EVALUATION OF PARTIALLY ACIDULATED MUSSOORIE ROCK PHOSPHATE FOR RICE-BASED CROPPING SYSTEMS.

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR

IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(SOILS AND AGRICULTURAL CHEMISTRY)

By
Artatran Mishra

DEPARTMENT OF SOILS AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE
BHUBANESWAR

1985

HESIS ADVISER : **Dr. N. PANDA**

DEDICATED TO
MY
PARENTS

ACKNOWLEDGEMENT

I avail this opportunity of expressing my profound sense of gratitude to Dr.N.Panda, B.Sc.(Ag) (B.H.U.), M.Sc.(Allahabad), Ph.D.(Missouri), Professor, Department of Soils and Agricultural Chemistry, College of Agriculture, Orissa University of Agriculture and Technology for his valuable guidance, constant supervision and constructive criticisms during the entire course of this investigation.

I am very much grateful to Dr.G.N.Mitra, M.Sc. Assoc.I.A.R.I., Ph.D., Professor and Head of the Department of Soils and Agricultural Chemistry for providing all possible laboratory facilities during the course of this investigation.

I am indebted to Sri Dwijabar Sahoo, Soil Scientist, L.T.F.Experiment and Dr.M.Panda, Operational Research Officer, Department of Soils and Agricultural Chemistry for their help and valuable suggestions during the research work.

Thanks are also due to Bapi, Khanda, Arun, Sachi, Bisu and Muna for their cordial co-operation during the period of investigation.

Financial assistances provided by the Govt.of Orissa and the Orissa University of Agriculture and Technology during the Post-graduate studies are also duly acknowledged.

I am also grateful to Pyrites phosphates and Chemicals Ltd. for providing the partially acidulated materials for this investigation.

Lastly, I am deeply indebted to my parents, brother and sister-in-law whose inspirations, love and blessings led me to this stage of success.

Bhubaneswar
The 8th July, 1986

Artatran Mishra
(Artatran Mishra)

LIST OF TABLES

LIST OF FIGURES

APPENDIX TABLE

CHAPTER-I
INTRODUCTION

INTRODUCTION

The significant role of phosphorus in sustaining and building up of land fertility particularly under intensive system of agriculture, has been amply demonstrated from the results of large number of studies carried out all over the world. Soils are known to vary widely in their 'P' supplying power to crops. The dynamics of phosphorus transformation in the soil system and its fixation and release characteristics have been the subject of numerous research investigations, but in actual practice the most pertinent issue is to know how much 'P' can be made available to crop from the native pool. The work on phosphate nutrition of plant carried out in India and abroad suggest that about 15 - 25 % of the added phosphate is only utilised by the crop. The applied water soluble phosphatic fertilizers are likely to undergo transformation in the soil in accordance with the physical, chemical and b iological properties of the soil. Plants derive phosphate from the relatively less soluble transformed products after they undergo a process of dissolution or solubilization.

In India nearly one third of the cultivated land is under acid soils. A large part of Orissa is also covered with acidic red and lateritic soils having low available phosphorus content and very high phosphorus fixing capacities. Therefore, the quantities of phosphorus required to develop a satisfactory potential are so great that it is not economical to satisfy the absorptive capacity of soil by using water soluble phosphate carriers. So less expensive insoluble and citrate soluble sources of phosphorus like rock phosphate application in acid soils, as a source of phosphatic fertiliser, needs to be tested.

Recent mineralogical explorations by the Geological Survey of India have discovered extensive reserves of rock phosphates in various regions of India. A total estimated reserve of 220 million tons of rock phosphates occur in different states of India, like Uttar Pradesh, Rajasthan, Madhya Pradesh, Bihar, West Bengal, and Andhra Pradesh.

The rock phosphates which are the main raw material for manufacture of phosphatic fertilizer are neither sufficiently available in India nor they satisfy in most cases the requisite quality and specifications of fertilizer industry. Under these circumstances the problem of utilising the indigenous rock phosphates in fertilizer industries becomes very acute. Therefore, the need exists for relatively simple but reliable means for predicting the circumstances where in rock phosphates can be applied either directly or after some modifications, like partial acidulation for increasing the agronomic effectiveness of the source.

Another important issue is, the use of phosphatic fertilizer on the basis of soil test result. Soil testing as a tool is the key for profitable crop production provided the 'P' is well correlated with crop yield. Difficulties arise while establishing a good correlation between the amount of P extracted by a particular method with the response of a particular crop. Therefore evolution of a suitable soil test method for such condition will be useful for better utilisation of phosphates.

OBJECTS OF THE INVESTIGATION :-

1. To investigate whether Mussoorie rock phosphate can be used as a phosphate source for acid lateritic soils.

2. To compare effectiveness of varying degree of acidulation of Mussoorie rock phosphate with varying amounts of H_3PO_4 and H_2SO_4.

3. To investigate both the direct and residual effect of partially acidulated Mussoorie rock phosphate for rice based cropping systems.

4. To test the applicability of Bray's-I and Olsen's extractant for determination of soil available 'P' in acid lateritic soil for rice based cropping systems .

CHAPTER-II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Phosphorus being one of the most important essential element for plants has drawn the attentión of soil scientists and agronomists for a long time. More soil fertility investigations have been conducted on phosphorus than on any other element, yet characterisation and assessment of its availability has not been fully possible.

1. PHOSPHORUS TRANSFORMATION IN ACID LATERITIC RICE SOIL :

Phosphatic fertiliser either water soluble or citrate soluble, when applied to acid soils undergo transformations depending upon the nature and condition of soil. It is recognised that only a small percentage of added P is absorbed by the plant and the rest is retained or fixed in soil in various relatively insoluble form.

According to (Seatz and Stanberry,1963) various phosphate compounds in soil may change due to environmental condition under which the soil is maintained. The nature of fertilizer 'P' added and the type of soil environment adjacent to the fertilizer particle determine the nature of reaction products formed in the soil which in turn serve as potential source of 'P' availability with passage of time .

Juo and Ellis (1967) in their phosphorus transformation studies found that soluble 'P' applied to acid soils dissolved during the process of chemical weathering, precipitated rapidly to form colloidal Al and Fe-P, which crystalise to form hydrated compounds such as variseite and strengite which are much less available to plants.

Chakravarty and Kar (1970) reported that about 30 - 50% of added 'P' was fixed in West Bengal soil having pH (4.3 - 6.1) . The Al-P, Fe-P and Ca-P greatly increased and occluded Al-P increased to a lesser degree . Ca-P was unaffected except in soils with pH 6.18.

According to Khanna and Mahajan (1971) in acid soils added 'P' was transformed in to Al-P (47 to 73% at pH 4.7 and 17 to 34% at pH 6.6).

Gupta and Nayar (1972) found that transformation of inorganic P under field moisture capacity and waterlogged condition resulted in a decrease in reductant soluble P and residual P and an increase in Ca-P and Fe-P with time. The amount of Al-P decreased under field moisture condition but increased slightly under reduced (waterlogged) condition.

Mandal and Chatterjee (1972) reported that the added 'P' remaining in equilibrium solution declined sharply depending on lesser Fe-oxide and native iron phosphate content of the soil. They also found that soils having higher Bray's-I extractable P experienced greater transformation in to Al-P. Transformation of added P to Fe-P and Al-P was directly related to total inorganic P already present in the soil.

Mandal and Khan (1972) showed that within 15 days of application more than 86% of the 'P' added as superphosphate was converted to unavailable form.

Mandal and Khan (1977) found that 65% of the amount of applied phosphate was fixed as Al-P, Fe-P and Ca-P after harvest of rice crop.

Mandal and Khan (1975) found that repeated cycling of alternate waterlogged and saturated moisture condition lowered the Bray's-I 'P'. These alternate moisture regime created condition for formation and accumulation of hydroxides of Fe and Al, which have high P fixing capacity.

Sarangnath, Shinde and Patnaik (1977) carried experiments with P^{32} tagged Ca $(H_2PO_4)_2$, Ca (HPO_4) and $Ca_3(PO_4)_2$ and found that in application of these sources to moist aerobic acid soils a considerable proportion of applied P even from dicalcium phosphate and tricalcium phosphate were converted to Al-P and/or Fe-P due to gradual dissociation of the H^+ ion in the system.

Biddappa and Perur (1978) workingon laterite soils under different moisture levels reported that application of phosphatic fertilizers increased Al and Fe-P fractions upto 60 days, but decreased the same subsequently.

Prabhudesai and Kadrekar (1984) studied phosphate reaction products formed after application of different carriers of fertilizer P in lateritic soil and found that reaction of mono-ammonium phosphate in the soil yielded mono-ammonium taranakite and variscite while mono-calcium phosphate gave rise to brushite, monetite, variscite and overite. Fe^{++} and Al^{+++} were found to be dominant cations involved in phosphate fixation particularly in acid soils.

DISSOLUTION OF ROCK PHOSPHATE AND AVAILABILITY OF PHOSPHORUS IN ACID SOILS .

Rock phosphate is the primary source of phosphorus in the mineral apatite which is present in the form of finely divided fluorapatite, hydroxy apatite, chloroapatite, Iron and Aluminium phosphates and phosphates in combination with clay. It may also be present in the form of simple soluble compounds in inorganic combinations.

(Olsen 1975, Chaveri and Black 1976) opined that crop response to phosphate rock application is strongly dependent upon the rate of dissolution of the phosphate rock in soil.

Khasumeh and Doll (1978) found 3 major factors influencing 'P' availability from phosphate rock.

i) Inherent differences among phosphate rock sources

ii) Soil properties

iii) Variation among crops in their ability to utilise 'P' from phosphate rocks.

There is a general agreement (Ellis et al. 1955, Graham 1955) that soil acidity has a marked influence on the availability of 'P' from rock phosphate, the availability increases as the pH is lowered. Rock phosphate is decomposed by acid to form monocalcium phosphate and other soluble compounds.

$$Ca_3\,(PO_4)_2 + 4H^+ \qquad 2H_2PO_4^- + 3Ca^{++}$$

Once, $H_2PO_4^-$ ions formed, their fate depend upon soil environment.

Hsu and Jackson (1960) have stressed the importance of pH in the formation of Al and Fe-phosphate as opposed to Ca-phosphate, the former being the main product in acid soils.

Chu, Moschler and Thomas (1962) studying several acid soils of Virginia reported that Al and Fe fractions decreased with increasing pH. The relationship between pH and Al-phosphate was essentially the same for all soils studied, whereas the amount of Fe-phosphate formed varied both with pH and soil free Fe content. From these relationships it appears that soils which respond well to rock phosphate application are those with low pH and relatively low free Fe content.

Several authors (Lehr and Mc Clellan 1972, Olsen 1975, Chien and Black 1976, Chien 1977) opined that the reactivity of phosphate rocks utilised for direct application varies with mineral composition and the solubility of 'P' in a phosphate rock source can be used as an index of its reactivity.

Chien and Hammond (1978) studied the reactivity of phosphate rocks and suggested that factors such as :

i) Calcite depression of apatite solubility in neutral ammonium citrate.

ii) The grade effect (Total P content) on the apparent solubility.

iii) The textural effect of apatite silica intermixing, need to be considered when the correlation of chemical reactivity of the various phosphate rocks and their agronomic effectiveness are compared.

Lehr and McClellan (1972) examined the important world deposits and observed that with few exception the apatites were not fluorapatite, but belonged to series of carbonate apatite in which PO_4 was partially replaced by CO_3 and F, and Ca by Na and Mg in the apatite structure. They also found that citrate soluble P of the apatite increased as the degree of CO_3 substitution for PO_4 in the apatite structure increased.

Chien and Black (1976) and Chien (1977) found that the substitution of CO_3 for PO_4 in apatite structure decrease the free energy of neutralization in the acid solution, resulting in an increase in the chemical reactivity of phosphate rock, and the more the degree of substitution the greater the chemical reactivity of phosphate rock.

Chien (1977) studied the dissolution of phosphate rocks in an acid 'P' deficient soil under water-logged condition and found that the concentration of 'P' in the soil solution equilibrated with various phosphate rocks during incubation varied considerably among sources and the solubility differences of various phosphate rocks decreased as incubation time increased. The 'P' concentration in the soil equilibrated with phosphate rocks reached a maximum 1-3 weeks after the soil was flooded and then decreased. There was a linear relationship between the logarithm of the maximum 'P' concentration in the soil solution equilibrated with phosphate rock and the degree of

CO_3 substitution for PO_4^- in the apatite structure.

Bhujabal and Mistry (1981) also found in 9 Indian phosphate rocks that citrate solubility of the phosphate rock increased as the mole ratios of CO_3: PO_4 in each apatite increased. The solubility of phosphate rock incubated in an acid soil under flooded condition increased upto 3rd week and decreased thereafter.

Khasvneh and Doll (1978) found that Ca is one of the product in phosphate rock dissolution in acid soils, which is released in amount proportional to the rate of 'P' released. The dissolved 'P' undergo transformation while Ca remain as an exchangeable cation in soil solution, affecting the rate of dissolution of phosphate rocks. He reported that phosphate rock dissolution was greater when soil Ca levels were low.

Chaudhury and Mishra (1980) found that the transformation of rock phosphate in soil was mainly related to soil acidity and phosphate potential as these two soil parameters accounted for 94% variation in the degree of transformation of rock phosphate.

