1900
Iron (Fe_2O_3)	(%)	0.5020
Calcium	(%)	0.0610

2. Paddy variety

Seeds of the popular high yielding strain IR8-288.3 was used for the trial.

3. Pots

Earthen pots were used for the experiment. 8 kg of the air dried soil was weighed into each pot.

4. Manures and fertilizers

Farm yard manure analysing 0.45 per cent N, 0.25 per cent P_2O_5 and 0.44 per cent K_2O was used at the rate of 5000 kg/ha.

Fertilizers

Nitrogen

Ammonium sulphate analysing 20 per cent nitrogen was used to supply nitrogen at the rate of 80 kg/ha uniformly for all the treatments.

Phosphorus

Superphosphate containing 16 per cent water soluble P_2O_5 and Ultraphos containing 30 per cent citric acid soluble P_2O_5 were used to supply phosphorus as per various treatments.

Potassium

Muriate of potash analysing 60 per cent K_2O was used to supply potash at the rate of

50 kg/ha uniformly for all the treatments.

METHODS

1. Treatments

Three levels of P_2O_5 viz. 0, 30 and 60 kg/ha each supplied from two sources ie., superphosphate and ultraphos with and without farm yard manure. All the same treatments were repeated in sand culture also. There were altogether 20 treatments. The details of the treatments were as follows:-

1.	T_1	30 kg	P_2O_5/ha	(Superphosphate)	+ 5000 kg FYM/ha
2.	T_2	60 kg	,,	(,,)	+ ,,
3.	T_3	30 kg	,,	(,,)	+ no FYM
4.	T_4	60 kg	,,	(,,)	+ ,,
5.	T_5	30 kg	,,	(Ultraphos)	+ 5000 kg FYM/ha
6.	T_6	60 kg	,,	(,,)	+ ,,
7.	T_7	30 kg	,,	(,,)	+ no FYM
8.	T_8	60 kg	,,	(,,)	+ ,,
9.	T_9	No P fertilizer + 5000 kg FYM/ha			
10.	T_{10}	No P fertilizer + no FYM (control)			

2. Lay out

The experiment was statistically laid out in randomised block design with 3 replications.

3. Application of manures and fertilizers

Farm yard manure at the rate of 5000 kg/ha was applied for the treatments which were included with farm yard manure.

All the treatments received a uniform application of nitrogen and potash at the rate of 80 kg/ha and 50 kg/ha respectively. Nitrogen was supplied in 3 instalments half basally and the remaining half in two instalments ie., 30 and 60 days after sowing.

The whole quantity of phosphorus as per treatments and potash were applied basally one day prior to sowing and mixed thoroughly with the soil.

4. Sowing

The seeds were sown directly in the pots on the 10th November 1969 at the rate of 3 seeds per pot.

5. 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.

6. Plant protection measures

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

7. Harvest

The crop was harvested on the 27th March 1970. Weight of grain and straw were recorded pot wise.

A. Laboratory studies

1. Soil samples were collected at 45th, 90th and at harvest and were analysed for the following.

(a) Available phosphorus

(b) Organic carbon

(c) pH

(a) Available phosphorus

Soil samples from all the treatments were collected, dried, seived and analysed for available phosphorus calorimetrically using Bray's extractant No. 2 (0.025 HCl and 0.03 NH_4F) as outlined by Jackson (1958).

(b) Organic carbon

Soil samples collected from all the treatments were dried, seived and analysed for organic carbon volumetrically (Walkley, 1947).

(c) pH

The pH of the soil samples was determined in a 1:2 soil water suspension by electrical conductivity method.

2. Analysis of the plant material

The grain and straw were dried to a constant weight in an air oven at 105°C. The dried grain was ground in an electrical grinder and the straw was cut in small pieces. The samples of straw and grain thus prepared were stored in air tight labelled glass containers for chemical analysis. They were analysed for nitrogen, phosphorus and potassium.

Nitrogen was estimated by the Kjeldahl method as described in A.O.A.C. (1960).

Phosphorus and potassium were estimated after wet digestion with the triple acid mixture. The calorimetric method suggested by Jackson (1958) was used for the determination of phosphorus and the volumetric procedure detailed by Piper (1950) was followed for the estimation of potassium.

B. Observations

The yield of grain and straw were recorded. Plants in each pot were harvested separately, the yield of grain and straw on dry basis were recorded pot wise.

RESULTS

RESULTS

The results of the present study are given in the following pages. The data obtained from the present study are presented in Tables I to XVIII.

A. Available phosphorus

The available phosphorus content of the soils estimated at 3 stages after the application of phosphatic manures are given in the Table I.

Effect of form of P on available phosphorus

Table II gives the effect of form of phosphorus on the available phosphorus content of the soils.

At all stages of observation application of ultraphos had significantly increased the content of available phosphorus in the laterite soil. At the lower level of 30 kg P_2O_5/ha ultraphos recorded an increase of 7 kg P_2O_5/ha during 45th day, 10 kg/ha during 90th day and 12 kg/ha at the time of harvest. At the higher level of 60 kg P_2O_5/ha ultraphos recorded an increase of 12 kg P_2O_5/ha on 45th day

Table I

Available phosphorus at different stages

Treatments		Available phosphorus in kg/ha					
		Laterite soil			Sand		
		45th day	90th day	At harvest	45th day	90th day	At harvest
T_1	Super (30 kg P_2O_5/ha) + F.Y.M.	68	62	72	24	22	22
T_2	Super (60 kg P_2O_5/ha) + F.Y.M.	84	86	86	40	38	38
T_3	Super (30 kg P_2O_5/ha) + no F.Y.M.	57	60	58	18	16	16
T_4	Super (60 kg P_2O_5/ha) + no F.Y.M.	68	62	60	36	38	36
T_5	Ultraphos (30 kg P_2O_5/ha) + F.Y.M.	72	76	76	28	24	24
T_6	Ultraphos (60 kg P_2O_5/ha) + F.Y.M.	84	88	88	46	46	46
T_7	Ultraphos (30 kg P_2O_5/ha) + no F.Y.M.	64	70	70	26	24	24
T_8	Ultraphos (60 kg P_2O_5/ha) + no F.Y.M.	80	84	84	36	36	36
T_9	F.Y.M. alone	66	68	68	16	18	16
T_{10}	Control	56	55	52	14	16	16
C.D. at 0.05 per cent level		4.05	3.97	5.40	4.35	5.36	5.13

22 kg P_2O_5/ha on the 90th day and 24 kg P_2O_5/ha at the harvest of observation over superphosphate.

As regards sand the superiority of ultraphos over superphosphate was manifested only at the lower level of 30 kg P_2O_5/ha. At this level ultraphos recorded an increase of 4 kg P_2O_5/ha on 45th day, 3 kg P_2O_5/ha on 90th day and 4 kg P_2O_5/ha at the harvest stage of observation. However it may be seen from the Table II that the difference between the effect of superphosphate and ultraphos was not significant at higher levels where the observations on 45th day and at harvest recorded the same amount of 36 kg P_2O_5/ha. On 90th day ultraphos indicated a slight superiority over superphosphate when it showed an increase in 2 kg of available phosphorus per hectare.

Effect of levels of P on the available phosphorus

In Table III the data relating to the effect of levels of P on the available phosphorus are given.

Application of graded doses of phosphorus to the laterite soil had increased significantly the

Table II

Effect of form of P on the available phosphorus

Treatments	Available phosphorus in kg/ha					
	Laterite soil			Sand		
	45th day	90th day	At harvest	45th day	90th day	At harvest
Control	56	55	52	14	16	16
Superphosphate	62	61	59	27	27	21
Ultraphos	72	77	77	31	30	30
C.D. at 0.05 level	3.17	2.56	4.68	3.86	4.64	4.43

status of available phosphorus in the soil at all stages of observation.

Table III

Effect of levels of P on available phosphorus

Treatments	Available phosphorus in kg/ha					
	Laterite soil			Sand		
	45th day	90th day	At harvest	45th day	90th day	At harvest
Control	56	55	52	14	16	16
30 kg P_2O_5/ha	60	65	64	22	20	20
60 kg P_2O_5/ha	74	73	72	36	37	36
C.D. at 0.05 level	3.17	2.56	4.68	3.86	4.64	4.43

Application of 30 kg P_2O_5/ha had increased the available phosphorus by 4 kg P_2O_5/ha on 45th day after application. This difference later increased to 10 kg P_2O_5/ha on 90th day and 12 kg P_2O_5/ha at harvest. The corresponding increase in the content of available phosphorus in the soil over control due to the application of 60 kg P_2O_5/ha were 18 kg P_2O_5/ha on 45th day and 90th day of observation which increased to 20 kg P_2O_5/ha at harvest.

It may also be seen from the Table III that the addition of 30 kg P_2O_5/ha over no manure plots increased the available phosphorus only by 4 kg P_2O_5/ha whereas a further addition of 30 kg P_2O_5/ha had increased the status of available phosphorus by 14 kg P_2O_5/ha during the 45th day of observation. This enhancing effect of further increments in phosphorus application over the basal dose was not found lasting towards the later stages where the rate of increase in available phosphorus was found to be lower.

As regards to sand, results presented on Table III shows that application of graded doses of phosphorus had brought about significant increase in the content of available phosphorus. In sand application of 30 kg P_2O_5/ha recorded an increase of 8 kg P_2O_5/ha of available phosphorus on 45th day which later declined to 4 kg P_2O_5/ha. Application of 60 kg P_2O_5/ha brought about an increase of 22 kg P_2O_5/ha of available phosphorus in the soil on the 45th day which declined to 21 and 20 kg P_2O_5/ha on 90th day and at the time of harvest respectively.