Anderson, Kussow and Corey (1985) studied in acid soils, how and to what degree phosphate rock and soil characteristics influence release of 'P' from phosphate rocks and found that relative agronomic effectiveness of the phosphate rocks were directly related to their substituted CO_3 content which accounted for 71 - 84% of the variation in 'P' released.

No single soil characteristics appeared to have consistent and predominate influence on phosphate release. Overlapping of spheres serving as a sink for dissolution products of adjacent phosphate rock particles decrease dissolution rate of individual particles. Within these sphere of influence are contained the elements i.e. (buffer power, pH, solute concentration gradient) driving dissolution.

PARTIAL ACIDULATION OF ROCK PHOSPHATE :

Preliminary work done at the IFDC suggested that the initial agronomic effectiveness of most phosphate rocks sources are low and inferior to that of superphosphate. Partial acidulation is one way to increase the agronomic effectiveness of phosphate rocks.

The results obtained by McLean and his co-workers in Ohio (McLean and Wheeler 1964, McLean and Balam 1967, McLean and Logan 1970) indicated that finely ground partially acidulated phosphate rock with 10-20% acidulation by H_3PO_4 was as good or better than concentrated superphosphate in soils with high 'P' sorption capacity.

McLean and Wheeler (1964) reported that part of the acidity produced by the dissolution of monocalcium phosphate in partially acidulated phosphate rock would be neutralised by the unacidulated rock. This not only protects the water-soluble 'P' of partially acidulated phosphate rock from reacting with substantial quantities of Al and Fe, but additional 'P' could be released in to the water soluble pool from the reaction of acid with unacidulated phosphate rock partially acidulated phosphate rock produce relatively small concentration of 'P' in soil solution thereby reducing the fixation of 'P' by metal oxide polymer or immobilization through displacement on structural silicate.

Chatterjee, Guha and Ghosh (1968) and Chatterjee, Sircar and Ghosh (1970) found that partial acidulation of rock phosphate with HCl or H_2SO_4 resulted in the formation of a mixture of water-soluble (Probably monocalcium phosphate), citrate soluble (probably dicalcium phosphate) and insoluble phosphates, the proportion of the first two forms increases at the expense of the tricalcium phosphate with increasing degree of acidulation.

Espedo (1968) found P uptake by rice highest when fertilised with rock phosphate acidulated with H_2SO_4. The 10% acidulated products produced effects comparable to the products of higher acidulation.

Mishra and Panda (1969) from their experiment in Bhubaneswar lateritic soil found on very acid soils (pH 4.0) 10 and 20% acidulated materials were good P sources for corn and rice. When soils were limed to pH 5.6 and 6.5, 50 and 100% acidulated materials performed better than lower acidulated material. They also suggested the use of acidulated material with H_3PO_4 for short duration crop and HNO_3 acidulation for long duration crop.

Panda (1969) reported that partial acidulation beyond 10% either by H_3PO_4 or HNO_3 did not prove economical for lateritic soils of pH around 4.5 and with a very low cation exchange capacity.

Panda and Mishra (1970) reported that acid lateritic soils have high fixing capacity of 'P', which is more so when only water soluble 'P' source is applied. They obtained lesser fixation of 'P' and better efficiency of rock phosphate or partially acidulated rock phosphate containing a combination of water soluble, citrate soluble and citrate insoluble source of P .

McLean and Logan (1970) found yield response to P were greater from 20% than from 100% acidulated phosphate rock on soils of high 'P' sorption capacity.

Equal amount of water soluble 'P' in the form of granulated partially acidulated phosphate rock (20% by H_3PO_4) and concentrated superphosphate when added to acid soils, the amount of water extracted 'P' was higher in soils treated with PAPR (Mokwunye and Chien 1980). They found the relative effectiveness of PAPR highest in oxisol which had the highest capacity to sorb 'P' .

Shinde, Sarangmath and Patnaik (1978) with different rock phosphates acidulated to various degrees either with HCl or H_2SO_4 and applied to a flooded P deficient acid soil to rice crop found that the behaviour of HCl or H_2SO_4 acidulated product in respect of 'P' availability in soil, grain yield response and P uptake by rice was more or less similar. He concluded that 50% partially acidulated phosphate rock with either of the acids would be suitable for growing rice under flooded soil condition.

Marwaha (1983) from a field experiment conducted for 2 years in an acid soil pH 5.6 evaluated the suitability of H_3PO_4 or HNO_3 acidulated rock phosphate as sources of P in wheat - blackgram cropping sequence. His results revealed that

i) Raw rock phosphate (without acidulation) was of no fertilizer value.

ii) Acidulation at all the levels improved the effectiveness of rock phosphate.

iii) Samples acidulated with HNO_3 were as effective as those prepared with H_3PO_4 at almost all the comparable levels of acidulation.

iv) Acidulation of rock phosphate to the extent of 50% with either of the two acids was as effective as superphosphate.

Sood and Marwaha (1983) found ground (-100 mesh) Mussoorie rock phosphate when acidulated with graded levels of concentrated HNO_3 or dilute acid the magnitude of all the P form except total phosphate was higher with concentrated acid. Which is due to more intensive chemical reaction.

Marwaha, Kanwar and Tripathy (1983) working on partial acidulation of finely ground Indian Rock phosphates with HNO_3 and H_3PO_4 found that

i) the total 'P' content in acidulated products increased with degree of acidulation with H_3PO_4 and decreased with HNO_3. Effect was highest in case of Mussoorie rock phosphate.

ii) for all the rock phosphates there was a linear type of relationship of water soluble content with increasing levels of acidulation with both the acids. Mussoorie rock phosphate had the minimum quantity of water soluble phosphate with both the acidulants.

iii) the increase in citrate soluble phosphate was conspicuously more with HNO_3 than with H_3PO_4 treated and the increase was maximum in case of Mussoorie rock phosphate with both the acids.

Marwaha (1984) found that differences in results from pot tests with partially acidulated phosphate rocks, could be attributed to the differences in the form of acidulant, degree of acidulation, form of acidulated phosphate rocks (powdered or granulated), nature of the soil, crop species used for test and the rate of phosphate application. He concluded that for upland crops and for soils of pH around 5.5 with high'P' fixing capacity 10-20% acidulated rock phosphate may give optimum yield.

For soils having low 'P' fixing capacity and for flooded rice a similar response may be obtained by using 50% acidulated product. For the preparation of acidulated rock phosphate those showing most promise however appear to be H_3PO_4 and HNO_3.

DIRECT AND RESIDUAL EFFECT OF ROCK PHOSPHATE :

There appears to be a general agreement among scientists that rock phosphates could be best used in acid soils where its availability increased with time

ii) for all the rock phosphates there was a linear type of relationship of water soluble content with increasing levels of acidulation with both the acids. Mussoorie rock phosphate had the minimum quantity of water soluble phosphate with both the acidulants.

iii) the increase in citrate soluble phosphate was conspicuously more with HNO_3 than with H_3PO_4 treated and the increase was maximum in case of Mussoorie rock phosphate with both the acids.

Marwaha (1984) found that differences in results from pot tests with partially acidulated phosphate rocks, could be attributed to the differences in the form of acidulant, degree of acidulation, form of acidulated phosphate rocks (powdered or granulated), nature of the soil, crop species used for test and the rate of phosphate application. He concluded that for upland crops and for soils of pH around 5.5 with high 'P' fixing capacity 10-20% acidulated rock phosphate may give optimum yield.

For soils having low 'P' fixing capacity and for flooded rice a similar response may be obtained by using 50% acidulated product. For the preparation of acidulated rock phosphate those showing most promise however appear to be H_3PO_4 and HNO_3.

DIRECT AND RESIDUAL EFFECT OF ROCK PHOSPHATE :

There appears to be a general agreement among scientists that rock phosphates could be best used in acid soils where its availability increased with time

(Mandal and Khan 1972, Marwaha, 1981).

Mandal and Khan (1972) and Hundal <u>et al</u> (1977) found that the advantages of applying rock phosphate a few days before sowing short season crops may be owing to its slow but steady rate of solubilization in the soil under the possible influence of soil solvents, which makes the soil solution adequately rich in available 'P' to meet a part of 'P' requirement of the crop plants in the initial stage of growth.

Panda and Panda (1968) investigating the direct effect of raw rock phosphate on acid lateritic soils of Orissa found that ground U.A.R. rock phosphate of proper fineness can effectively be used in acid lateritic soils for growing rice.

Panda and Mishra (1972) working with different sources of rock phosphates in red and lateritic soils of Orissa reported increase in yield of dry matter and uptake of phosphate by rice.

Patnaik, Sarangnath and Shinde (1974) studying the ways of increasing the efficiency of citric acid soluble and insoluble phosphates for rice in acid lateritic soils found that when 'P' is to be applied at flooding and puddling, it is desirable to use water soluble phosphate. Citric acid soluble phosphate and rock phosphate can replace water soluble phosphate in acid soils, if they are applied sufficiently in advance to allow time for the soil to remain in most aerobic state.

Minhas and Rick (1974) concluded that rock phosphates were more economical than superphosphate as a source of 'P' in acid soils.

Hundal *et al.* (1977), Bailey *et al.* (1977) reported that sources with low water solubility perform better at higher than at lower rate of application. Higher rate of application of rock phosphate give not only higher crop yield and 'P' uptake but also improve the available 'P', status of soil.

Gumansingh and Panda (1978) studying the effect of Mussoorie rock phosphate on rice in acid lateritic soil of Bhubaneswar found that the yield differences between 60 Kg P_2O_5/ha through superphosphate and 8 90 Kg P_2O_5/ha through Mussorie rock phosphate were not significant. So due to difference in cost direct application of Mussoorie rock phosphate may be preferred over superphosphate.

Raj and Van (1980) studying the P supplying capacity of TSP and 3 apatitic rock phosphate for soybean found that TSP supplied highest amount of P, but lost efficiency during longer in-cubation period, The rock phosphates maintained their original efficiencies probably as a result of balance between P released from fertiliser P converted into non labile form.

Sdobnikova (1980) found that it could be more beneficial to make a single heavy application of ground rock phosphate than more frequent application in smaller doses to every crop every year.

Subramanian and Manjunath (1983) studied the response of rice to superphosphate and Mussoorie rock phosphate on neutral and acid soils. Responses to Mussoorie rock phosphate with or without irrigation was similar to or better than the response to superphosphate and since Mussoorie rock phosphate in the cheapest source of 'P' its use as recommended in acid soils.

Mishra, Kumar and Dwivedi (1985) in studying the effectiveness of five Indian and one Imported (Jordan) rock phosphates as 'P' source for wheat and rice in three acid soils found that the order of effectiveness as Jordan $\geq$ Jhabua $\geq$ Mussoorie $>$ Udaipur $\geq$ Purulia $>$ Singhbhum rock phosphate.

RESIDUAL EFFECT :

Raheja and Bains (1960) opined that in general the residual effect of P depends upon the factors, total amount of 'P' applied, time and frequency of application, physical and chemical proportion of soil , sources of phosphate used, weather condition and the succeeding crop.

Motsara and Dutta (1971) reported that for all the crops the rock phosphates had higher residual effect than superphosphate.

Sanchez *et al.* (1978) in a field experiment in an acid soil, applying TSP, basic slag and rock phosphate for a groundnut crop taken for 2 successive year found superphosphate and basic slag produced higher yield in first year, but residual 'P' concentration in soil two years after fertilizer application was greater from rock phosphate followed by basic slag and TSP.

Marwaha *et al.* (1981) in a two year field experiment with wheat and maize found that finely ground (100 mesh) Mussoorie rock phosphate was significantly inferior to superphosphate in its direct as well as residual effectiveness when compared on the basis of equal 'P'. The efficiency of Mussoorie rock phosphate however improved greatly at higher levels and when time of application was advanced. The residual effect of Mussoorie rock phosphate measured by yield and total 'P' uptake on the succeeding crop maize, however, was higher than direct effect.

Marwaha, Kanwar and Tripathi (1981) studied the response of 2 leguminous and 2 non-leguminous crops to ground Mussoorie rock phosphate alone and alongwith superphosphate, farm yard manure, or its partial acidulation with H_3PO_4 @ 10% in an acidic soil (pH 5.7). The yield and 'P' uptake in all the crops except berseem increased significantly with Mussoorie rock phosphate application and the effect of partially acidulated Mussoorie rock phosphate being highest and comparable to an equal dose of superphosphate both on the basis of direct and residual effect on crop yield and 'P' uptake.

Sarkar and Sarker (1982) in a field experiment to assess the fertilizer value of Mussoorie rock phosphate in an acid soil in term of direct effect on summer rice and residual effect on kharif rice found that although the direct effect was not statistically significant the residual effect as well as direct + residual effect taken together as judged by grain yield and total 'P' uptake was significant. There was practically no advantage due to increased fineness of rock phosphate beyond 60 mesh. It is suggested that in assessing the fertilizer value of rock phosphate its residual effect must be taken into account.

Debnath and Basak (1984) in a 2 year field experiment in acid lateritic soil in rice-wheat-greengram, cropping found that neither purulia rock phosphate, nor Mussoorie rock phosphate nor Tata basic slag was effective in increasing yield and P uptake by wet land rice grown as the first crop, but greengram responded favourably, Mussoorie rock phosphate and basic slag were as effective as superphosphate.

Marwaha (1986) in a 4 year study with wheat and soybean grown in rotation in a clay loam acid alfisol found Mussoorie rock phosphate to be an efficient phosphate carrier. A single heavy dose of application through Mussoorie rock phosphate once in 3 or 4 years to the first crop of the rotation was found to be superior to frequent application with smaller doses when adjudged in terms of relative agronomic effectiveness and total 'P' uptake. Residual effect of rock phosphate was greater than superphosphate which become especially marked after 2-3 years of application

The available literature reviewed, clearly indicate that rock phosphates are potential phosphate carriers for direct application in acid soils, and since they have direct effect on the first crop and residual effect on the succeeding crops, their application in acid soils are advisable for phosphorus economy.

EVALUATION OF SOIL TEST METHOD FOR PREDICTING 'P' AVAILABILITY

Various extractants have been recommended to measure the available 'P' status of soil. Many workers have investigated to find a suitable method for the purpose and have suggested different extractants to be used in different conditions but an extractant is suitable when the soil test value well correlate with the yield and uptake of nutrient by the crop.

In most of the soil testing laboratories Bray's-I method is recommended for acid soils and Olsen's method for neutral and alkaline soils. It is true that none of the chemical methods is suitable for all type of soils.

Bray's-I and Kurtz (1945) developed two extracting solution containing HCl and NH_4F. The strong solution contained 0.1N HCl and 0.03N NH_4F which is Bray's-2 extractant and 0.025N HCl and 0.03N NH_4F known as Bray's-I extractant.

Olsen et al. (1954) reported that 0.5M $NaHCO_3$ at pH 8.5 has been found to be an important and useful method for measuring available soil phosphorus.

Ghosh (1965) reported Olsen and Bray's-I method to be superior over other methods in acid laterite soils of Orissa.

carriers for direct application in acid soils, and since they have direct effect on the first crop and residual effect on the succeeding crops, their application in acid soils are advisable for phosphorus economy.

EVALUATION OF SOIL TEST METHOD FOR PREDICTING 'P' AVAILABILITY:

Various extractants have been recommended to measure the available 'P' status of soil. Many workers have investigated to find a suitable method for the purpose and have suggested different extractants to be used in different conditions but an extractant is suitable when the soil test value well correlate with the yield and uptake of nutrient by the crop.

In most of the soil testing laboratories Bray's-I method is recommended for acid soils and Olsen's method for neutral and alkaline soils. It is true that none of the chemical methods is suitable for all type of soils.

Bray's-I and Kurtz (1945) developed two extracting solution containing HCl and NH_4F. The strong solution contained 0.1N HCl and 0.03N NH_4F which is Bray's-2 extractant and 0.025N HCl and 0.03N NH_4F known as Bray's-I extractant.

Olsen *et al.* (1954) reported that 0.5M $NaHCO_3$ at pH 8.5 has been found to be an important and useful method for measuring available soil phosphorus.

Ghosh (1965) reported Olsen and Bray's-I method to be superior over other methods in acid laterite soils of Orissa.

Panda and Mishra (1970) working on utilisation of rock phosphate in acid laterite soils of Orissa reported that Olse n's extractant is highly suitable over other methods for acid soils.

Laxminarasingham and Krishnamoorthy (1978) found Bray's-I extractant for red and black soil, Olsen and Bray's-I extractant for alluvial soils are suitabke for extracting available 'P' for paddy.

Ramamoorthy and Hasan (1979) reported that Olsen's 'P' gave higher correlation with yield of paddy and not related to 'A' value and Bray's-I gave significant correlation with yield of wheat.

Dhilon et al. (1979) found that Bray's-I gave positive and highly significant correlation with yield and uptake parameter of rice and wheat than other methods.

Holford (1980 b) found that with increasing soil 'P' buffer capacity there is corresponding decrease in the proportion of labile 'P' taken up by plants. He suggested that a satisfactory extractant should also extract a portion of labile 'P', and reported that Bray's-I overcompensate for soil 'P' buffer capacity in soil with low pH.

Sharma and Bhumbla (1980) found in soils varying in pH 4.9 - 7.4, P extracted by the Bray's-I and Olsen's method was equally suitable for estimation of available 'P' in these soils. However, they observed ian interdependence of pH, organic matter content and clay content and their effects on the extraction of available 'P'.

Panda and Mishra (1970) working on utilisation of rock phosphate in acid laterite soils of Orissa reported that Olse n's extractant is highly suitable over other methods for acid soils.

Laxminarasinghan and Krishnamoorthy (1978) found Bray's-I extractant for red and black soil, Olsen and Bray's-I extractant for alluvial soils are suitabke for extracting available 'P' for paddy.

Ramamoorthy and Hasan (1979) reported that Olsen's 'P' gave higher correlation with yield of paddy and not related to 'A' value and Bray's-I gave significant correlation with yield of wheat.

Dhilon et al. (1979) found that Bray's-I gave positive and highly significant correlation with yield and uptake parameter of rice and wheat than other methods.

Holford (1980 b) found that with increasing soil 'P' buffer capacity there is corresponding decrease in the proportion of labile 'P' taken up by plants. He suggested that a satisfactory extractant should also extract a portion of labile 'P', and reported that Bray's-I overcompensate for soil 'P' buffer capacity in soil with low pH.

Sharma and Bhumbla (1980) found in soils varying in pH 4.9 - 7.4, P extracted by the Bray's-I and Olsen's method was equally suitable for estimation of available 'P' in these soils. However, they observed ian interdependence of pH, organic matter content and clay content and their effects on the extraction of available 'P'.

Biddapa *et al.* (1981) reported high correlation of Olsen's available 'P' with different inorganic fractions and proposed Olsen's soil test method to be reliable for evaluation of 'P' requirement of rice in flooded soils.

Yost and Kamprath (1982) comparing different extractants for soil 'P' found that double acid overestimated available 'P' where rock phosphate had been applied and that 'P' availability was better assessed by 0.5M $NaHCO_3$ and Bray's-I method.

✓Sharma and Tripathi (1984) in a study on the indices of 'P' availability in some Himalayan acid soils found that Olsen's extractant removed most of its 'P' from the Al-P fraction followed by Ca-P fraction. Bray's procedure derived mainly from Al-P followed by Fe-P and Ca-P in almost equal proportion.

Mackay and Syer's (1984) found the better predictive ability of the Bray's test with soil receiving phosphate rock appear to result from the ability of the procedure to extract both unreacted phosphate rock which is likely to dissolve in the short term and absorbed 'P'. Poor initial performance of Olsen's procedure was found. So in situations where unreacted phosphate rock contributed significantly to plant available 'P' in the soil e.g. where phosphate rock applied annually the Bray's procedure appears to be the most effective soil testing procedure.

CHAPTER-III
MATERIALS AND METHODS

MATERIALS AND METHODS

EXPERIMENTAL SITE :

Two trials i.e. Trial-B_1 and Trial-B_2 were conducted in the 'D' block of the Central Research station of the Orissa Univer sity of Agriculture & Technology, Bhubaneswar which lies between longitude of $85^{\circ}48'E$ and $85^{\circ}49'E$ and the latitude $20^{\circ}16'N$ and $20^{\circ}17'N$. The annual rainfall of the area is around 1500 mm.

The trials were conducted in medium land. The soil is lateritic classified as Haplaquepts. The experiments were designed to study the direct and residual effect of the various phosphatic fertilizer materials derived from the partial acidulation of Mussoorie rock phosphate, for Rice based cropping systems. The experiments were carried out in the same fields for two seasons i.e. kharif and summer season of the year 1984-85.

PHOSPHORUS SOURCES FOR THE TRIALS :

In these two field trials the main phosphate carrier was the Mussoorie rock phosphate and the other sources were the modified products derived from the partial acidulation of the Mussoorie rock phosphate. Triple superphosphate was taken as the standard phosphatic fertiliser for comparison. The details of the 'P' sources used are as follows.

1. Triple superphosphate (Granulated)
2. MPR (Mussoorie phosphate rock-finely ground).
3. MPR-C (Mussoorie phosphate rock-concentrated-finely ground)
4. IFDC-301 (Mussoorie PR- Minigranulated with 8.1% H_2SO_4 binder)
5. IFDC-400 (Mussoorie PR- Minigranulated with 7.7% H_3PO_4 binder)
6. IFDC-605 (Mussoorie PR- partially acidulated with 40% H_2SO_4- granulated)
7. IFDC-702 (Mussoorie PR- partially acidulated with 50% H_3PO_4- granulated)
8. IFDC-810 (Mussoorie PR- concentrated acidulated with 50% H_2SO_4- Granulated)
9. IFDC-812 (Mussoorie PR- concentrated -Partially acidulated with 50% H_3PO_4- Granulated)
10. IFDC-813 (Mussoorie PR- concentrated- Partially acidulated with 25% H_3PO_4- Granulated)
11. IFDC-816 (Mussoorie PR- Partially acidulated with 25% H_3PO_4- Granulated)

The chemical composition of the material have been presented in Table-1 .

Table-1

Chemical composition of Mussoorie rock phosphate and modified partially acidulated products.

(Expressed in wt. %)

Sources	Total P_2O_5	S.S. P_2O_5	C.S. P_2O_5	CaO	F	SO_4	H_2O
1.MPR	18	0.2	0.7	41.1	2.6	-	-
2.IFDC-301	16.2	0.5	0.8	36.3	1.7	7.0	0.1
3.IFDC-400	23.9	1.4	6.3	39.8	1.8	-	0.3
4.IFDC-605	14.1	3.8	1.7	31.3	1.0	26.6	2.1
5.IFDC-702	32.3	14.8	4.7	31.2	1.6	-	0.4
6.IFDC-810	18.2	9.0	1.0	32.3	1.1	30.7	3.3
7.IFDC-812	36.3	20.0	1.5	33.4	1.9	-	1.5
8.IFDC-813	32.8	7.8	4.3	40.0	2.3	-	0.7
9.IFDC-816	26.5	3.6	8.1	33.5	1.7	-	1.4

N.B:- All the materials and analytical data have been provided by PPCL.

Triple superphosphate taken as the standard phosphatic fertiliser for comparison contains Total P_2O_5(46%), W.S. P_2O_5(99.0% of total P_2O_5), C.S. P_2O_5 (0.9% of total P_2O_5), Available P_2O_5(99.9% of total P_2O_5).

TRIAL -B_1

The experiment was designed to evaluate the direct and residual effect of the phosphatic fertilizer materials derived from the partial acidulation of Mussoorie rock phosphate for a Rice-Greengram cropping system. The trial was conducted in a moderately acid soil of pH 5.8 and of clay loam texture. Initially composite soil samples were collected from different locations of the field for characterisation of the soil. (Details of soil characteristics on Chapter - IV).

Evaluation of Direct Effect (Kharif- Rice)

Experimental procedure :

For evaluation of the direct effect of the partially acidulated Mussoorie rock phosphate products, rice crop was taken in the kharif season of the year 1984. High yielding paddy variety Pratap (OR-131-3-1) of duration 125 days was grown.

The details of the phosphate treatments of the experiment are as follows.

No.of Treatment	Particulars of Treatment
T_1	Control i.e. no P_2O_5 .
T_2	40% P_2O_5/ha through TSP .
T_3	80% P_2O_5/ha " " .
T_4	120% P_2O_5/ha " " .
T_5	40% P_2O_5/ha through IFDC-605.
T_6	80% P_2O_5/ha " " .
T_7	120 % P_2O_5/ha " " .

No.of Treatment	Particulars of Treatment
T_8	40kg P_2O_5/ha through IFDC-702 .
T_9	80kg P_2O_5/ha " " .
T_{10}	120kg P_2O_5/ha " " .
T_{11}	40kg P_2O_5/ha through IFDC-810 .
T_{12}	80kg P_2O_5/ha " " .
T_{13}	120kg P_2O_5/ha " " .
T_{14}	40kg P_2O_5/ha through IFDC-812.
T_{15}	80kg P_2O_5/ha " " .
T_{16}	120kg P_2O_5/ha " " .
T_{17}	40kg P_2O_5/ha through IFDC-813 .
T_{18}	80kg P_2O_5/ha through IFDC-813 .
T_{19}	120kg P_2O_5/ha through IFDC-813.
T_{20}	40kg P_2O_5/ha through IFDC-816.
T_{21}	80kg P_2O_5/ha " " .
T_{22}	120kg P_2O_5/ha " " .

Design : All the 22 treatments were allocated in a randomised complete block design, having gross subplot size 4M x 3M and replicated thrice.

Cultural practices :-

35 days old seedlings of the rice variety Pratap were transplanted on 17.8.84. With a spacing of 15cm x 15 cm giving 3-4 seedlings/hill.

To all the treatments Nitrogen was applied @ 75kg/ha as Ammonium sulphate in 3 splits i.e. 50% basal at final puddling, 25%, 15 days after transplanting, and the remaining 25%, 7 days before panicle initiation.

Potash was applied @ 60 Kg K_2O/ha as Muriate of Potash in 2 splits i.e. at the time of final puddling and 10 days before panicle initiation. Normal plant protection measures were taken.