Unlike the results obtained in laterite soil the increments in phosphorus levels had helped to enhance the status of available phosphorus in sand culture. It can also be seen that these higher status of available phosphorus was maintained throughout whereas the effect of further addition of phosphorus over a basal dose was only temporary.

Effect of farm yard manure on available phosphorus

It can be seen from the Table IV that application of farm yard manure had significantly increased the status of available phosphorus in laterite soil at all stages of observation.

On 45th day of observation farm yard manure recorded 66 kg P_2O_5/ha of available phosphorus in the soil which later increased to 68 kg P_2O_5/ha on 90th day and at harvest. The corresponding figures in the control plots were 56, 55 and 52 kg P_2O_5/ha respectively.

Table IV

Effect of farm yard manure on available phosphorus

Treatments	Available phosphorus in kg/ha					
	laterite soil			Sand		
	45th day	90th day	At harvest	45th day	90th day	At harvest
Control	56	55	52	14	16	16
Farm yard manure	66	68	68	16	18	16
C.D. at 0.05 level	4.05	3.97	5.40	N.S.	N.S.	N.S.

Data presented in the Table IV shows that the effect of farm yard manure in increasing the available phosphorus content of the sand culture was not significant. However at all stages of observation except at harvest farm yard manure had increased the status of available phosphorus by 2 kg P_2O_5/ha.

Interaction effects

The interaction between form of P and farm yard manure and that between the levels of P and farm yard manure are given in Tables V and VI.

Table V

Interaction between form of P and farm yard manure

Treatments	Available phosphorus in kg/ha					
	Laterite soil			Sand		
	45th day	90th day	At harvest	45th day	90th day	At harvest
Farm yard manure	66	68	68	16	18	16
Ultraphos	72	77	77	31	30	30
Ultraphos + FYM	78	82	82	37	35	35
Superphosphate	70	69	68	27	27	26
Superphosphate + FYM	76	74	79	31	30	30
C.D. at 0.05 level	4.05	3.97	5.40	4.35	5.36	5.13

Table V clearly indicates that there were significant interaction between the forms of P and the content of available phosphorus. Table VI shows that there were significant interaction between the levels of P and the content of available phosphorus.

Table VI

Interaction between levels of P and farm yard manure

Treatments	Available phosphorus in kg/ha					
	Laterite soil			Sand		
	45th day	90th day	At harvest	45th day	90th day	At harvest
Control	56	55	52	14	16	16
Farm yard manure	66	68	68	16	18	16
30 kg P_2O_5/ha	60	65	64	22	20	20
60 kg P_2O_5/ha	74	73	72	37	36	36
30 kg P_2O_5/ha + FYM	70	69	74	26	23	23
60 kg P_2O_5/ha + FYM	84	87	87	43	42	42
C.D. at 0.05 level	4.05	3.97	5.40	4.35	5.36	5.13

Strong interrelationships between applied phosphorus levels and available phosphorus was observed in the laterite soil as well as in sand. In both the relationships were more pronounced and significant in the case of ultraphos at all stages.

r for laterite soil = 0.96^{+}

r for sand = 0.99^{++}

In the case of superphosphate the relationship was significant only at the time of harvest in soil as well as in sand (r for soil = 0.954^{+}; r for sand = 0.997^{++}).

B. Effect of phosphate application on uptake of nutrients

The P_2O_5 content of grain and straw as influenced by phosphate manuring are recorded in Table VII.

It can be seen from the Table VII that the treatment effect had been highly significant. In the forms as well as the levels of phosphorus had resulted in increased absorption on phosphorus.

Effect of form of P on phosphorus absorption

Data presented in the Table VIII shows that in both the type of soils though the application of ultraphos had caused a slight increase in the phosphorus content of grain the increase was not significant.

Table VII

Effect of phosphatic manuring on the P_2O_5 content of grain and straw

Treatments		Laterite soil		Sand	
		Per cent P_2O_5 content in			
		Grain	Straw	Grain	Straw
T_1	Super (30 kg P_2O_5/ha) + F.Y.M.	0.42	0.054	0.60	0.062
T_2	Super (60 kg P_2O_5/ha) + F.Y.M.	0.57	0.082	0.71	0.083
T_3	Super (30 kg P_2O_5/ha) + no F.Y.M.	0.40	0.056	0.58	0.058
T_4	Super (60 kg P_2O_5/ha) + no F.Y.M.	0.49	0.080	0.70	0.088
T_5	Ultraphos (30 kg P_2O_5/ha) + F.Y.M.	0.43	0.058	0.62	0.063
T_6	Ultraphos (60 kg P_2O_5/ha) + F.Y.M.	0.56	0.083	0.72	0.084
T_7	Ultraphos (30 kg P_2O_5/ha) + no F.Y.M.	0.41	0.058	0.60	0.060
T_8	Ultraphos (60 kg P_2O_5/ha) + no F.Y.M.	0.52	0.031	0.70	0.090
T_9	F.Y.M. alone	0.29	0.031	0.27	0.030
T_{10}	Control	0.28	0.030	0.27	0.029
C.D. at 0.05 level		0.0224	0.00001	0.047	0.0022

Table VIII

Effect of form of P on phosphorus absorption

Treatments	Laterite soil		Sand	
	Per cent P_2O_5 content in			
	Grain	Straw	Grain	Straw
Control	0.280	0.030	0.27	0.029
Superphosphate	0.445	0.068	0.64	0.073
Ultraphos	0.465	0.069	0.65	0.075
C.D. at 0.05 level	N.S.	0.00002	N.S.	0.00021

However significant difference in effect between superphosphate and ultraphos was recorded as regards the phosphorus content of straw. Application of ultraphos was found to be significantly superior to superphosphate in increasing the phosphorus content of straw. The same trend was noticed in sand culture studies as well. In sand culture ultraphos was found to be significantly superior to superphosphate in increasing the phosphorus content of straw.

Effect of levels of P on phosphorus absorption

It can be seen from the Table IX that the graded doses of phosphorus application had increased significantly the phosphorus content of grain in both laterite soil and in sand culture.

The maximum content of phosphorus in grain and straw was recorded at the highest level of phosphorus namely 60 kg P_2O_5/ha. However plants grown in the sand culture recorded a higher percentage of phosphorus both in grain and straw.

Table IX

Effect of levels of P on phosphorus absorption

Treatments	Laterite soil		Sand	
	Per cent P_2O_5 content in			
	Grain	Straw	Grain	Straw
Control	0.280	0.030	0.270	0.029
30 kg P_2O_5/ha	0.405	0.057	0.590	0.059
60 kg P_2O_5/ha	0.505	0.080	0.700	0.089
C.D. at 0.05 level	0.0211	0.00001	0.038	0.0020

At 60 kg P_2O_5/ha. plants in sand culture recorded 0.70 per cent P_2O_5 in grain and 0.089 per cent in straw whereas the corresponding figures in the laterite soil were 0.505 per cent and 0.08 per cent respectively.

Significant interrelationship between application and absorption of phosphorus had also been found to exist with both the forms of phosphorus in the soil types studied. In the case of superphosphate the correlation coefficient was ($r = 0.963^+$) and in the case of ultraphos it was $r = 0.954^+$ in the laterite soil. The interrelationship was highly significant in sand culture. The corresponding figures being $r = 0.991^{++}$ and $r = 0.962^+$ respectively.

<u>Effect of farm yard manure on P uptake</u>

The data relating to the effect of farm yard manure on phosphorus absorption by grain and straw are furnished in Table X.

It can be seen from the Table X that farm yard manure did not produce any effect in increasing the phosphorus content of grain in both laterite soil and in sand culture.

Table X

Effect of farm yard manure on phosphorus absorption

Treatment	Laterite soil		Sand	
	Per cent P_2O_5 content in			
	Grain	Straw	Grain	Straw
Control	0.28	0.030	0.27	0.029
Farm yard manure	0.29	0.031	0.27	0.030

However in the case of straw the phosphorus content showed an increase due to the application of farm yard manure in both sand culture and in laterite soil. The results also indicate that farm yard manure was less effective in sand than in laterite soil.

Interaction effects

The data showing the interaction effect of farm yard manure and form of phosphorus is presented in Tables XI and XII.

Table XI

Interaction between form of P and FYM

Treatments	Laterite soil		Sand	
	Per cent P_2O_5 content in			
	Grain	Straw	Grain	Straw
Farm yard manure	0.290	0.031	0.27	0.031
Ultraphos	0.465	0.069	0.65	0.075
Ultraphos + FYM	0.495	0.075	0.67	0.073
Superphosphate	0.495	0.068	0.64	0.073
Superphosphate + FYM	0.445	0.068	0.65	0.072

It can be seen from the Table XI that the interaction effect between forms of phosphorus and farm yard manure was not significant.

Table XII

Interaction between levels of P and farm yard manure on phosphorus absorption

Treatments	Laterite soil		Sand	
	Per cent P_2O_5 content in			
	Grain	Straw	Grain	Straw
Control	0.280	0.030	0.27	0.029
Farm yard manure	0.290	0.031	0.27	0.030
30 kg P_2O_5/ha	0.405	0.057	0.69	0.057
60 kg P_2O_5/ha	0.501	0.080	0.50	0.089
30 kg P_2O_5/ha + FYM	0.425	0.056	0.61	0.062
60 kg P_2O_5/ha + FYM	0.535	0.082	0.71	0.080

As seen from the Table XII there was no interaction between the levels of phosphorus and the farm yard manure in both laterite soil and in sand.