Sampling :-

Two adjacent hills from each of the 2 rows (leaving the 2 border rows) were collected at panicle initiation stage and dried under sun and then inside oven at 70°C and preserved.

The crop was harvested on 15.11.84. Net area harvested 2.1 x 3M . Crop was threshed and grain yields of individual sub-plots were recorded.

Surface soil samples were collected after harvest of the crop, by taking 5 cores from each subplot by soil sample tube .

Trial-B_1 (Summer crop- Greengram)

Evaluation of Residual Effect :

For the evaluation of the residual effects of the phosphatic fertiliser materials applied in the kharif season to the Rice crop, a second crop of Greengram was taken in the Summer season in the same sub-plots, in the same design, as in kharif season. Greengram variety Hybrid 12-4 was grown.

Cultural practices :-

The seeds were sown on 25.3.85 in furrows at a depth of 2.5 to 3cm @ 25k/ha. To facilitate germination water was sprinkled.

Except phosphatic fertilizers, Nitrogen @ 20Kg/ha Calcium Ammonium Nitrate and K_2O @ 20Kg/ha as Muriate of Potash were applied as basal in the furrows before sowing. The crop was irrigated once after 40 days of germination in the flowering stage.

Sampling :

Plant samples were collected from 2 rows (leaving the border row) 0.5M sections from each row were sampled by uprooting the plants. The plant samples were first dried under the sun and then in the Oven at 70°C.

The crop was harvested within the period, 28.5.85 to 3.6.85. Net area harvested was 3M x 2M. The dry pods were picked and threshed for recording of yield.

After harvest of the crop surface soil samples were collected by taking 5 cores from each subplot by soil sample tube.

TRIAL - B_2

The experiment was designed to evaluate the direct and residual effect of Mussoorie rock phosphate applied either as such or after partial acidulation for a Rice-Groundnut cropping system. The trial was conducted in an acid soil having pH 5.2 and of silty loam texture. Initially composite soil samples were collected from different locations of the field for characterisation of the soil. (Details of soil characteristics on Chapter-IV).

EVALUATION OF DIRECT EFFECT :

Experimental procedure :

For evaluation of the direct effect of the various phosphatic fertilizer materials derived from Mussoorie rock phosphate Rice was taken in the Kharif season of the year 1984.

High yielding paddy variety Pratap was grown. The details of the phosphate treatments of the experiment are as follows.

No.of Treatments	Particulars of Treatment
T_1	Control i.e. no P_2O_5.
T_2	40% P_2O_5/ha applied through TSP.
T_3	80% P_2O_5/ha " " .
T_4	120% P_2O_5/ha " " .
T_5	40% P_2O_5/ha applied through MPR.
T_6	80% P_2O_5/ha " " .
T_7	120% P_2O_5/ha " " .
T_8	40% P_2O_5/ha applied through MPR-C.
T_9	80% P_2O_5/ha " " .
T_{10}	120% P_2O_5/ha " " .
T_{11}	40% P_2O_5/ha applied through IFDC-301.
T_{12}	80% P_2O_5/ha " " .
T_{13}	120% P_2O_5/ha " " .
T_{14}	40% P_2O_5/ha applied through IFDC-400.
T_{15}	80% P_2O_5/ha " " .
T_{16}	120% P_2O_5/ha " " .

No. of Treatments	Particulars of Treatment
T_{17}	40% P_2O_5/ha applied through IFDC-605.
T_{18}	80% P_2O_5/ha -do- " .
T_{19}	120% P_2O_5/ha " " .
T_{20}	40% P_2O_5/ha applied through IFDC-816.
T_{21}	80% P_2O_5/ha " " .
T_{22}	120% P_2O_5/ha " " .
T_{23}	40% P_2O_5/ha applied through IFDC-702.
T_{24}	80% P_2O_5/ha " " .
T_{25}	120% P_2O_5/ha " " .

Design :-

All the 25 treatments were allocated in a randomised complete block design having gross subplot size 4M x 3M and replicated thrice.

Cultural practices :-

Thirtyfive days old rice seedlings of variety Pratap were transplanted on 10.8.84. Other cultural practices and collection of plant and soil samples are same as in case of Trial-B_1 (Kharif-Rice). The crop was harvested on 9.11.84. Crop was threshed and grain yields of individual subplots were recorded.

TRIAL -B_2 (Summer crop - Groundnut)

Evaluation of Residual effect :

For the evaluation of the residual effect of the phosphatic fertilizer materials applied in kharif season to the rice crop, a second crop Groundnut was taken in the summer season in the same subplots in the same design as in kharif season. Groundnut variety AK-12-24 was taken.

Cultural practices :-

The groundnut kernels were sown on 5.3.85 @ 35Kg/ha at a spacing of 20 cms x 20 cms.

Except phosphatic fertilisers, Nitrogen @ 20Kg/ha as Calcium Ammonium Nitrate and K_2O @ 40Kg/ha has Muriate of Potash were applied as basal in furrows before sowing.

Germination was facilitated by giving a light irrigation after sowing. The crop was irrigated thrice during the growth period.

Sampling :-

Four plants were collected from 2 rows (leaving the border rows)when the plants were about 45 days old, dried under sun and then in the Oven at 70°C.

The crop was harvested on28.6.85, with a net area of harvest 1M x 1M. The pod yields were recorded.

Five core surface samples were collected from each subplot by soil sampling tube, following harvest of the crop.

(A) SOIL ANALYSIS

Processing of the soil samples :-

The samples collected were air dried under shade and ground with a wooden hammer and allowed to pass through a 2mm sieve and stored in polyethylene packets for further analysis.

Soil analysis :

The moisture percentage and water holding capacity were determined as described by Piper (1950).

Mechanical analysis of the soil was done by the method developed by Bouyoucos (1962).

The pH of 1:1 soils:water and soil: 0.01M $CaCl_2$ suspensions were measured by using Digital pH meter.

The cation exchange capacity was determined by leaching the soil with neutral normal ammonium acetate (Chapman,1965).

Organic carbon was determined by Walkley and Black method (1934).

Exchange acidity was determined by leaching the soil with 1N KCl and titrating the leachate with standard NaOH as described by McLean,1965). Exchangeable Al was determined by adding NaF and back titrating with standard HCl. Exchangeable H^+ was calculated from difference of the total exchange acidity and exchangeable Al.

Fusion extract was prepared by fusing 0.5g 100 mesh soil sample with 4-5g, Na_2CO_3 by means of a platinum crucible following the method described by Jackson (1962).

Total Fe_2O_3 from fusion extract was estimated colorimetrically by using sodium salicylate by the method advocated by Scott (1941). Total Al_2O_3 was estimated colorimetrically using Aluminon method outlined by Robinson George (1950).

Total phosphorus of the soil was determined by digesting the soil with $HClO_4$ method of Volk and Jones(1958) as described by Jackson (1958).

Available 'P' of soil was determined using Olsen's and Bray's-I extractants following the procedure described by Jackson (1958).

(B) PLANT ANALYSIS

Plant samples collected were dried in an Oven at 80°C and the dry weights were taken.

Plants were further dried in an oven at 105°C to facilitate grinding. The plant materials of each treatment were then chopped, ground with a mechanical grinder fitted with 40 mess sieve and stored in aluminium containers for chemical analysis.

Plant samples of 0.5g were taken in 100 ml corning conical flask and 15 ml of concentrated HNO_3 was added and kept over night. Then it was boiled on a hot plate until brown fumes subsided. Five ml. mixture of HNO_3+ $HClO_4$(3:2 ratio) was added and boiled until white fumes accumulate in the flask. Two ml.of 6N HCl was added followed by 20ml of hot distilled water and filtered to 100 ml volumetric flask washing with water and the final volume was made upto mark.

Five ml.of aliquot was taken in 25 ml volumetric flask and 5 c.c. of ammonium vanadomolybdic solution was added and kept for 30 minutes for colour development. Then volume was made upto 25 ml. The degree of absorbance was measured at 420 nm. wavelength in a colorimeter, using standards of 0,2,4,6 and 8 ppm.

(C) STATISTICAL ANALYSIS

The data obtained both from the chemical analysis and from the field experiments were statistically analysed for correlation coefficient and analysis of variance.

CHAPTER-IV
RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Two trials i.e. Trial-B_1 and Trial-B_2 were conducted to evaluate the direct and residual effect of various modified, partially acidulated products of Mussoorie rock phosphate.

Results of the physical and chemical analyses of the soils of the fields where the experiments were conducted have been presented in Table-2.

Soil characteristics of the Trial-B_1 experimental site:

The mechanical analysis shows that the soil is of clay loam texture with 25.26% clay. It has 33.0% water holding capacity. Chemical analysis of the soil reveals that the soil has a low cation exchange capacity of the order 9.2 me/100g. The soil is moderately acidic with a pH of 5.8 and exchange acidity 0.11 me/100g. The soil has 13.35% sesquioxide with good fixing capacity of phosphorus. Available P status is low and organic carbon content is also of the low level.

Soil characteristics of Trial-B_2 experimental site:

The mechanical analysis shows that the soil is of silty loam texture with 20.56% of clay. It has a water holding capacity of 30.0%. Chemical analysis of the soil reveals that the soil has a low cation exchange capacity of the order 7.9 me/100g. The soil is acidic with a pH of 5.2 and exchange acidity 0.15 me/100g. Exchangeable Al

Table-2

Results of Physical and Chemical Analysis of Soils.

Sl. no.	Particulars of Analysis	Results Trial-B_1	Results Trial-B_2
1.	Mechanical Analysis		
	(a) Sand	57.4%	54%
	(b) Silt	17.34%	25.44%
	(c) Clay	25.26%	20.56%
2.	Textural Class	Clay loam	Silty loam
3.	Moisture percentage	2.15%	2.0%
4.	Water holding capacity (Oven dry basis)	33.0%	30.0%
5.	pH_w	5.8	5.2
	pH_s	5.4	4.7
6.	Cation exchange capacity (me/100g)	9.2	7.9
7.	Exchange acidity (me/100g)	0.11	0.15
	(a) Exchangeable Al^{+++}	0.02	0.05
	(b) Exchangeable H^+	0.09	0.10
8.	Sesquioxide percentage		
	(a) Total Fe_2O_3	5.20%	4.90%
	(b) Total Al_2O_3	8.15%	9.25%
	(c) Total Fe_2O_3 + Al_2O_3	13.35%	14.15%
9.	Organic carbon	0.40%	0.61%
10.	Total soil 'P' in percentage	0.018	0.021
11.	Available soil 'P' in ppm		
	(a) Olsen's 'P'	4.2	5.0
	(b) Bray's-I 'P'	3.9	4.5

Table-2

Results of Physical and Chemical Analysis of Soils.

Sl. no.	Particulars of Analysis	Results Trial-B_1	Results Trial-B_2
1.	Mechanical Analysis		
	(a) Sand	57.4%	54%
	(b) Silt	17.34%	25.44%
	(c) Clay	25.26%	20.56%
2.	Textural Class	Clay loam	Silty loam
3.	Moisture percentage	2.15%	2.0%
4.	Water holding capacity (Oven dry basis)	33.0%	30.0%
5.	pH_w	5.8	5.2
	pH_s	5.4	4.7
6.	Cation exchange capacity (me/100g)	9.2	7.9
7.	Exchange acidity (me/100g)	0.11	0.15
	(a) Exchangeable Al^{+++}	0.02	0.05
	(b) Exchangeable H^+	0.09	0.10
8.	Sesquioxide percentage		
	(a) Total Fe_2O_3	5.20%	4.90%
	(b) Total Al_2O_3	8.16%	9.25%
	(c) Total Fe_2O_3 + Al_2O_3	13.36%	14.15%
9.	Organic carbon	0.40%	0.61%
10.	Total soil 'P' in percentage	0.018	0.021
11.	Available soil 'P' in ppm		
	(a) Olsen's 'P'	4.2	5.0
	(b) Bray's-I 'P'	3.9	4.5

also contribute a lot towards soil acidity in this soil. The soil has 14.15% sesquioxide with good fixing capacity of phosphorus. Available phosphorus status of this soil is of low level and organic carbon content is of medium level.

FIELD EXPERIMENT - TRIAL B_1 (Kharif-Rice)

Evaluation of Direct Effect :-

Rice was grown in the kharif season to study the direct effect of the different phosphatic materials taking triple superphosphate as the standard.

(I) Relative effect of phosphate sources on the grain yield of Rice :-

The yield of grain obtained from individual subplots have been converted to yield per hectare and the mean grain yield in q/ha have been presented in Table-3 .

From the table it may be clearly noted that an average yield of 31.8 q/ha was obtained from the control plot whereas the highest mean yield was of the order of 39.9 q/ha. in case of treatment which received IFDC-702 phosphatic fertilizer material. This is about 25% higher than the control and 4% higher than the plot which received triple superphosphate.

Analysis of variance showed that the yield difference due to various treatments were significant. There was highly significant difference between the control and the rest. Although yield difference due to various phosphate sources was not significant , there was significant difference between the different levels of the phosphatic fertilizer materials applied.

Table-3

Mean grain yield of Rice in q/ha as affected by the dose and source of phosphate.

	'P' LEVELS (P_2O_5 in Kg/ha)				
'P' sources	0	40	80	120	MEAN
Control	31.8	-	-	-	31.8
TSP	-	38.7	38.6	37.7	38.3
IFDC-605	-	35.8	39.6	42.3	39.2
IFDC-702	-	38.8	39.3	41.6	39.9
IFDC-810	-	36.6	39.3	40.6	38.8
IFDC-812	-	38.7	38.3	39.3	38.8
IFDC-813	-	36.3	38.4	38.3	37.7
IFDC-816	-	36.7	38.7	38.9	38.1
MEAN	31.8	37.4	38.9	39.8	37.8

	'F' test	S.E.(m)	C.D(0.05)
Treatments	Sig*	1.42	3.9
Control vs.rest	Sig**	1.44	2.8
'P' levels	Sig**	0.53	1.4
'P' source	N.S.		
'P' source x 'P' level	N.S.		

** Significant at 1% level, * Significant at 5% level.

N.S.- Not significant.

The results showed that definitely there was increase in yield over control due to application of various phosphatic fertiliser materials derived from partial acidulation of Mussoorie rock phosphate.

Eventhough there was no significant difference in yield due to various sources, IFDC-702 (50% acidulation with H_3PO_4) proved to be a better source giving the highest grain yield. Mishra and Panda (1969) also found that 50% acidulated materials with H_3PO_4 performed better than lower acidulated material for short duration crop in Bhubaneswar lateritic soils having pH 5.6 and 6.5 .

Higher levels of application of phosphatic fertiliser materials increased the grain yield significantly. However, 80% and 120 % levels were statistically at par.

Effect of phosphate treatments on the uptake of phosphorus by rice at P.I.stage.:-

From the percentage of 'P' in plants and the total dry matter yield at panicle initiation stage the total uptake of 'P' at P.I. stage was found out. The mean uptake of 'P' by rice plant as affected by various phosphorus treatments have been presented in Table-4.

Analysis of variance showed that as regards to total uptake of phosphorus there was no significant difference between various treatments of phosphate sources. But there was significant difference between control vs. rest and the various levels of phosphate application.

Table-4

Mean Uptake of 'P' by rice in Kg/ha at P.I. stage as affected by dose and source of phosphate.

'P' SOURCES	'P' LEVELS (P_2O_5 in Kg/ha.)				MEAN
	0	40	80	120	
Control	9.4	-	-	-	9.4
TSP	-	10.7	10.8	11.4	11.0
IFDC-605	-	10.8	11.1	11.3	11.1
IFDC-702	-	11.4	11.8	12.8	12.0
IFDC-810	-	10.1	11.7	11.2	11.0
IFDC-812	-	10.2	12.5	12.8	11.8
IFDC-813	-	10.4	10.6	11.4	10.8
IFDC-816	-	11.3	11.3	11.4	11.3
MEAN	9.4	10.7	11.4	11.8	11.0

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	N.S.		
Control vs.rest	Sig.*	0.76	1.5
'P' source	N.S.		
'P' levels	Sig*	0.28	0.8
'P' source x 'P' level	N.S.		

* Significant at 5% level.

N.S. - Not significant.

This result showed that definitely there is more uptake of 'P' at P.I. stage due to application of various phosphatic fertilizers, over that of control. Eventhough there is no significant differences between different 'P' sources, highest amount of 'P' uptake was from the treatment that received IFDC-702 material. This is about 27% higher than the control and 9 % higher than the plot which received Triple superphosphate.

Increase in the levels of application of phosphatic fertiliser materials increased the total uptake of 'P' at P.I. stage significantly.

Effect of phosphate treatments on the available 'P' status of soil :-

The available soil phosphorus was extracted both by Olsen's and Bray's-I method after harvest of the crop.

The average Olsen's 'P' status of soil after harvest of the rice crop have been presented in Table 5.

Analysis of variance showed that there was significant differences between different treatments, control vs. rest, different phosphatic fertiliser sources and various levels of phosphatic fertiliser application.

This is quite indicative that different phosphatic fertilizer materials helped in building up of the phosphate level of soil over that of control.

Amongst various phosphate sources IFDC-702 (50% acidulated with H_3PO_4) also proved to be a better source in building up of the 'P' level in soil followed by IFDC-816 (25% acidulated with H_3PO_4). The dry matter yield and uptake of phosphorus as measured at panicle initiation stage were

Table-5

Mean available Olsen's 'P' of soil in ppm as affected by dose and source of phosphate.

'P' sources	'P' LEVELS (P_2O_5 in Kg/ha) 0	40	80	120	Mean
Control	3.4	-	-	-	3.4
TSP	-	4.6	5.3	6.3	5.4
IFDC-605	-	4.9	5.9	6.9	5.9
IFDC-702	-	5.4	5.8	9.0	6.7
IFDC-810	-	4.3	4.9	6.6	5.3
IFDC-812	-	4.3	5.8	7.1	5.7
IFDC-813	-	4.4	5.0	5.9	5.1
IFDC-816	-	4.4	5.9	8.3	6.2
MEAN	3.4	4.6	5.5	7.2	5.5

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	Sig**	0.40	1.1
Control vs.rest	Sig**	0.41	0.8
'P' sources	Sig**	0.22	0.6
'P' Levels	Sig**	0.15	0.4
'P' source x 'P'level N.S.			

** Significant at 1% level

N.S. - Not significant.

highest with the treatment receiving IFDC-702 source was possible because this material has a combination of water soluble, citrate soluble and citrate insoluble sources of phosphorus. Water soluble source was used by the plant as a starter phosphate whereas the citrate insoluble source was released slowly, due to inherent acidity of the soil. The Olsen's P as measured after harvest was also highest under this treatment because fixation of water-soluble phosphorus was minimum. The acidity created by the transformation of watersoluble 'P' to $CaHPO_4$ and H_3PO_4 did help in the dissolution of the unreacted rock phosphate. This result is in confirmity with the result of McLean and Wheeler (1964).

Increase in the level of application of phosphatic fertiliser sources increased the available 'P' status of soil significantly. This result corroborated with the results of Mundal et al (1977) and Bailey et al. (1977).

The available Bray's-I 'P' status of soil have been presented in Table-6. Analysis of variance showed that there was no significant difference between control vs. rest but there was significant difference between various treatments. 'P' sources and 'P' levels. In this also IFDC-702 source proved to be best source and increased level of application of phosphate increased the 'P' status of soil significantly.

Table-6

Mean available Bray's-I 'P' of soil in ppm as affected by dose and source of phosphate.

	'P' Levels (P_2O_5 in Kg/ha)				
'P' sources	0	40	80	120	Mean
Control	3.5	-	-	-	3.5
TSP	-	3.6	4.2	4.7	4.2
IFDC-605	-	2.7	3.6	4.8	3.7
IFDC-702	-	3.2	3.9	7.7	4.9
IFDC-810	-	2.9	3.5	4.6	3.7
IFDC-812	-	3.4	3.7	4.4	3.8
IFDC-813	-	3.0	3.3	4.1	3.5
IFDC-816	-	3.3	4.0	6.9	4.7
MEAN	3.5	3.2	3.7	5.3	4.0

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	Sig**	0.43	1.2
Control vs.rest	N.S.		
'P' sources	Sig**	0.25	0.7
'P' levels	Sig**	0.16	0.4
'P' source x 'P' level	Sig*	0.43	1.2

* Significant at 5% level.
** Significant at 1% level.
N.S.- Not significant.

Correlation studies :-

(a) Available 'P' estimated by Olsen's and Bray's-I methods after harvest of the rice crop were significantly and positively correlation values r = 0.706 and 0.517 respectively (Fig.1).

This indicated that the grain yield of the rice is verymuch influenced by the available 'P' level of the soil. Hence it is highly desirable to maintain a good status of 'P' in the soil to produce a good crop of paddy.

(b) Available 'P' estimated by Olsen's and Bray's-I method were significantly and positively correlated with the uptake of phosphorus by the crop at P.I. stage with coefficient of correlation values r = 0.74 and 0.522 respectively,(Fig.2).

This indicated that the uptake of phosphorus at the P.I. stage is much influenced by the available 'P' status of soil. The 'P' status of soil naturally depended on the dose of applied phosphorus and the type of the carrier used.

(c) Relationship between uptake of 'P' and grain yield was worked out. A highly significant and positive correlation with coefficient of correlation value r = 0.631 was obtained between the two parameters. From the 'P' uptake values, one may notice that greater the available 'P' status of soil greater is the uptake and so also the grain yield.

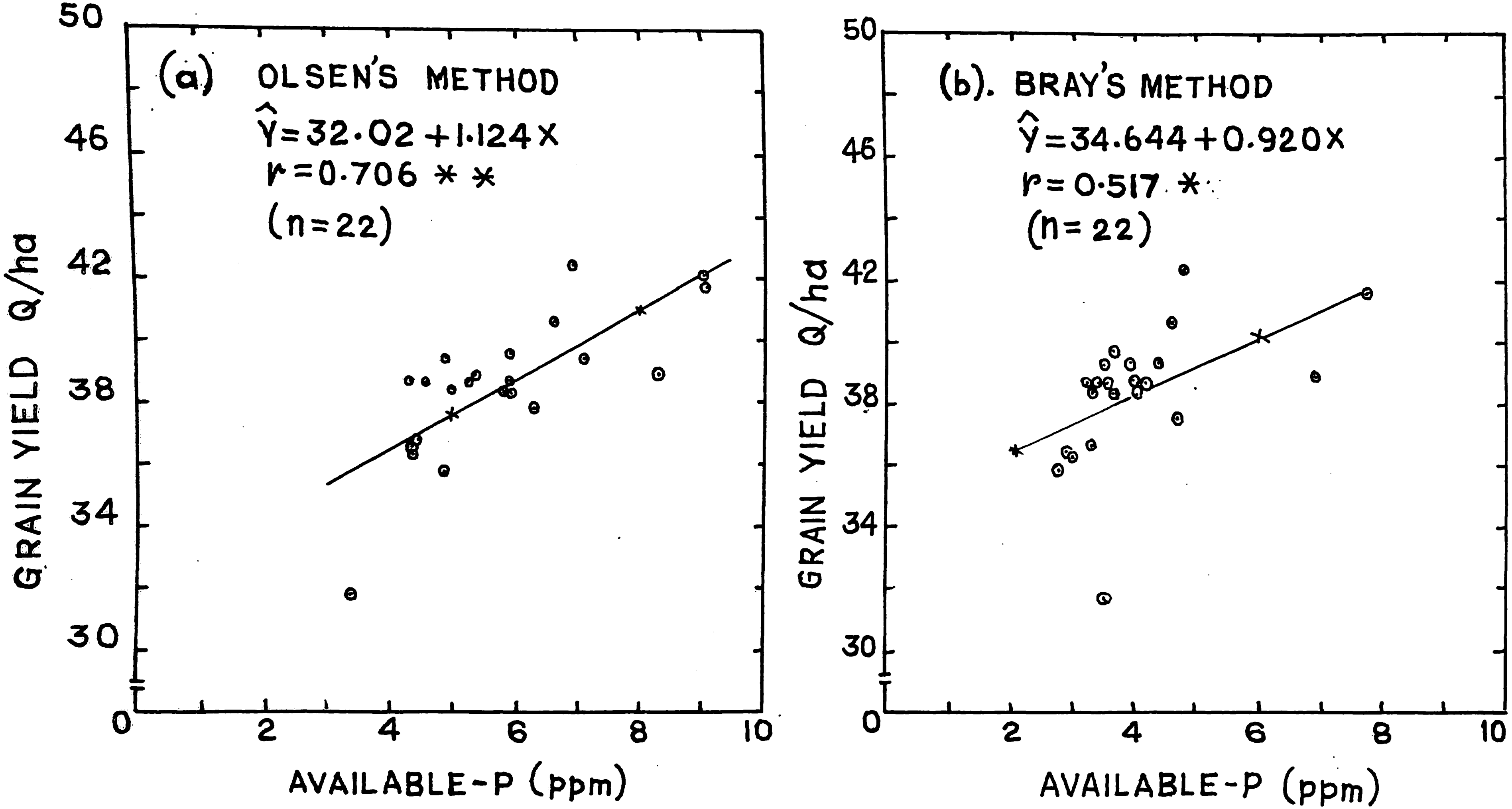

Fig.1 RELATIONSHIP BETWEEN AVAILABLE-'P' AND GRAIN YIELD OF RICE (TRIAL-B_1)