C. Uptake of other major nutrients

(1) Nitrogen

The nitrogen content of grain and straw as influenced by phosphatic manuring are recorded in the Table XIII.

Application of phosphorus had significantly increased the nitrogen content of grain and straw both in the laterite soil and in sand.

Application of farm yard manure increased the nitrogen content. 60 kg P_2O_5/ha recorded the highest percentage of nitrogen in grain (1.39 per cent), and in straw (0.62 per cent).

Nitrogen increments in rice plants in the sand were also in similar lines with that of the laterite soil. The maximum percentage of nitrogen viz., 1.29 per cent in grain and 0.59 per cent in straw were observed for the application of 60 kg P_2O_5/ha.

(2) Potassium

The effect of phosphatic manuring on the uptake of potassium is represented in the Table XIV.

Table XIII

Effect of phosphatic manuring on the uptake of nitrogen by grain and straw

	Treatments	Laterite soil		Sand	
		Per cent nitrogen content in			
		Grain	Straw	Grain	Straw
T_1	Super (30 kg P_2O_5/ha) + F.Y.M.	1.23	0.58	1.20	0.54
T_2	Super (60 kg P_2O_5/ha) + F.Y.M.	1.38	0.62	1.28	0.58
T_3	Super (30 kg P_2O_5/ha) + no F.Y.M.	1.20	0.56	1.10	0.56
T_4	Super (60 kg P_2O_5/ha) + no F.Y.M.	1.38	0.60	1.12	0.57
T_5	Ultraphos (30 kg P_2O_5/ha) + F.Y.M.	1.24	0.49	1.22	0.52
T_6	Ultraphos (60 kg P_2O_5/ha) + F.Y.M.	1.39	0.61	1.25	0.59
T_7	Ultraphos (30 kg P_2O_5/ha) + no F.Y.M.	1.22	0.48	1.10	0.46
T_8	Ultraphos (60 kg P_2O_5/ha) + no F.Y.M.	1.39	0.58	1.29	0.56
T_9	F.Y.M. alone	1.16	0.39	1.08	0.35
T_{10}	Control	1.14	0.36	1.08	0.34
	C.D. at 0.05 level	0.086	0.014	0.045	0.013

Table XIV

Effect of phosphatic manuring on the K_2O content of grain and straw

Treatments		Laterite soil		Sand	
		Per cent K_2O content in			
		Grain	Straw	Grain	Straw
T_1	Super (30 kg P_2O_5/ha) + F.Y.M.	0.40	2.02	0.50	2.10
T_2	Super (60 kg P_2O_5/ha) + F.Y.M.	0.52	2.10	0.59	2.10
T_3	Super (30 kg P_2O_5/ha) + no F.Y.M.	0.40	2.00	0.49	2.00
T_4	Super (60 kg P_2O_5/ha) + no F.Y.M.	0.40	2.00	0.56	2.10
T_5	Ultraphos (30 kg P_2O_5/ha) + F.Y.M.	0.45	1.62	0.48	2.00
T_6	Ultraphos (60 kg P_2O_5/ha) + F.Y.M.	0.50	1.90	0.58	2.08
T_7	Ultraphos (30 kg P_2O_5/ha) + no F.Y.M.	0.40	1.69	0.57	1.90
T_8	Ultraphos (60 kg P_2O_5/ha) + no F.Y.M.	0.49	1.80	0.52	2.90
T_9	F.Y.M. alone	0.34	1.76	0.30	1.74
T_{10}	Control	0.32	1.74	0.30	1.72
	C.D. at 0.05 level	0.035	0.027	0.023	0.058

The experiment had brought out that the application of phosphorus had significantly increased the potash content of grain and straw in rice plants of laterite soil and in sand.

The data has also indicated that graded doses of phosphorus had brought about corresponding increments in the K_2O content of grain and straw in the laterite soil while in sand culture the efficiency of phosphorus showed a tendency of decline with increasing levels of its efficiency. In the case of K_2O content of straw increments in phosphorus levels beyond 30 kg P_2O_5/ha did not have any effect at all.

D. Yield of grain

The mean table indicating the yield of grain in laterite soil and sand is furnished in Table XV. It can be seen from the data that application of phosphorus did not have any significant effect in increasing the yield of grain in the laterite soil. In fact application of higher doses of phosphorus had shown a tendency to reduce the yield. Though farm yard manure had increased the yield slightly it was not significant.

Table XV

Yield of grain in g/pot

	Treatments	Yield of grain in g/pot: Laterite soil	Yield of grain in g/pot: Sand
T_1	Super (30 kg P_2O_5/ha) + F.Y.M.	26.33	18.33
T_2	Super (60 kg P_2O_5/ha) + F.Y.M.	25.33	15.66
T_3	Super (30 kg P_2O_5/ha) + no F.Y.M.	25.66	17.66
T_4	Super (60 kg P_2O_5/ha) + no F.Y.M.	25.66	15.66
T_5	Ultraphos (30 kg P_2O_5/ha) + F.Y.M.	26.33	18.00
T_6	Ultraphos (60 kg P_2O_5/ha) + F.Y.M.	25.33	16.00
T_7	Ultraphos (30 kg P_2O_5/ha) + no F.Y.M.	25.33	17.00
T_8	Ultraphos (60 kg P_2O_5/ha) + no F.Y.M.	25.33	15.00
T_9	F.Y.M. alone	25.66	14.00
T_{10}	Control	25.66	12.30
	C.D. at 0.05 level	N.S.	2.71

However significant increase in the yield of grain due to the application of phosphorus had been recorded in sand culture studies. The maximum yield of 18.33 g/pot was recorded by the treatment of 30 kg P_2O_5/ha in conjunction with farm yard manure followed by the same treatment with ultraphos. But increasing levels of phosphorus had tended to decrease the yield in sand culture also. The effect of form of fertilizer and the effect of farm yard manure and the interaction effect between farm yard manure and levels and forms of phosphorus were not significant.

(ii) Yield of straw

The data relating to the yield of straw is represented in the Table XVI. It was found that the phosphatic manuring did not influence the yield of straw in both sand and laterite soil. None of the treatments nor their interactions had any significant effect in increasing the yield of straw in sand culture as well as in the laterite soil.

Table XVI

Yield of straw in g/pot

	Treatments	Yield of straw in g/pot	
		Laterite soil	Sand
T_1	Super (30 kg P_2O_5/ha) + F.Y.M.	28.00	20.00
T_2	Super (60 kg P_2O_5/ha) + F.Y.M.	24.00	17.66
T_3	Super (30 kg P_2O_5/ha) + no F.Y.M.	27.00	19.66
T_4	Super (60 kg P_2O_5/ha) + no F.Y.M.	23.66	17.00
T_5	Ultraphos (30 kg P_2O_5/ha) + F.Y.M.	28.00	20.00
T_6	Ultraphos (60 kg P_2O_5/ha) + F.Y.M.	27.00	17.66
T_7	Ultraphos (30 kg P_2O_5/ha) + no F.Y.M.	23.66	19.66
T_8	Ultraphos (60 kg P_2O_5/ha) + no F.Y.M.	23.66	17.00
T_9	F.Y.M. alone	23.66	15.66
T_{10}	Control	23.66	14.00

Interrelationships between phosphorus absorption and yield

Analysis of the data for correlation on the yield of grain and straw and phosphorus absorption had revealed that the phosphorus absorption did not have any bearing on the yield of grain and straw in the laterite soil.

Though not significant positive correlation ($r = 0.54$) between the yield of grain and straw and phosphorus absorption was found to exist in sand culture.

In laterite soil increase in the absorption of phosphorus was found to had a depressing effect on the yield.

Correlation studies have also brought out that the available phosphorus at the time of harvest had significant correlation with the phosphorus content of grain and straw in both sand and in laterite soil.

E. Organic carbon

The percentage of organic carbon estimated at three stages after the application of phosphatic

Table XVII

Effect of phosphatic manuring on the organic carbon content

	Treatments	Per cent organic carbon					
		Laterite soil			Sand		
		45th day	90th day	At harvest	45th day	90th day	At harvest
T_1	Super (30 kg P_2O_5/ha) + F.Y.M.	1.48	1.50	1.55	0.22	0.25	0.25
T_2	Super (60 kg P_2O_5/ha) + F.Y.M.	1.60	1.60	1.69	0.22	0.22	0.21
T_3	Super (30 kg P_2O_5/ha) + no F.Y.M.	0.96	0.93	0.95	0.21	0.20	0.20
T_4	Super (60 kg P_2O_5/ha) + no F.Y.M.	0.96	0.94	0.95	0.20	0.20	0.22
T_5	Ultraphos (30 kg P_2O_5/ha) + F.Y.M.	1.40	1.45	1.45	0.21	0.23	0.25
T_6	Ultraphos (60 kg P_2O_5/ha) + F.Y.M.	1.60	1.64	1.65	0.22	0.22	0.22
T_7	Ultraphos (30 kg P_2O_5/ha) + no F.Y.M.	0.95	0.93	0.93	0.21	0.19	0.21
T_8	Ultraphos (60 kg P_2O_5/ha) + no F.Y.M.	0.95	0.92	0.94	0.20	0.21	0.22
T_9	F.Y.M. alone	1.40	1.45	1.50	0.22	0.23	0.24
T_{10}	Control	0.93	0.94	0.94	0.21	0.22	0.22
	C.D. at 0.05 level	0.028	0.012	0.013	N.S.	0.014	0.012

manures are given in the Table XVII.

The data reveal that the organic carbon content fluctuated during crop growth. Addition of farm yard manure helped to increase the percentage of organic carbon in the soil significantly. Neither the form nor the levels of phosphorus had any significant effect in increasing the organic carbon percentage of the soil. Appreciable increase in the percentage of organic carbon was observed in the treated plots both in the laterite soil and in sand.

The data also shows that the organic carbon per cent reached its maximum at the stage of the harvest of the crop.

F. pH

The pH of the soils was not influenced very much by phosphatic manuring. But a gradual increase in pH was noted with the lapse of crop growth and it was found to be maximum immediately after the crop was harvested. The data on pH observation is presented in Table XVIII.

Table XVIII

pH at different stages of growth

	Treatments	pH observation					
		Laterite soil			Sand		
		45th day	90th day	At harvest	45th day	90th day	At harvest
T_1	Super (30 kg P_2O_5/ha) + F.Y.M.	5.0	5.1	5.2	5.9	6.0	6.2
T_2	Super (60 kg P_2O_5/ha) + F.Y.M.	5.1	5.1	5.2	5.9	6.1	6.3
T_3	Super (30 kg P_2O_5/ha) + no F.Y.M.	5.1	5.3	5.4	5.8	5.9	6.1
T_4	Super (60 kg P_2O_5/ha) + no F.Y.M.	5.0	5.2	5.4	5.8	5.9	6.2
T_5	Ultraphos (30 kg P_2O_5/ha) + F.Y.M.	5.0	5.2	5.3	5.9	6.1	6.4
T_6	Ultraphos (60 kg P_2O_5/ha) + F.Y.M.	5.1	5.4	5.5	6.0	6.1	6.3
T_7	Ultraphos (30 kg P_2O_5/ha) + no F.Y.M.	5.1	5.3	5.4	5.8	5.9	6.2
T_8	Ultraphos (60 kg P_2O_5/ha) + no F.Y.M.	5.1	5.3	5.5	5.8	5.9	6.1
T_9	F.Y.M. alone	5.1	5.2	5.4	6.0	6.1	6.3
T_{10}	Control	4.9	5.0	5.1	5.7	5.8	5.8

DISCUSSION

DISCUSSION

Phosphatic fertilizers applied to rice grown in laterite soils of Kerala, have invariably manifested inadequate response. In the following pages the results of the study conducted with varying doses of different phosphatic fertilizers applied to a typical laterite soil from Pattambi are discussed.

In order to have a better assessment of the complex soil factors governing the availability of phosphorus in soils, the treatments were simultaneously repeated in sand culture also. Since the variations in the available phosphorus is a reliable indication of the potential capacity of the soil for phosphorus fixation and phosphorus absorption being the indication of its efficient utilisation by plants, attempt has been made in this investigation to assess the effect of applied phosphorus on the availability and absorption of phosphorus by rice plants. Attempt has also been made to study the role of farm yard manure in modifying the adverse soil factors affecting the availability of applied phosphorus and its consequent effects on phosphorus nutrition of rice.

<u>Available phosphorus in soil</u>

Identical with the observations by Patel (1963) and Motiramani <u>et al</u> (1964), in the present study it has also been observed that the availability of phosphorus increased with increasing amounts of added phosphatic fertilizers as is evidenced by the results in Table I. However further additions of phosphorus could never increase the status of the available phosphorus in the soil as the lower levels could, indicating that the applied phosphorus gets fixed with increasing levels of phosphorus application. Even the higher status of available phosphorus through fertilizers is only temporary as evidenced by the fact that this increased available phosphorus gets fixed immediately. Similar reports where the status of available phosphorus decreases in course of time in fertilizer treated plots has been reported by Bred field (1952), Sreeramulu and Mariakulandai (1963).

Application of farm yard manure at the rate of 5000 kg/ha containing 12.5 kg P_2O_5 has recorded a higher status of available phosphorus in the soil than for the treatments of 30 kg P_2O_5/ha applied through fertilizers. The capacity of farm yard manure in making available the dormant reserves of soil phosphorus has been reported by a number of workers among which may be cited Midgley and Dunklee (1955), Frustorfer (1955). The possible mechanism by which the farm yard manure increases the availability of soil phosphorus may be either by the action of CO_2 in solubilising phosphorus compounds (Gerretson, 1948) or by the formation of humus colloids which form a protective coating over the colloidol sesquioxides thus reducing the phosphorus fixing capacity of the soil (Gaarder and Nelson, 1935). The soil used for the present study contained a high sesquioxide content.

The interaction between farm yard manure and phosphatic fertilizers at its lower levels in increasing the available phosphorus of the soil in the present study also indicates that the efficiency of lower levels of fertilizer phosphorus could be increased considerably by the addition of farm yard manure which will be superior to application of higher levels of fertilizers. The above observations thus tend to point out that the lack of response to applied phosphatic fertilizers may be due to the fact that the farm yard manure is usually applied along with the fertilizer which will invariably increases the availability of native phosphorus.

Phosphorus absorption

Data pertaining to the uptake of phosphorus by the rice plants grown in laterite soil as well as in sand (Table VII) shows that with increase in the content of available phosphorus in the soil there was a corresponding increase in the absorption of phosphorus. The uptake of phosphorus being favourably influenced by the availability of this nutrient, evidently the factors responsible for the lack of response for applied phosphorus might be mainly those that impede the availability of this nutrient. The beneficial effect of available phosphorus on the uptake of this nutrient is not however adequately manifested in the yield. It is seen that rice plants grown on sand have given increasing yields with the application of phosphatic fertilizers. This is not the case with laterite soil in which, there is rather a decrease in the yield of rice with increase in the absorption of phosphorus. Persumably the plants grown in laterite soil have absorbed phosphorus in excess of its normal requirement from the reserves of phosphorus dormant in the soil. It needs mention in this connection, that such dormant reserves of phosphorus are negligible in sand. This therefore explains the divergence as regards effect of absorption of phosphorus on the yield in the two soil types. That plants absorb an unusually high proportion of phosphorus from those already present in the soil has been shown by Bear (1949). Similar findings have also been reported by Fried and Dean (1952), Nishagaki et al (1958) and Goswami et al (1969).

The above observations indicate that more than the availability of phosphorus in the soil and the total quantity of phosphorus absorbed by plants the factor that governs the response of rice to applied phosphorus may be the optimum levels of the nutrient content in plants below and beyond which lack of response may be exhibited. According to Velley (1959) response to added phosphorus will be obtained only when the percentage of phosphorus as shown by the leaf analysis is 0.28 per cent or less.

Krishnamoorthy *et al* (1963) put this limit between 0.17 and 0.30 per cent. These authors have further suggested that response will be uneconomic if the phosphorus content is beyond 0.30 per cent. In the present study the phosphorus levels in plants grown in the laterite soil is beyond 0.28 per cent irrespective of the treatments. The lack of response may therefore be attributed to this high status of phosphorus in the plant tissues.

Yield of grain and straw

The experiment has brought out that the application of graded doses of phosphorus did not produce any significant effect in increasing the yield of grain and straw in the laterite soil. As explained earlier the lack of response in yield may be due to the fact that the critical levels of the nutrient required in the plant tissue had been met from the soil reserves of phosphorus. Application of phosphorus had only helped to increase the phosphorus content of plant tissues beyond this level which was not at all essential for contributing towards the yield of grain and straw.

The results of the experiment have indicated that though the availability and absorption of phosphorus in the control plots were the lowest the status of available phosphorus in the control plots was sufficiently high to provide the minimum requirement of this nutrient for maximum crop production. The amount of available phosphorus in the soil was 52 kg/ha which was fairly sufficient to support normal crop growth. It may be mentioned in this connection that according to Ghose et al (1956) and Dutta (1967) the phosphorus requirement of rice plant is comparatively low. Further more the content of total phosphorus in the soil is about 0.09 per cent amounting to 1800 kg/ha out of which 2.9 per cent ie., 52 kg/ha was in the available form. The fact that this was adequate to meet the requirement of the crop is sufficient to show that the lack of response to applied phosphorus was only due to its being present in excess of normal requirements. The data also shows that the available phosphorus which was originally 52 kg/ha rose to 56 kg/ha during crop growth phase which again came to the level of 52 kg/ha in the control plot at the time of harvest, the reduction being only 4 kg.

But the data on the absorption shows that the crop had removed about 40 kg P_2O_5/ha which reveals that more of the native phosphorus had become available during the growth period of the crop. This shows that the crop had met its requirement of the nutrient from the soil, the applied phosphorus, being superfluous. It would thus appear that the lack of response to applied phosphorus is due to its being already present in adequate amounts in the soil.

Water logging in the rice fields creates a series of physical, microbiological and chemical processes which favour the reduction of iron and aluminium phosphate compounds. The solubilisation of phosphates through reduction of iron and aluminium compounds under an anaerobic condition render a heavy quantum of the native phosphorus becoming available to the crop as evidenced by the investigations of Islam and Elahi (1954), Ponnamperuma (1955) and Mitsui (1960). Fujiwara (1958), Shapiro (1958) and Mitsui (1960) attributed the increase in availability of phosphorus under submerged conditions as due to the hydrolysis of soil phosphates and increased solubility of iron phosphate and aluminium phosphates. The observations on the available phosphorus in the present study also confirm the fact that availability of phosphorus is increased by keeping the soil under submerged conditions.