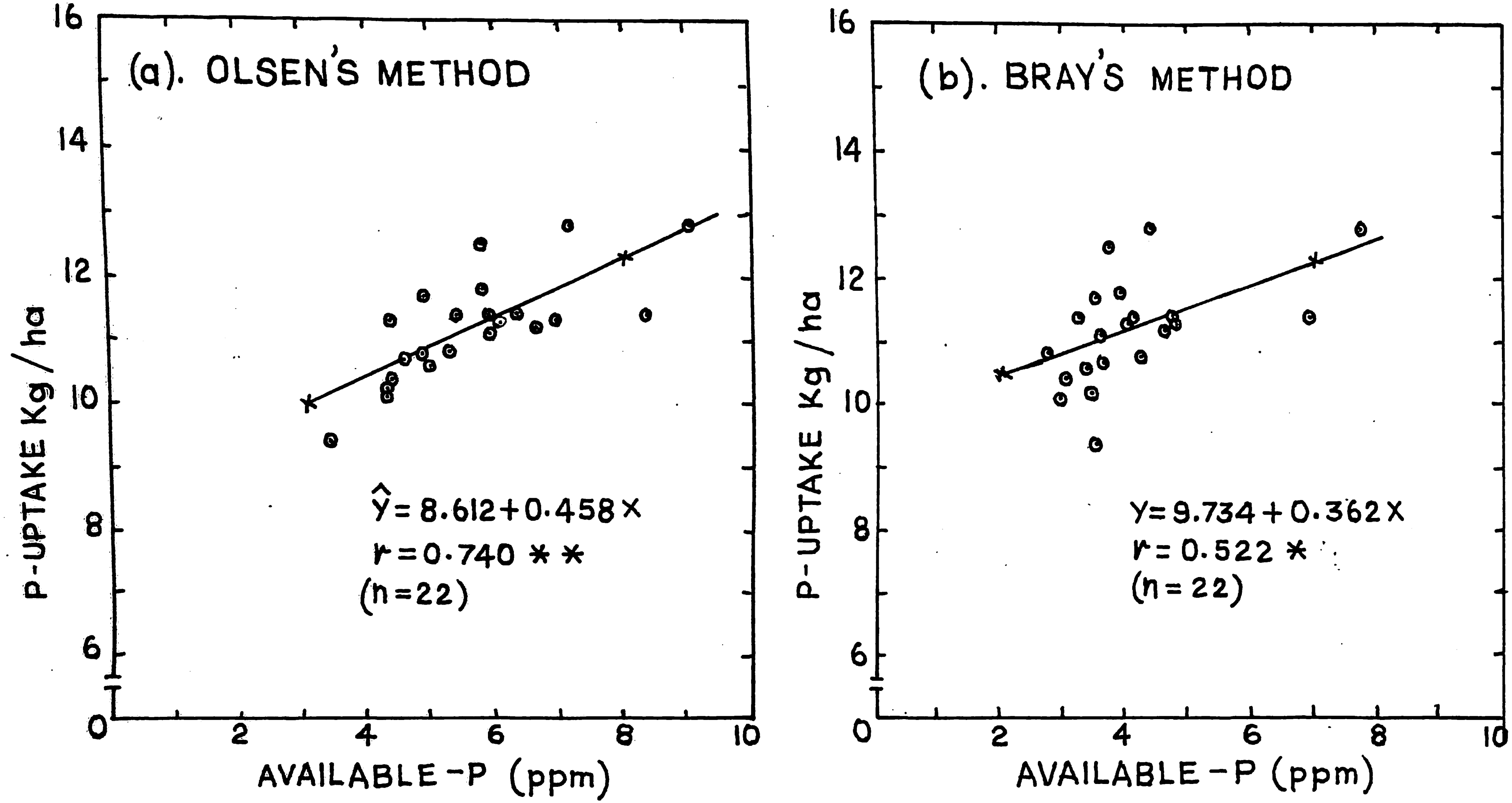

Fig.2. RELATIONSHIP BETWEEN AVAILABLE-P AND P-UPTAKE OF RICE AT P.I. STAGE (TRIAL-B_1)

(I) Residual effect of phosphate sources on the grain yield of greengram.

The yield of grain obtained from individual subplots have been converted to yield per hectare and the average grain yield in q/ha have been presented in Table-7.

Results indicated that an average yield of 7.9 q/ha was obtained from the control plots whereas the highest mean yield was of the order of 9.5 q/ha, in case of treatments which received IFDC-313 (granulated PAPR treated with 25% H_3PO_4) and IFDC-605 (acidulated with 40% H_2SO_4), phosphate sources. There were 20% higher grain yield in these treatments as against control but as against triple superphosphate the yield increase was of the order of 3% only.

Analysis of variance showed that there was highly significant difference between the control vs. rest and different phosphate levels, but difference in yield due to residual effect of various phosphate sources was not significant.

Table-7

Mean grain yield of greengram in q/ha. as affected by residual effect of ' P ' treatments

	'P' LEVELS (P_2O_5 in Kg/ha applied to kharif crop)				
'P' sources	0	40	80	120	MEAN
Control	7.9	-	-	-	7.9
TSP	-	8.8	9.0	9.9	9.2
IFDC-605	-	8.9	9.7	9.9	9.5
IFDC-702	-	8.7	9.1	9.8	9.2
IFDC-810	-	8.9	9.2	9.9	9.3
IFDC-812	-	8.6	9.6	9.8	9.3
IFDC-813	-	9.0	9.6	10.0	9.5
IFDC-816	-	9.0	9.4	9.9	9.4
MEAN	7.9	8.8	9.4	9.9	9.2

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	N.S.		
Control vs.rest	Sig**	0.48	0.9
'P' sources	N.S.		
'P' levels	Sig**	0.18	0.5
'P' source x 'P' level	N.S.		

** Significant at 1% level.

N.S.- Not significant

The results indicated that definitely there was increase in yield over control due to the residual effect of various phosphatic fertiliser materials.

Even-though there was no significant difference amongst various P-sources, IFDC-313 and IFDC-605 sources proved as better sources. Partial acidulation either with 25% H_3PO_4 or 40% H_2SO_4 yielded the same result in respect of grain yield as far as residual effects are concerned. A partially acidulated insoluble phosphatic source like rock phosphate when reacts with the soil for a longer period is able to show its long range effect reflecting in the grain yield. Higher levels of application of all phosphate sources in kharif season increased the grain yield of summer crop significantly due to their residual effects. This result corroborated with the result of Debnath and Basak (1984).

(II) Uptake of 'P' at preblooming stage as affected by residual effect of phosphate treatments :-

The total uptake of 'P' was calculated from the 'P' concentration and the total dry matter yield at preblooming s tage and have been presented in Table-3.

Analysis of variance showed that with respect to 'P' uptake residual effect of various sources was not significant, but significant difference was found between the treatments and the various levels of phosphate application.

The results showed that the 'P' uptake is more due to residual effect of phosphate application over control and the uptake is more due to increased levels of phosphate application to the kharif crop irrespective of sources.

Table-8

Mean uptake of 'P' by greengram in Kg/ha at preflowering stage as affected by residual effect of 'P' treatments.

	'P' LEVELS (P_2O_5 Kg/ha applied to kharif crop)				
'P' sources	0	40	80	120	MEAN
Control	1.6	-	-	-	1.6
TSP	-	1.7	2.0	2.0	1.9
IFDC-605	-	1.9	1.9	2.3	2.0
IFDC-702	-	1.6	1.8	2.2	1.9
IFDC-810	-	1.5	1.8	2.3	1.9
IFDC-812	-	1.6	1.9	2.2	1.9
IFDC-813	-	1.8	2.0	2.7	2.2
IFDC-816	-	1.7	2.1	2.3	2.0
MEAN	1.6	1.7	1.9	2.3	1.9

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	Sig*	0.18	0.5
Control vs.rest	N.S.		
'P' sources	N.S.		
'P' levels	Sig**	0.07	0.2
'P' source x 'P'level	N.S.		

* Significant at 5% level.

** Significant at 1% level.

N.S. - Not significant.

(III) <u>Available 'P' status of soil</u> :

The available 'P' status of soil estimated by Bray's-I method have been presented in Table-6. Analysis of variance showed that there is no significant difference between various 'P' sources, but there is significant differences between the levels of phosphate applied.

The result indicated that higher level of phosphate application to the main crop, also increased the residual available 'P' status of soil, that influenced the second crop.

<u>Correlation Studies</u> :

(a) Available soil phosphorus estimated by Bray's-I method were significantly and positively correlated with the grain yield of greengram with coefficient of correlation value r = 0.564 (Fig. 3a).

This showed that the grain yield is verymuch influenced by the available 'P' status of soil be it due to residual effect or immediate prior application.

(b) Available Bray's-I 'P' were significantly and positively correlated with the total uptde of phosphorus by the greengram crop at preflowering stage with a coefficient of correlation value r = 0.583 (Fig.3b).

This indicated that the total uptake of phosphorus by the crop is influenced by the available 'P' level of soil. The residual 'P' level of soil depended on

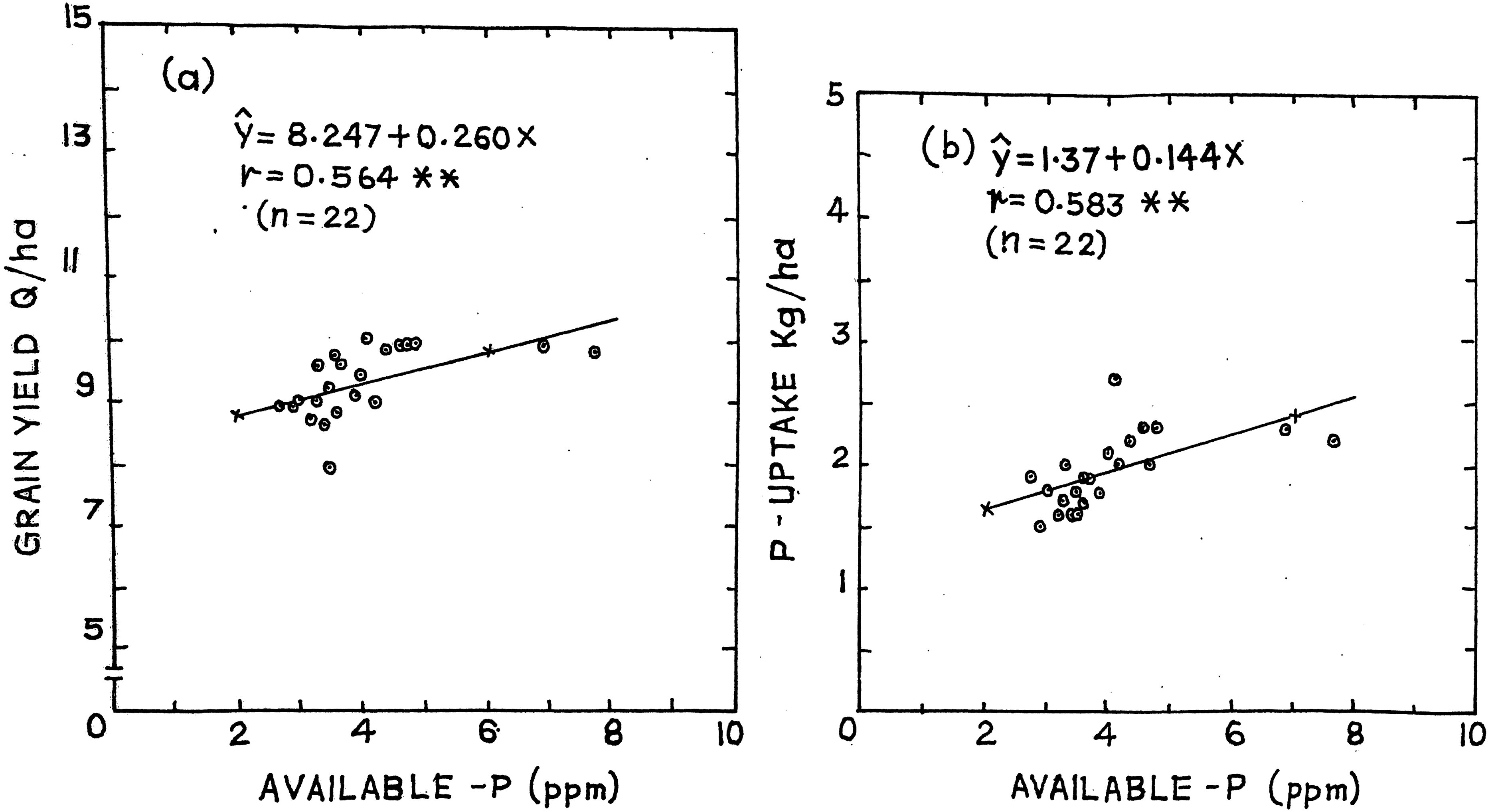

Fig. 3. RELATIONSHIP OF AVAILABLE SOIL-P (BRAY'S) WITH (a) GRAIN YIELD OF GREEN GRAM (b) P.UPTAKE AT PRE FLOWERING STAGE (TRIAL-B_1)

the dose of applied phosphorus and the type of carrier used for the previous crop.

(e) Relationship between the uptake of 'P' by the plant at preflowering stage and grain yield was worked out. A highly significant positive correlation with coefficient of correlation value $r = 0.823$ was obtained between the above two parameters.

It indicated that the grain yield is verymuch influenced by the total 'P' uptake of the plant.

FIELD EXPERIMENT - TRIAL-B_2(Kharif-Rice)

EVALUATION OF DIRECT EFFECT :

Direct effect of phosphatic sources were compared as against triple superphosphate taking rice as a test crop in the kharif season.

(I) Relative effect of phosphate sources on the grain yield of rice :

The yield of grain obtained from individual subplots have been converted to yield per hectare and the average grain yield in q/ha from different phosphate treatments have been presented in Table-9.