Similar results have been reported by Sasidhar (1969) and Suseelan (1969) in the case of the red loam soil of Vellayani. These authors have further shown that native phosphorus gets released as the growth phase of the crop advances. The present study thus confirms these findings. The fact that the available phosphorus increases with advances in the growth phase of the crop appears to suggest that "phosphorus fixation" is not altogether irreversible as has been stated by Tisdale and Nelson (1965). This would mean that the phenomenon of phosphorus fixation need not be a serious problem affecting successful crop production.

The data in the present study also indicates that the status of available phosphorus in the soil remained almost unchanged inspite of its removal by the crop. This observation may suggest that as the available forms of phosphorus is utilised by plants more and more of the unavailable forms may be rendered available for crop growth. It would thus appear that more than the status of the available phosphorus, the content of total phosphorus may be the factor that invariably affects the response of crop to added fertilizers. These observations also tend to suggest the existence of an equilibrium between the unavailable native phosphorus and the available forms of phosphorus present in the soil. Possibly the presence of this equilibrium might help to maintain the status of the available phosphorus in the soil inspite of the crop removal.

Long term experiments conducted by Digar and Mandal (1957), Kampath (1967) to study the effect of application of phosphorus have shown that the response for phosphorus application will be obtained only in those plots where phosphorus had not been applied for 2 or 3 years. This response for phosphorus application after 2 or 3 years cropping may be due to the fact that either the equilibrium between available and unavailable form is not maintained by natural means or the native phosphorus has been depleted to the extent that it is not adequate to meet the requirements of the crop.

These observations bring out clearly that the object achieved by the application of phosphatic fertilizer is to maintain the status of the nutrient in the soil as well as to tilt the equilibrium between available and unavailable forms of phosphorus to the advantage of the growing plants. This rather changes the concept of fertilizer application from "fertilizer for crop" to "fertilizer for soil".

However in the sand culture studies significant increase in the yield of grain was obtained by the application of phosphatic fertilizers. Evidently the sand contains only very little native phosphorus and hence the phosphorus requirements of the plants had to be met primarily from the applied sources resulting in significant response for phosphorus application. The maximum grain yield was recorded by 30 kg P_2O_5/ha in conjunction with farm yard manure (Table XV) which indicates that the further application of phosphorus beyond this level had helped only to increase the quality of the grain and not the quantity of the grain. The lack of response for higher levels of phosphorus may also be due to the fact that the enhanced requirements of other nutrients consequent on higher doses of phosphorus application are not being met with due to the paucity of supply.

The data have also shown that though phosphorus application has not been of much benefit in increasing the yields quantitatively, the quality of the grain had increased significantly over the control. Similar results have also been reported by Sanyasiraju <u>et al</u> (1954), Sreeramulu <u>et al</u> (1969), Mohankumar (1967), Nair (1968), Suseelan (1969).

<u>Nitrogen absorption</u>

Data presented in Table XIII reveal that absorption of nitrogen has been significantly increased by the application of phosphatic fertilizers, the results being in agreement with the observations made by Williams (1948), Sreeramulu and Mariakulandai (1962).

<u>Potassium absorption</u>

Chavos Sanchez and Gozalez Gracia (1956), Sreeramulu and Mariakulandai (1962) have shown that higher levels of phosphorus enhances the uptake of potassium. In the present study also significant increase in the absorption of potassium with increased levels of phosphorus has been observed in the treated plots.

<u>Organic carbon</u>

As seen from the results (Table XVII) the organic carbon fluctuates during the period of crop growth. Saunderlet and Graetgner (1953) have shown that such fluctuations are possible during the growth of the crop. In this study it is observed that the percentage of organic carbon was much higher in plots treated with the farm yard manure then in the plots receiving no farm yard manure. It was also noted that organic carbon content was very high at all stages in plots receiving farm yard manure than the plots receiving phosphatic fertilizers alone. However, a slight increase in the content of organic carbon in the soils receiving combination of farm yard manure and fertilizer phosphorus over that in soils receiving only farm yard manure was noted. A rise in organic carbon content consequent on an application of farm yard manure along with fertilizer phosphorus was reported also by Sreeramulu and Mariakulandai (1963), Chandrasekharan <u>et al</u> (1963) and Ghosh and Sen (1963).

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A study has been made to investigate the reasons for the lack of response to applied phosphorus for rice in the laterite soils of Kerala by a pot culture experiment using laterite soil collected from the Central Rice Research Station, Pattambi. In order to have a better assessment of the factors responsible for the lack of response, the experiment was simultaneously conducted in sand culture also. The main findings from the study may be summarised as below:

1. A number of factors contribute to lack of response of applied phosphorus.

   (a) Farm yard manure applied along with the fertilizer phosphorus invariably increases the availability of native phosphorus.

   (b) The status of available phosphorus in the soil will be adequate enough to meet the requirement of the crop.

(c) The native phosphorus becomes available during the growth phase of the crop, thereby supplying the requirement of phosphorus resulting in inadequate response to applied phosphorus.

(d) The crop removes phosphorus in excess of its requirements for optimum production.

(e) Applied phosphorus has been utilised to improve the quality of the produce as well as to maintain the status of this nutrient in the soil.

(f) Fixation of phosphorus being not a completely irreversible process, normal crop production is not seriously affected.

2. Application of farm yard manure tends to release the unavailable form of native phosphorus present in the soil as well as to increase the availability of applied phosphorus. It is found that the application of farm yard manure alone enable the plant to meet its requirement. Thus the application of

fertilizer has not given any benefit over the application of farm yard manure.

3. Application of phosphatic fertilizers has helped to increase the absorption of other major nutrients namely nitrogen and potassium.

4. Eventhough applied phosphorus has no effect on the yield, the availability and absorption of phosphorus is better in ultraphos than in superphosphate.

5. When farm yard manure is applied along with fertilizers there is an increase in the organic carbon content of the soil.

6. Phosphorus application does not appear to have any appreciable effect on soil reaction.

The results of the present study has thus shown that what is achieved by the application of phosphatic fertilizers is maintenance of the level of this nutrient in the soil as well as tilting the equilibrium between available and unavailable forms of phosphorus to the advantage of the growing plants.

Thus it would appear to be more appropriate to modify the concept "fertilizer for crop" to "fertilizer for soil".

REFERENCES

REFERENCES

Agerberg, L.S. 1957 Comparative efficiency of superphosphate and basic slag. St. Jordbr. Fors. Medd. 85: 15. Soils and Fert. 21 (1): 52, 1958.

Allen, E.F. and Coulter, J.K. 1956 Wet paddy manurial experiments on peat soils in Malaya. IRC News letter 18: 16-23.

Anonymous 1961 Hand book of Agriculture I.C.A.R., New Delhi. Revised edition 1966. p. 99.

*Aoki, Moichi 1941 Studies on the behaviour of soil phosphoric acid under paddy field conditions. J.Sci.Soil Man. Japan 15: 182-202.

Aslander, A. 1950 The availability of phosphates after standard fertilization. Trans. 4th Intern Congr. Soil Sci. 2: 158-163.

Association of Official Agricultural Chemists 1960 Methods of Analysis, U.S.A.

Bapat, M.V. and Badekar, V.G. 1965 Fertilizer phosphorus in Fractions of soil phosphorus. J. Indian Soc. Soil Sci. 13: 237-240.

Bartz, J.F.	1959	Diss. Abstr. 20: 835-875. Soils and Fert. 23 (2): 982, 1960.
Basak, M.N.	1956	Effect of Bulky Organic Manures on the Nutrition of Rice. J. Ind. Soc. Soil Sci. 4: 95-103.
Basak, M.N., Bhattacharya, P.K. and Sen, S.K.	1960	Effect of Supplementary phosphate and potash with nitrogen on the yield of water logged rice. Ind. J. Agric. Sci. 30 (4): 272-280.
Basak, M.N., Chaudhari, S.B. and Romabhattacharya	1961	Effect of fertilizers on the nutritive value of rice grain. Indian J. Agric. Sci. 31 (2): 113.
Basak, M.N. and Bhattacharya, R.	1962	Phosphate transformations in rice plants. Soil Sci. 94 (4): 258-262.
Firman, E. Bear	1949	Utilisation of phosphorus from various fertilizer materials. Soil Sci. 68: 113.
Bhattacharya, P.B. Sinha, M.P. and Dasgupta, K.P.	1965	Response of paddy to different forms of nitrogenous and phosphatic fertilizers in Bihar. Rice news Teller. 13 (2).
Black, C.A.	1957	Soil Plant relationship Joh Wiley and Sons, New York.

*Boishet, P. and Sylvester, P.	1949	Solubilisation de laoide phosphorique dans les soils calcaries. <u>Compt</u>. <u>rend</u>. <u>229</u>: 596-598.
Buckman, H.O. and Brady, N.C.	1957	<u>The nature and properties of soils</u>. Eurasia Publishing House, New Delhi 2nd Indian reprint p. 464-465.
Chai-moo-cho and Cladwell, A.C.	1959	Forms of phosphorus and fixation in soils. <u>Soil Sci</u>. <u>Soc</u>. <u>Amer</u>. <u>Proc</u>. <u>23</u>: 459.
*Chaminde , R. and Blanchet, R.	1952	Influence de l'humus ur la nutrition minerale de la plante dans de sol. <u>Cromp</u>. <u>rende</u>. <u>234</u>: 878-879.
Chandani, J.J. and Obhria, S.R.	1955	Studies on the relative values of different phosphatic manures. <u>Indian J</u>. <u>Agrl</u>. <u>Sci</u>. <u>25</u>: 175-192. <u>Soils</u> and <u>Ferti</u>. <u>19</u> (1): 86, 1956.
Chandraratna, M.F.	1951	Rice in Java. <u>Trop</u>. <u>Agr</u>. <u>107</u> (2): 103-109.
Chandraratna, M.F. and Fernando, L.H.	1954	Studies on the fertilizer response of rice. Direct, residual and cumulative effect of various phosphatic fertilizers. <u>Trop</u>. <u>Agricl</u>. <u>110</u>: 178-179 <u>Soils</u> and <u>Fert</u>. <u>18</u> (3): 268, 1955.

Chandraratna, M.F.	1957	Report of the Co-ordination for investigation of interaction between varieties and fertilizers. IRC/FP/BP/57.
Chandrasekharan, M.P., Mathur, M.L. and Das, N.B.	1953	Rotation and fertilization as effecting the quality of wheat. Sci. and Cult. 19: 119-120.
Chang, S.C. and Chiang, C.T.	1953	The availability of various phosphatic fertilizers for rice on main soil groups of Taiwan. Soils and Fert. Taiwan, 90-91. Soils and Fert. 18 (1): 74, 1955.
Chang, S.C. and Jackson, M.L.	1958	Soil phosphorus fractions in some representative soils. J. Soil Sci. 9: 109-119.
Chavan, V.M., Gopalakrishna, N. and Sangave, R.A.	1957	Nitrogen and phosphorus requirements of paddy crop. Ind. J. Agron. 11(2): 95.
Chin, T.F. and Li, V.T.	1965	Varietal difference in fertilizer response and absorption of rice in Taiwan Potash Rev 6/28, 10. Soils and Fert. 29 (3): 306.
Choudhary, S.K.	1967	Comparative efficiency of superphosphate and bonemeal. Fert. News 12 (6): 32.

Chu, W.L. and Chang, S.C.	1951	The fate of soluble phosphate applied to soils. J. Soil Sci. 12 (2): 286-293.
*Chvessanchez, M. and Gozatez Gracia	1956	Influence of fertilizers on yield and composition. VI Cong. Inst. Sci. Soil Renn. D. 231-381.
Coleman, R.	1942	Utilisation of adsorbed phosphate by cotton and oats. Soil Sci. 54: 237-246.
Coleman, R.	1944	Phosphorus fixation by the coarse and fine clay fractions of kaolinitic and montmorillonitic clays. Soil Sci. 58: 71-77.
Gilbert H. Collings	1956	Commercial Fertilizers Mc Graw Hill Co. New York - pp. 387-388.
Coulter, J.K. and Locakrd, R.G.	1955	Risiculture 36: 264-265. Soils and Fert. 1919-1921.
*Dalton, J.D., Russel, C.C. and Sieling, D.H.	1952	Utilisation of phosphorus in farm manure. Unpublished manuscript. Department of Agronomy Cornell University, Ithaca, New York.
*Davide, J.G.	1960	Phosphate studies in flooded soils. Unpublished Ph.D. thesis. North Carolina State College, Raleigh. N.C.

Davide, J.G. 1964 of izer e Mineral Plant. Symposium 94.

Dean, L.A. and Maurice Fried 1953 Soil Plant relationships in the phosphorus nutrition of Plants. Soil and Fertilizer phosphorus in Crop Nutrition IV: 43

Dedatta, S.K., Moomaw, J.C. and Racho, V.V. 1966 Phosphate supplying capacity of low land rice soils. Proc. Soil Sci. Soc. Amer. 30: 613-17.

Desai, A.D., Krishnamoorthy, C. and Reddy, M.K. 1954 Response of rice to phosphate in black soils. Rice news letter 2: 7.

Digar, S. and Mandal, A.K. 1957 Effect of continuous application of bone meal in a gangetic alluvium soil on the yield and composition of paddy. Ind. J. Agron. 2: 81-87.

Digar, S. 1960 Manurial requirement of paddy in lateritic soils. J. Indian Soc. Soil Sci. 8 (1): 23-33.

Dutta, N.P. 1967 Recent trends in Fertilizer use. J. Indian Soc. Soil Sci. 15 (3) 193-200.

Edward, G.E.A. 1956 Observation on the response of crops to rockphosphate. VI Congr. Int. Sci. Sol. Rapp. D: 13.
Soils and Fert. 19 (6): 515.

Fried, M. and Dean, L.A. 1952 A concept concurring the measurement of available soil nutrients. Soil Sci. 73: 263-71.

*Frustorfer, A. 1958 Evaluation of phosphatic Fertilizers. Land. W. Forschi Sandesh pp. 124-128

Fugiwara, A. 1950 Chemical constitution and availability of iron and aluminium phosphates. Part I. Tohoku. J. Agr. Res. (1): 129-41.

Fujiwara, A. and Mizuouchi, T. 1961 Characteristics of the developmental process in the leaf blade of rice plants. J. Sci. Soil and Manure Japan. Japan 32 (8): 351-55.

Fuller, W.H. and Dean, L.A. 1949 Utilisation of phosphorus. Soil Sci. 73: 263-271.

*Fuller, W.H. and Rogers, R.N. 1951 Utilisation of phosphorus from barley residues in calcareous soils. Arizona Agr. Expt. Sta. Tech. Bull. 123.

*Gaarder, T. 1930 Die Binding der phosphorsaure im Erdboden. Vest landets. Forst. Forsokstation, Meddelese 14. Bergen.

*Gaarder, T. and Grahl-Nielson, O.	1935	Die Bindung der phosphorsaure im Erdboden. II. Vestlandes Forstlige Forsks station Meddel, 18.
Gerretson, F.C.	1948	The influence of micro-organism on the phosphate intake by the plant. Plant and Soil. 1: 51-81.
*Geus, J.G. De	1954	Means of increasing rice production. Centred 'Etude del' Azote Geneva.
Ghani, M.O. and Aleem, S.A.	1943	Fraction of soil phosphorus I. The distribution of some different forms of phosphorus in some Indian Soils. Indian J. Agr. Sci. 13: 283.
Ghose, R.L.M., Ghatge, M.B. and Subrahmanyan, V.	1956	Rice in India. I.C.A.R., New Delhi.
Ghosh, S.K.	1963	Effect of phosphatic fertilizers on the yield of paddy and soil conditions in different regions of West Bengal. Indian J. Soc. Soil Sci. 11 (2) 129-135.
Goswami, N.N., Gopalakrishnan, S.S. and Bagchi, D.	1969	Effect of rate of addition of phosphorus on the uptake of soil and fertilizer phosphorus by Jute. J. Ind. Soc. Soil Sci. 17 (1): 101-107.

Hibbard, P.L.	1935	Factors influencing phosphate fixation in soils. Soil Sci. 39: 337-358.
Hilgard, E.W.	1907	Soils, Their Formations, Properties, Composition and Relations to Climate and Plant growth in the Humid and Arid regions. Macmillan Company, New York.
*Ishizuka, Y. and Tanak, A.	1950	Studies on the Nitrogen Phosphorus and Potassium metabolism of rice plant. J. Sci. Soil Manures, Japan 22: 7-12 and 103-106.
Islam, M.A. and Elahi, M.A.	1954	Reversion of ferric iron to ferrous iron under water logged conditions and its relation to available phosphorus. J. Agric. Sci. 45: 1-2.
Jackson, M.L.	1958	The Soil chemical analysis. Prentice - Hall, Inc., Englewood Cliffs, N.J.
Jagadeeshchandran Nair, N.P.	1968	Effect of different forms and levels of phosphorus on the growth, yield and composition of three high yielding varieties of rice (IR-8, TN-1 and Culture 28) M.Sc.(Ag.) Thesis: University of Kerala (unpublished).

Jensen, C.A. 1917 Effect of decomposing organic matter on the solubility of certain inorganic constituents of the soil. J. Agr. Research 9: 253-268.

Kalam, M.A., Thampi, P.S. and George, C.M. 1966 Direct and cumulative effects of nitrogen, phosphorus and potassium on rice. Agri. Res. J. of Kerala IV (1) 11-16.

Kanapathy, K. 1957 Mineral nutrition of paddy. I N and P uptake of paddy grown on an extremely poor lateritic soil compared with that of dry land crops. Malay. Agric. J. 40: 110-121 Soils and Fert. 21 (2): 133-158.

*Kanapathy, K. and Tampoo, S. 1960 Phosphate studies on some Kelantine paddy soils. Malayan Agr. J. 43 (2): 104-111.

Kanwar, J.S. and Meelu, O.P. 1963 Wheat fares with NPK. Ind. Farming. 13 (8).

Kampath, E.J 1967 Residual effect of large applications of phosphorus on high phosphorus fixing soils. J. Ame. Soc. of Agron. 59: 25-27.

Kar, A.K. and Chakravarthy, S.N. Availability and fixation of applied phosphate in some Indian Acid Soils. J. Ind. Soc. Soil Sci. 17: 47.

Koshy, M.M. and Britomutunayagam, A.P.A.	1961	Fixation and availability of phosphorus in soils of Kerala. Agr. Res. J. Kerala I: 70-78.
----------	1965	The mechanism of phosphorus fixation in soils and the nature of retained phosphates. Agr. Res. J. Kerala 3: 32-39.
Krishnamurthy, C.H., Nair, P.K. and Jayaram, N.S.	1963	Dose required to correct phosphorus deficiency in soil for rice. J. Indian Soc. Soil Sci. 2 (2): 159-164.
Kurtz, T. Deturk, E.E. and Bray, R.H.	1946	Phosphorus adsorption by Illionis Soils. Soil Sci. 61: 111-124.
Larsen, S.	1952	The use of p^{32} in studies on the uptake of phosphorus by plants. Plant and Soil 4: 1-10.
*Lawton, K., Robertson, L.S., Cook, R.L. and Rood, P.J.	1952	Michigan Agric. Exptl. Sta. Quart. Bull. 34 (4) 466-471.
Mariakulandai, A.	1957	Manuring of Crops. Rice in Madras. Madras Agric. J. 44 (7) 271-280.