From the table it may be noted that an average yield of 26.8 q/ha was obtained from the control plot whereas the highest mean yield was of the order 31.4 q/ha. in case of treatment which received IFDC-702 source (60% acidulation with H_3PO_4) which amounts to 17% more than the control and 5% more than that of the treatment which received triple superphosphate.

Table-9

Mean grain yield of Rice in q/ha. as affected by the dose and source of phosphate.

'P sources	'P' LEVELS (P_2O_5 in Kg/ha) 0	40	80	120	MEAN
Control	26.8	-	-	-	26.8
TSP	-	30.6	29.8	28.7	29.7
MPR	-	26.2	28.3	29.9	28.1
MPR-C	-	24.5	26.8	29.2	26.8
IFDC-301	-	29.6	28.2	30.3	29.4
IFDC-400	-	27.4	28.9	28.9	28.4
IFDC-606	-	26.5	28.7	28.8	28.0
IFDC-816	-	28.1	29.5	29.4	29.0
IFDC-702	-	30.2	31.6	32.3	31.4
MEAN	26.8	27.9	29.0	29.7	28.6

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	Sig**	1.1	3.0
Control vs.rest	N.S.		
'P' sources	Sig*	0.63	1.7
'P' levels	Sig**	0.39	1.0
'P' source x 'P'level	N.S.		

* Significant at 5% level.

** Significant at 1% level.

N.S. - Not significant.

Analysis of variance showed that the yield differences due to various treatments are significant. There is significant difference between the sources and also the various levels of phosphate applied.

The results showed that there is increase in yield over control due to application of phosphate, and amongst the various sources IFDC-702 was found to be the best source which was statistically at par with triple super-phosphate. Other sources following IFDC-702 are in the order IFDC-301 $\geq$ IFDC-816 $\geq$ IFDC-400 $\geq$ MPR $\geq$ IFDC-605 $\geq$ MPR-C.

In this trial also IFDC-702 (50% acidulated with H_3PO_4) source proved as a better source for rice in acid soils.

However, higher levels of phosphate application increased the grain yield significantly. There were hardly any significant difference in grain yield between 80 and 120 Kg P_2O_5/ha application.

(II) Uptake of 'P' at P.I. stage as affected by phosphate treatments :

From the percentage of 'P' in plants and the total dry matter yield at panicle initiation stage, the total 'P' uptake was found out. The average uptake of 'P' by rice plant at P.I. stage as affected by various P-treatments have been presented in Table-10.

Analysis of variance showed that there was no significant difference between different phosphate sources in respect of total 'P' uptake, but there was significant difference between the control vs.rest and the different levels of applied phosphate.

Table-10

Mean uptake of 'P' by rice in Kg/ha at P.I. stage as affected by dose and source of phosphate.

'P' SOURCES	'P' LEVELS (P_2O_5 in Kg/ha)				MEAN
	0	40	80	120	
Control	9.4	-	-	-	9.4
TSP	-	11.0	11.6	11.6	11.4
MPR	-	10.2	11.2	11.1	10.8
MPR-C	-	10.9	11.6	11.0	11.2
IFDC-301	-	10.7	10.8	10.9	10.8
IFDC-400	-	10.5	10.9	11.3	10.9
IFDC-605	-	10.4	10.5	11.0	10.6
IFDC-816	-	10.9	11.2	11.6	11.2
IFDC-702	-	10.3	11.7	12.5	11.5
MEAN	9.4	10.6	11.2	11.4	10.8

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	N.S.		
Control vs.test	Sig**	0.61	1.2
'P' sources	N.S.		
'P' levels	Sig*	0.23	0.6
'P' source x 'P' level	N.S.		

* Significant at 5% level.

** Significant at 1% level.

N.S. - Not significant.

This result showed that definitely there is more uptake of 'P' at P.I. stage by rice due to application of phosphatic fertilizer materials, over that of control. Though significant difference was not found between 'P' sources, still the P uptake was more from the treatment that received IFDC-702, followed by TSP. Increased levels of phosphate application definitely increased the uptake of 'P' significantly. However, 80 and 120 Kg P_2O_5/ha applied did not significantly increase the uptake of 'P'.

(III) Effect of phosphate treatment on the available 'P' status of soil :

The available soil 'P' was determined both by Olsen's and Bray's-I method, after harvest of the rice crop.

The average 'P' status of soil estimated by Olsen's method have been presented in Table-11.

Analysis of variance showed that difference between different phosphate sources was not significant in building up of the 'P' status of soil, but significant difference was found between various levels of phosphate applied.

Available 'P' status of soil estimated by Bray's-I method have been presented in Table-12.

Analysis of variance showed that difference between 'P' sources was not significant as regards the available 'P' status of soil, but significant difference was found between control vs.rest and the different levels of phosphorus application.

Table-11

Mean available Olsen's 'P' of soil in ppm as affected by dose and source of phosphate.

	'P' LEVELS (P_2O_5 in Kg/ha)				
'P' SOURCES	0	40	80	120	MEAN
Control	5.4	-	-	-	5.4
TSP	-	5.9	6.7	7.5	6.7
MPR	-	5.1	6.2	7.0	6.1
MPR-C	-	5.3	6.5	7.2	6.3
IFDC-301	-	5.4	5.9	6.5	5.9
IFDC-400	-	5.8	6.3	7.5	6.5
IFDC-605	-	5.9	6.0	8.8	6.9
IFDC-816	-	5.1	6.6	7.6	6.4
IFDC-702	-	5.4	6.3	8.7	6.8
MEAN	5.4	5.5	6.3	7.6	6.3

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	Sig**	0.60	1.6
Control vs.rest	N.S.		
'P' sources	N.S.		
'P' levels	Sig**	0.20	0.5
'P' source x 'P' level	N.S.		

** Significant at 1% level

N.S. - Not significant.

Table-12

Mean available Bray's-I 'P' of soil in ppm as affected by dose and source of phosphate

	'P' LEVELS (P_2O_5 in Kg/ha)				
'P' sources	0	40	80	120	MEAN
Control	4.2	-	-	-	4.2
TSP	-	4.8	5.5	6.2	5.5
MPR	-	4.4	5.2	5.9	5.2
MPR-C	-	4.1	5.4	6.2	5.2
IFDC-301	-	3.6	4.6	5.5	4.6
IFDC-400	-	4.1	5.0	5.7	4.9
IFDC-605	-	4.3	5.5	6.3	5.4
IFDC-816	-	4.1	5.5	6.1	5.2
IFDC-702	-	4.2	5.1	8.6	6.0
MEAN	4.2	4.2	5.2	6.3	5.1

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	Sig**	0.52	1.4
Control vs.rest	Sig*	0.51	1.0
'P' sources	N.S.		
'P' levels	Sig**	0.19	0.5
'P' source x 'P' level	N.S.		

* Significant at 5% level.

** Significant at 1% level.

N.S. - Not significant.

Results of both the soil test indicated that different phosphatic fertiliser materials helped in building up of the 'P' status of soil over that of control. Higher level of application of phosphate sources increased the available 'P' status of soil significantly. This result is in consonance with the results of Hundal et al (1977) and Bailey et al (1977) that sources with low water solubility perform better at higher, than at lower rate of application. Higher rate of application of rock phosphate give not only higher crop yield and 'P' uptake but also improve the available 'P' status of soil.

Correlation studies :

(a) Available phosphorus estimated by Olsen's and Bray's-I method were significantly and positively correlated with the total uptake of phosphorus by the crop at panicle initiation stage with coefficient of correlation values r = 0.473 and 0.731 respectively (Fig.4).

This indicated that the total uptake of phosphorus by the rice crop at P.I. stage is much influenced by the available 'P' level of the soil. The level of available 'P' naturally depended on the dose of applied phosphorus and the type of carrier used.

(b) Available Olsen's P and Bray's-I 'P' were significantly and positively correlated with the grain yield of rice with coefficient of correlation with value r = 0.473 and 0.539 respectively (Fig.5). This indicated

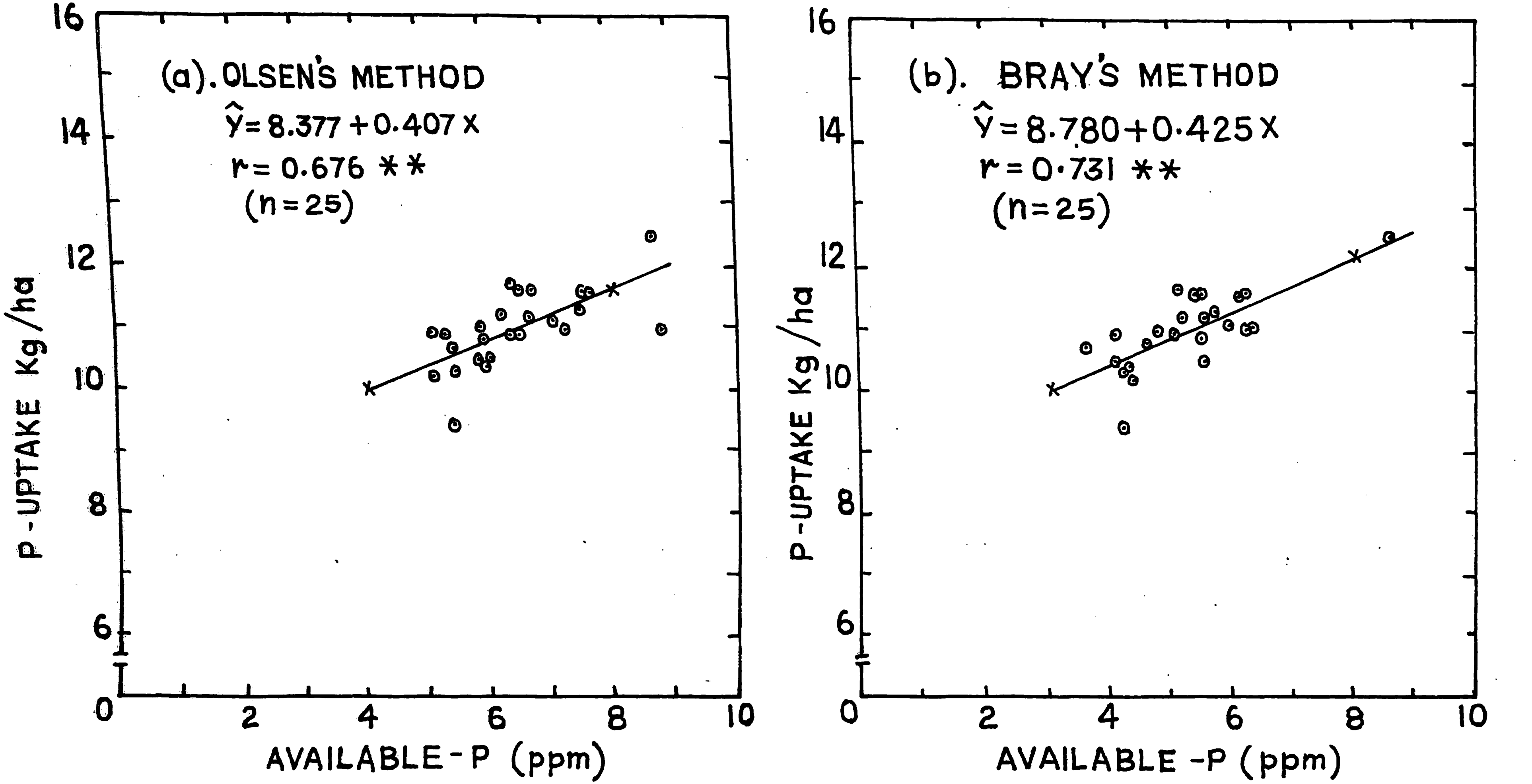

Fig.4. RELATIONSHIP BETWEEN AVAILABLE-P AND P UPTAKE BY RICE AT P.I. STAGE (TRIAL-B_2)