Mariakulandai, A. and Thyagarajan, S.R. | 1965 | Results of manurial trials in Madras State. Advances in Agricultural Sciences and their application. Edited by S. Krishna Moorthy.

*Mattingly, G.E.G. | 1963 | The agricultural value of some water and citrate soluble phosphate fertilizers. Fertil. Soc. Proc. 75: 57-108.

Maung-Mya-Thaung | 1960 | Relative absorption of phosphorus by rice plants from native and additive sources, using radioactive phosphorus as a tracer. Soil Sci. 90 (5): 284-289.

Mc Aulliffe, C., Stanford, G. and Bradfield, R. | 1949 | Utilisation to plants of organic and inorganic forms of phosphorus in sheep manure. Soil Sci. 68: 185-196.

Mc Aulliffe, C., and Bradfield, R. | 1952 | Utilisation of phosphorus in farm manure III. The uptake of phosphorus by Sudangrass from manure and superphosphate when incorporated into the soil at different depths. Unpublished manuscript. Department of Agronomy, Cornell University, Ithaca, New York.

*Mc George, W.T. and Greene, R.A.	1935	Oxidation of Sulphur in Arizona soils and its effect on soil properties. Arizona Agr. Expt. Sta. Tech. Bull. 59.
*Mc George, W.T.	1939	Factors influencing the availability of native soil phosphate and phosphate fertilizers in Arizona soils. Arizona Agr. Expt. Sta. Tech. Bull. 82.
McLean, E.O. and Hoelscher, J.E.	1954	Factors affecting yield and uptake of phosphorus by different crops. Soil Sci. 78: 453-462.
Mc Lean, E.O.	1956	Factors affecting yield and uptake of phosphorus by different crops. Soil Sci. 80: 181-190.
Metzger, W.H.	1940	Significance of adsorption or surface fixation by some soils of the praire group. J. Am. Soc. Agron. 32: 513-525.
Mhote, B.V. and Patel, J.M.	1963	Some aspects of phosphorus availability in Gujarat Soils. J. Ind. Soc. Soil Sci. 11 (2): 151-158
*Midgley, A.R. and Dunklee, D.E.	1945	The availability of plants of phosphates applied with cattle manure. Vermont Agr. Expt. Sta. Bull. 525.

*Mitsui, S. 1960 Inorganic nutrition, Fertilization and soil amelioration for low land rice. 4th ed. Yokendo Press, Tokyo p.107.

Mohan Kumar, B. 1967 Effect of different levels of phosphorus on the growth, yield and nutrient uptake of two newly introduced varieties of rice. M.Sc.(Ag.) Thesis, University of Kerala (Unpublished).

Motiramani, D.P., Vyas, K.K. and Sharma, N.K. 1964 Availability of phosphate fertilizers in some soils of Madhya Pradesh. J. Indian Soc. Soil Sci. 12: 157-163.

*Murphy, W.F. 1939 The role of kaolinite in phosphate fixation. Hilgardia 12: 343-382.

Nishigaki, S., Shibuya, M. and Koyama 1958 Study on the improvement of fertilizer dressing and soil management in the rice field experiments using P^{32} labelled fertilizer. Soil and Plant Food. 4: 117-126.

Owens, J.S. 1953 Better yields with Fertilizers. IRC News letter 7: 7-19.

Ponnamperuma, F.N. 1955 The chemistry of submerged soils in relation to growth and yield of rice. Ph.D. thesis, Cornell University, Ithaca, New York.

Potty, N.S. 1964 Studies on the response curves of major nutrients on rice in Kerala. M.Sc.(Ag.) Thesis. University of Kerala.

Pierre, W.H. 1948 The phosphorus cycle and soil fertility. J. Am. Soc. Agron. 40: 1-14.

*Peters. 1867 Uber das Verhalten derphosphorsaure in Erdleden. Ann. Landw. p. 31.

Perkins, A.T. and King, H.H. 1944 Phosphorus fixation by soil minerals III particle size. Soil Sci. Soc. Amer. Proc. 9: 61-65.

Patnaik, S., Bandopadya, A.K. and Nanda, B.B. 1968 Liming and phosphorus materials on rice yields and nutrient uptake in acid lateritic soil. Indian J. Agric. Sci. 38(2): 262-268.

Patel, S.P., Ghosh, S.B. and Sen, S. 1963 Effect of phosphatic manuring of Berseem on the fertility status of Delhi Soil. J. Indian Soc. Soil Sci. 11 (2): 225-238.

Parthasarathy, N. 1953 Recent developments in the methods of rice cultivation in India. Curr. Sci. 22: 129-132.

Pauw, F. and Vander 1950 Cause of the different effects of superphosphate and basic slag. Versl. Landbouwk Ondezoek: 56 (6) 94. Soils and Fert. 15 (3): 218, 1957.

Piper, C.S.	1950	Soil and Plant Analysis. Interscience Publisher, New York, 1950.
Relwani, L.L.	1959	Response of rice varieties to different levels of nitrogen and phosphate. Indian J. Agron. 4(1): 8-15.
Russel, E.W.	1961	Soil conditions and Plant growth. The English Language Book Society, Longman Green and Co. London. V.
*Salter, R.M. and Schollenberger, C.J.	1939	Farm manure. Ohio Agr. Expt. Stn. Bull. 605: 1-69.
*Sanyasiraju	1954	Preliminary Report on laterite soil. Effect of manuring on the composition of paddy grains. Madras Agric. J. XLVI (1): 17-19.
Sasidhar, V.K.	1969	Studies on the performance of Co.1 Lab Lab under graded doses of phosphorus and potash at different spacings. M.Sc.(Ag.) thesis, University of Kerala (Unpublished).
Searseth, G.D. and Tidmore, J.W.	1934	The fixation of phosphates by soil Colloids. J. Am. Soc. Agron. 26: 138-151.
Sen, S. and Bains, S.S.	1955	Effect of manures on berseem. J. Indian Soc. Soil Sci. 3: 31-49.

Seth, R.L., Ramiah, K. and Abraham, T.P.	1952	Manuring of rice in India. I.C.A.R. Misc. Bull. No. 38 (Revised edition).
Seetharama Rao, R.V. and Krishna Rao, D.V.	1961	Uptake of nutrients by plant in relation to growth. Report presented to the 8th meeting of the IRC Working Party on Rice Soils, Water and fertilizer practices, New Delhi. Working Paper 5 (Mimeographed).
Shapiro, R.E.	1958	Effect of flooding on the availability of phosphorus and nitrogen. Soil Sci. 85 (4): 190-197.
Singh, R.M. and Pancholy, S.K.	1967	Uptake of phosphorus by Sorghum Volgare as affected by nitrogen and phosphorus application. Madras Agrl. J. 54 (11): 512-517.
Sinha, P., Bhattacharya, P.B. and Sinha, M.P.	1962	Manurial experiments on cultivator's fields with paddy in Bihar. IRC News letter. 11: (3): 1-10.
Siregar, H.	1955	Investigations on the time of applications of ammonium sulphate. IRC/FP/55/29.
Sreeramulu, V.S. Daniel Sundararaj and Mariakulandai, A.	1959	Effect of manuring on the composition of paddy grain. Madras Agric. J. 46 (6): 181-185.

Sreeramulu, U.S. and Mariakulandai, A.	1962	Assessment of the availability of phosphorus from soils during crop growth and factors influencing it. Madras Agrl. J. 49 (8): 247-251.
----------	1963	Influence of phosphatic manuring on the Av. nitrogen, pH and Organic carbon of the soil. Madras Agrl. J. 50 (12): 455-462.
----------	1964	The composition of paddy grains as affected by the application of farm yard manure and super fertilizers. Madras Agrl. J. 51 (9): 379-385.
Srinivasulu, K. and Pawar, M.S.	1965	Studies on the influence of N, P and K on some quantitative characters in two indica x japonica rice hybrids. Rice News Letter. 13 (3): 81-83.
Srivastava, B.N., Biswas, T.D. and Das, N.S.	1955	Influence of manure and fertilizer on wheat. J. Indian Soc. Soil Sci. 3: 33-40.
Stanford, G. and Nelson, L.B.	1949	Utilization of phosphorus as affected by placement. I. Corn in Iowa. Soil Sci. 68: 129-135.

Stepenson, R.R.	1938	Effect of organic materials and fertilizer treatments upon the soluble nutrients in soils. Soil Sci. 45: 467-475.
Stout, P.R.	1939	Alterations in the crystal structure of clay minerals as a result of phosphate fixation. Soil Sci. Soc. Amer. Proc. 4: 177-182.
Suseelan, P.	1969	Studies on the effect of graded doses of phosphorus in conjunction with lime on growth, yield and phosphorus uptake in rice. M.Sc.(Ag.) thesis. University of Kerala. (Unpublished) 1969.
Swenson, R.M., Cole, C.V. and Sieling, D.H.	1949	Fixation of phosphate by iron and aluminium and replacement by organic and inorganic ions. Soil Sci. 67: 3-22.
Tamhane, R.V., Motiramani, D.P., Bali, Y.P. and Roy, L. Donahue.	1965	Soils - Their chemistry and fertility in tropical Asia. Prentice Hall of India Private Limited, New Delhi p. 192.
Thomas, A. Mc Coy., David, G. Bostwick and Charles Dench, A.	1951	Some effect of phosphorus on the development of vitamin B content of inorganic composition of Oats. Plant Physiol. 26 (4): 784.

Tidburg, G.E. 1956 Response of rice to certain fertilizers in Zanzibar. Trop. Agric. Trin. 33: 113-126. Abstracted in Soils and Fert. 19 (4): 1776-1956.

Tisdale, S.L. and Nelson, W.L. 1956 Soil Fertility and Fertilizers. Macmillan Company Ltd., Galt, Ontario.

Tomy, P.J. 1963 Varietal response to fertilizer application in rice. M.Sc.(Ag.) thesis, University of Kerala (Unpublished) 1963.

*Tyner, E.H. and Davide, J.G. 1962 Some criteria for evaluating soil phosphorus tests for low land rice soils. Trans. Joint Meeting. Comm. IV and V Internat. Soc. Soil Sci. New Zealand pp. 625-634.

Varma, G.P. 1960 Phosphatic manuring of paddy and its economics Radioisotopes, fertilizers and cowdung gas plants. I.C.A.R. Proc. Sem. 1961 p. 438.

*Velley, J. 1954 Quoted by Angladette, A. The mineral nutrition of the rice plant. p. 366. Oxford IBH. Publishing Co. Calcutta.

Venkitasubramonian, M.K. and Duraira,j	1954	Madras Agri. J. 39: 157.
Wallace, T.	1961	The diagnosis of mineral deficiencies in plants by visual symptoms. Second edition 1964. Her Majesty's Stationery Office, York House, King's Way, London W.C.2.
*Warrington, R.	1866	Research on the phosphates of calcium and upon solubility of tricalci phosphate. J. Chem. Soc. (London) 19: 226-317.
*Warrington, R.	1868	On the part taken by oxides of iron and alumina in the adsorptive action of soils. J. Chem. Soc. (London) 21: 1-19.
Williams, R.F.	1948	The effect of phosphorus supply on the rate of intake of P and N upon certain aspects of P metabolism in gramineous plants. Aust. J. Sci. Res. Ser. 333-361. Soils and Fert. 12 (5): 352. 1949.
Yuven, T.L., Robertson, W.K. and Neller, J.R.	1960	Forms of Newly fixed phosphorus in three acid sandy soils. Soil Sci. Soc. Amer. Proc. 24: 447-450.

Zannen, J.P. 1951 Fertilizing with basic slag. C.I.J.A. 2 Cong. Mondial Engr. p 8. 1951. Soils and Fert. 15 (4): 273, 1952.

* Original not seen.

APPENDICES

APPENDIX I

Available phosphorus on 45th day in laterite soil

(Analysis of variance)

Source	SS	DF	Variance	F
Total	3278	29		
Block	54	2	27.00	5.85**
Treatment	3141	9	349.00	75.70**
Error	83	18	4.61	

** Significant at 1 per cent level

APPENDIX II

Available phosphorus on 90th day in laterite soil

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	3787	29		
Block	52	2	26.00	8.66**
Treatment	3681	9	409.00	136.33**
Error	54	18	3.00	

** Significant at 1 per cent level

APPENDIX III

Available phosphorus at harvest in laterite soil

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	4124	29		
Block	64	2	32.00	3.21*
Treatment	3881	9	431.22	45.38**
Error	179	18	9.94	

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

APPENDIX IV

Available phosphorus on 45th day in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	3181.2	29		
Block	63.3	2	31.65	4.91**
Treatment	3002.1	9	333.55	51.80**
Error	115.8	18	6.43	

** Significant at 1 per cent level

APPENDIX V

Available phosphorus on 90th day in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	3151	29		
Block	73	2	36.50	3.32*
Treatment	2902	9	322.44	34.26**
Error	176	18	9.77	

** Significant at 1 per cent level

* Significant at 5 per cent level

APPENDIX VI

Available phosphorus at harvest in sand culture

Sources	SS	DF	Variance	F
Total	3164	29		
Block	63	2	31.50	2.52*
Treatment	2940	9	326.66	36.53**
Error	161	18	8.94	

** Significant at 1 per cent level

* Significant at 5 per cent level

APPENDIX VII

P_2O_5 content of grain in laterite soil

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.27550	29		
Block	0.00057	2	0.00028	1.466
Treatment	0.27300	9	0.03033	176.340**
Error	0.00193	18	0.00017	

** Significant at 1 per cent level

APPENDIX VIII

P_2O_5 content of straw in laterite soil

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.0115430	29		
Block	0.0000052	2	0.0000026	2.79*
Treatment	0.0115210	9	0.0012801	1376.45**
Error	0.0000168	18	0.0000009	

** Significant at 1 per cent level

* Significant at 5 per cent level

APPENDIX IX

P_2O_5 content of grain in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.78130	29		
Block	0.00033	2	0.000165	2.14
Treatment	0.76710	9	0.085200	110.91**
Error	0.01387	18	0.000770	

** Significant at 1 per cent level

APPENDIX X

P_2O_5 content of straw in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.013354	29		
Block	0.000094	2	0.000047	-
Treatment	0.013232	9	0.0014702	-
Error	0.000028	18	0.0000015	-

APPENDIX XI

Nitrogen content of grain in laterite soil

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.2524	29		
Block	0.0091	2	0.0045	1.73
Treatment	0.2524	9	0.0218	83.84**
Error	0.0471	18	0.0026	

** Significant at 1 per cent level

APPENDIX XII

Nitrogen content of straw in laterite soil

(Analysis of variance)

Source	SS	DF	Variance	F
Total	0.2696	29		
Block	0.0172	2	0.0086	7.82**
Treatment	0.2324	9	0.0258	33.47**
Error	0.0200	18	0.0011	

** Significant at 1 per cent level

APPENDIX XIII

Nitrogen content of grain in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.203	29		
Block	0.005	2	0.0025	5.68**
Treatment	0.194	9	0.0215	48.86**
Error	0.008	18	0.00044	

** Significant at 1 per cent level

APPENDIX XIV

Nitrogen content straw in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.2352	29		
Block	0.0004	2	0.0002	2.5
Treatment	0.2334	9	0.02593	324.12**
Error	0.0014	18	0.00008	

** Significant at 1 per cent level

APPENDIX XV

K_2O content of grain in laterite soil

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.1361	29		
Block	0.0012	2	0.0006	1
Treatment	0.1215	9	0.0135	18.2**
Error	0.0134	18	0.0074	

** Significant at 1 per cent level

APPENDIX XVI

K_2O content of straw in laterite soil

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.8524	29		
Block	0.0194	2	0.0097	97**
Treatment	0.8310	9	0.0923	923**
Error	0.0020	18	0.0001	

** Significant at 1 per cent level

APPENDIX XVII

K_2O content of grain in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.4592	29		
Block	0.0082	2	0.0041	1.15
Treatment	0.2865	9	0.0318	8.89**
Error	0.0645	18	0.00358	

** Significant at 1 per cent level

APPENDIX XVIII

K_2O content of straw in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	1.1550	29		
Block	0.0012	2	0.0006	
Treatment	1.1336	9	0.1259	114**
Error	0.0214	18	0.0012	

** Significant at 1 per cent level

APPENDIX XIX

Yield of grain in laterite soil

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	54.30	29		
Block	5.60	2	2.80	1.14
Treatment	4.30	9	0.48	1
Error	44.40	18	2.46	

APPENDIX XX

Yield of grain in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	153.00	29		
Block	12.00	2	6.00	2.38
Treatment	95.60	9	10.62	4.21*
Error	45.40	18	2.52	

* Significant at 5 per cent level

APPENDIX XXI

Yield of straw in laterite soil

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	236	29		
Block	21	2	10.50	1.68
Treatment	103	9	11.44	1.83
Error	112	18	6.22	

APPENDIX XXII

Yield of straw in sand culture

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	277	29		
Block	23	2	11.50	1.44
Treatment	111	9	12.33	1.55
Error	143	18	7.94	

APPENDIX XXIII

Organic carbon content in laterite soil on 45th day

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	2.40650	29		
Block	0.00038	2	0.00019	1
Treatment	2.40168	9	0.26685	988.33**
Error	0.00482	18	0.00027	

** Significant at 1 per cent level

APPENDIX XXIV

Organic carbon content in laterite soil on 90th day

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	2.9129	29		
Block	0.0054	2	0.0027	1
Treatment	2.8123	9	0.3125	58.96**
Error	0.0952	18	0.0053	

** Significant at 1 per cent level

APPENDIX XXV

Organic carbon content in laterite soil at harvest

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	3.1581	29		
Block	0.1003	2	0.05015	74.85**
Treatment	3.0566	9	0.33960	4851.00**
Error	0.0012	18	0.00006	

** Significant at 1 per cent level

APPENDIX XXVI

Organic carbon content in sand culture on 45th day

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.00330	29		
Block	0.00013	2	0.000065	1
Treatment	0.00168	9	0.001870	2.253
Error	0.00149	18	0.000083	

APPENDIX XXVII

Organic carbon content in sand culture on 90th day

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.0101	29		
Block	0.0009	2	0.00045	6.43**
Treatment	0.0080	9	0.00088	12.57**
Error	0.0012	18	0.00007	

** Significant at 1 per cent level

APPENDIX XXVIII

Organic carbon content in sand culture at harvest

(Analysis of variance)

Sources	SS	DF	Variance	F
Total	0.0106	29		
Block	0.0003	2	0.00015	1.584
Treatment	0.0086	9	0.00095	10.110**
Error	0.0017	18	0.000094	

** Significant at 1 per cent level