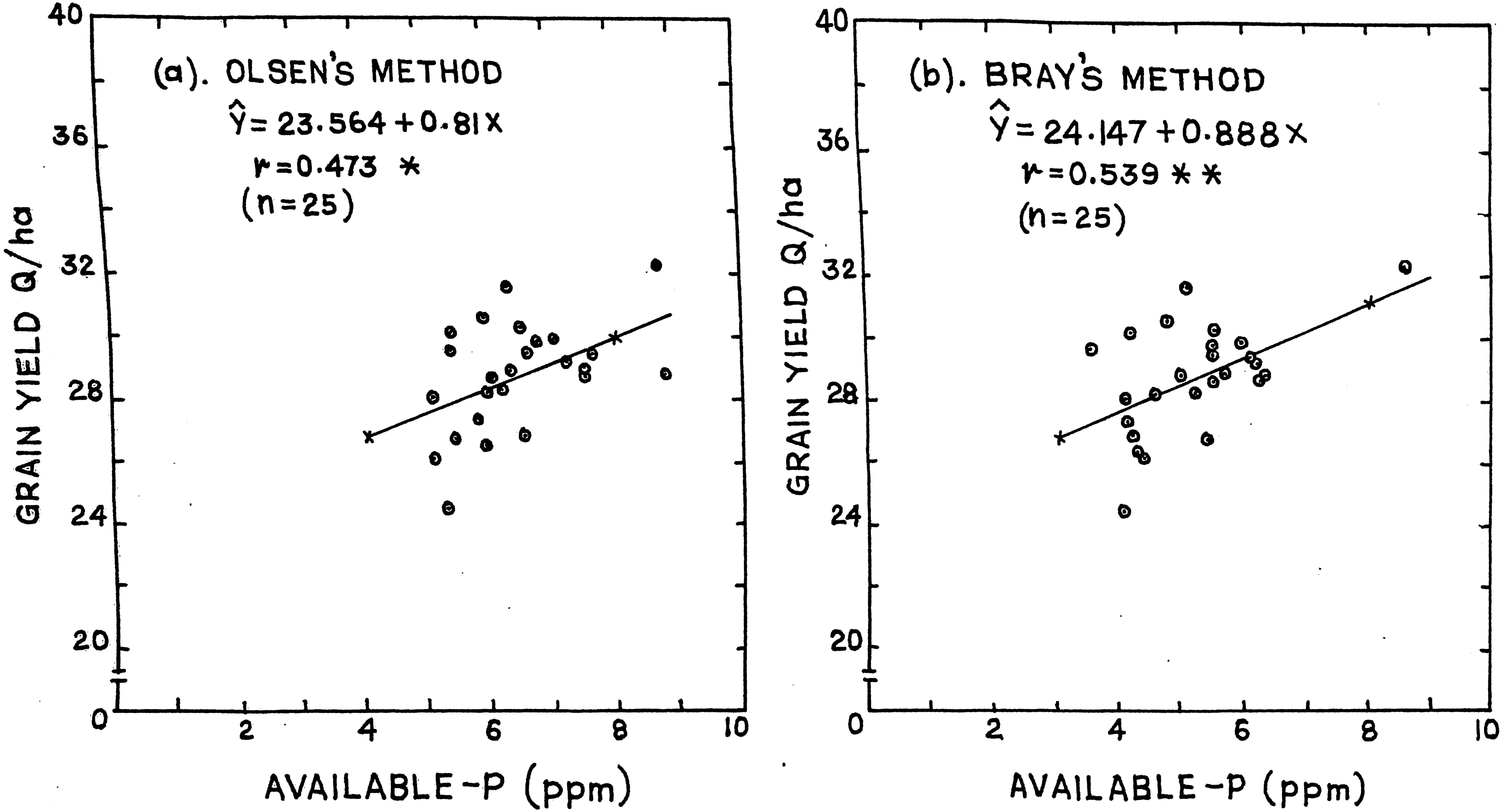

Fig. 5. RELATIONSHIP BETWEEN AVAILABLE-P AND GRAIN YIELD OF RICE (TRIAL-B_2)

that the grain yield is verymuch influenced by the available phosphorus status of soil and hence it is highly desirable to maintain a good status of 'P' in soil to get better yield.

(c) Relationship between the uptake of 'P' by the plant at P.I. stage and grain yield was worked out. A highly significant positive correlation with coefficient of correlation value r = 0.533 was obtained between the above two parameters.

It showed that grain yield is influenced by the total 'P' uptake of the plant, which is ultimately influenced by the available 'P' level of soil.

TRIAL- B_2 (Summer crop - Groundnut)

Evaluation of Residual Effect :

A summer crop of groundnut was grown after rice to study the residual effect of phosphatic sources already applied to rice during the preceding kharif season.

(I) Relative residual effect of phosphate sourceson the pod yield of groundnut :

The pod yield obtained from individual subplots have been converted to yield per hectare and the average pod yield in q/ha have been presented in Table-13.

It may be noted from the table that an average pod yield of 14.2 q/ha was obtained from the control whereas the highest mean yield was of the order of 17.7 q/ha in case of treatment which received IFDC-301 (Mini - granulated with 8% H_2SO_4 as binder) phosphate source.

Table-13

Residual effect of phosphate sources on the mean [illegible] pod yield of groundnut in q/ha.

'P' SOURCES	'P' LEVELS (P_2O_5 in Kg/ha)				MEAN
	0	40	80	120	
Control	14.2	-	-	-	14.2
TSP	-	14.3	15.3	17.1	15.6
MPR	-	15.9	17.3	18.8	17.3
MPR-C	-	14.5	16.2	17.9	16.2
IFDC-301	-	15.8	17.9	19.3	17.7
IFDC-400	-	14.4	16.3	17.4	16.0
IFDC-605	-	15.1	17.3	18.3	16.9
IFDC-816	-	15.0	18.1	18.9	17.3
IFDC-702	-	14.1	15.2	17.5	15.6
MEAN	14.2	14.9	16.7	18.2	16.3

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	Sig*	1.15	3.1
Control vs.rest	Sig*	1.13	2.2
'P' sources	N.S.		
'P' levels	Sig**	0.41	1.1
'P' sources x 'P' levels	N.S.		

* Significant at 5% level.
** Significant at 1% level .
N.S.- Not significant

In the phosphate treated plots the mean yield varied between 15.6 to 17.7 q/ha. Thus it may be seen that the plot which received IFDC-301 yielded 24.6% higher than the control. However, this difference was narrowed down to 13% when compared with the treatment which received triple superphosphate. When yields obtained from the plot receiving triple superphosphate and ground rock phosphate are seen the yield difference is of the order of 11%. Looking at the economic benefit of this 11% difference and lower cost of input in terms of phosphorus from rock phosphate, one would be convinced that for such acid soil, rock phosphate is preferable to completely water soluble source like triple superphosphate. The difference of cost per Kg of P_2O_5 from triple superphosphate and ground Mussoorie rock phosphate is of the order of Rs.2.40 . This difference amounts to Rs.192/- when 80 Kg P_2O_5 is applied and it is Rs.96/- when 40kg is applied.

Analysis of variance showed that there was significant difference between various treatments, control vs. rest and the different levels of phosphate applied as regards the yield of the crop, but there was no significant difference in yield due to residual effect of various phosphate sources.

The results indicated that definitely there was increase in yield over control due to the residual effect of various phosphate sources. Eventhough there was no significant difference between various P-sources still

IFDC-301 and IFDC-316 showed better residual effect, in increasing the yield in comparison to other sources. Higher levels of application of all the P-sources in kharif season increased the pod yield of groundnut in summer season significantly due to their residual effects.

(II) Uptake of 'P' at preflowering stage as affected by the residual effect of 'P' treatments.

From the percentage of 'P' in plants and the total dry matter yield at preflowering stage the total uptake of 'P' was found out and have been presented in Table 14.

Analysis of variance showed that as regard the total uptake of 'P' by the crop there is no significant difference between residual effect of various sources, but significant difference was found between control vs. rest and the various levels of phosphate applied.

The results showed that the 'P' uptake was more due to residual effect of phosphate application over that of control and the uptake is more due to higher level of phosphate application to the kharif crop irrespective of all the phosphate sources.

(III) Available 'P' status of soil :

The available 'P' status of soil estimated by Bray's-I method have been presented in Table 12. Analysis of variance showed that there is no significant difference between various phosphate sources in building up of the available 'P' status of soil, but there is significant difference between the levels of phosphate applied.

Table-14

Residual effect of phosphate sources on the mean uptake of 'P' by groundnut at preflowering stage in Kg/ha.

'P' SOURCES	'P' LEVELS (P_2O_5 in Kg/ha applied to the kharif crop)				MEAN
	0	40	80	120	
Control	3.0	-	-	-	3.0
TSP	-	3.5	3.8	4.3	3.9
MPR	-	3.6	4.0	4.6	4.1
MPR-C	-	3.8	4.5	4.5	4.3
IFDC-301	-	3.9	4.7	4.7	4.4
IFDC-400	-	4.2	4.5	4.6	4.4
IFDC-605	-	4.5	4.7	4.7	4.6
IFDC-816	-	3.9	4.4	4.7	4.3
IFDC-702	-	4.0	4.1	4.8	4.3
MEAN	3.0	3.9	4.3	4.6	4.1

	'F' test	S.E.(m)	C.D.(0.05)
Treatments	Sig*	0.33	0.9
Control vs.rest	Sig**	0.31	0.6
'P' sources	N.S.		
'P' levels	Sig**	0.12	0.3
'P' source x 'P' level	N.S.		

* Significant at 5% level.

** Significant at 1% level

N.S. - Not significant.

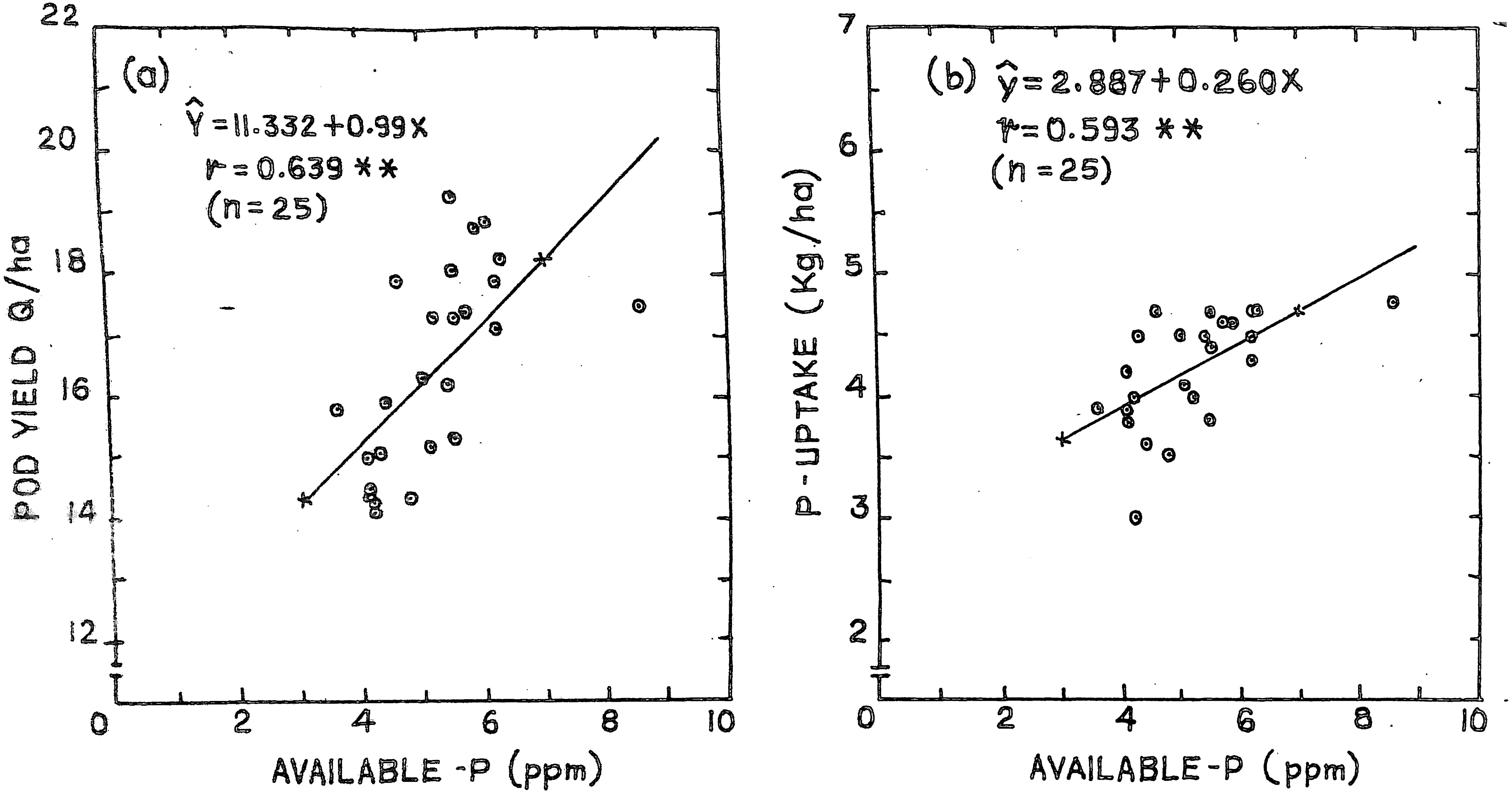

Fig. 6. RELATIONSHIP OF AVAILABLE SOIL-P (BRAY'S) WITH (a) POD YIELD OF GROUNDN
(b). P-UPTAKE AT PRE FLOWERING STAGE (TRIAL-B_2)

The result indicated that higher level of phosphate application to the main crop also increased the residual available 'P' status of soil that influenced the second crop.

Correlation studies :

(a) Available phosphorus estimated by Bray's-I method were significantly and positively correlated with the pod yield of groundnut with coefficient of correlation value r = 0.639 (Fig.6a). This indicated that the pod yield is verymuch influenced by the available 'P' status of soil.

(b) Available Bray's-I 'P' were significantly and positively correlated with the total uptake of 'P' by the groundnut crop at preblooming stage with a coefficient of correlation value r = 0.593 (Fig.6b). This revealed that the total uptake of 'P' by the crop is also influenced by the available 'P' lev el of soil. The residual 'P' level of soil naturally depended on the dose of applied phosphorus and the type of carrier used for the previous crop.

(c) Relationship between the uptake of 'P' by the plant at preblooming stage and pod yield was found out. A highly significant positive correlation with coefficient of correlation value r = 0.752 was obtained between the above two parameters.

It showed that the pod yield is verymuch influenced by the total 'P' uptake of the plant.

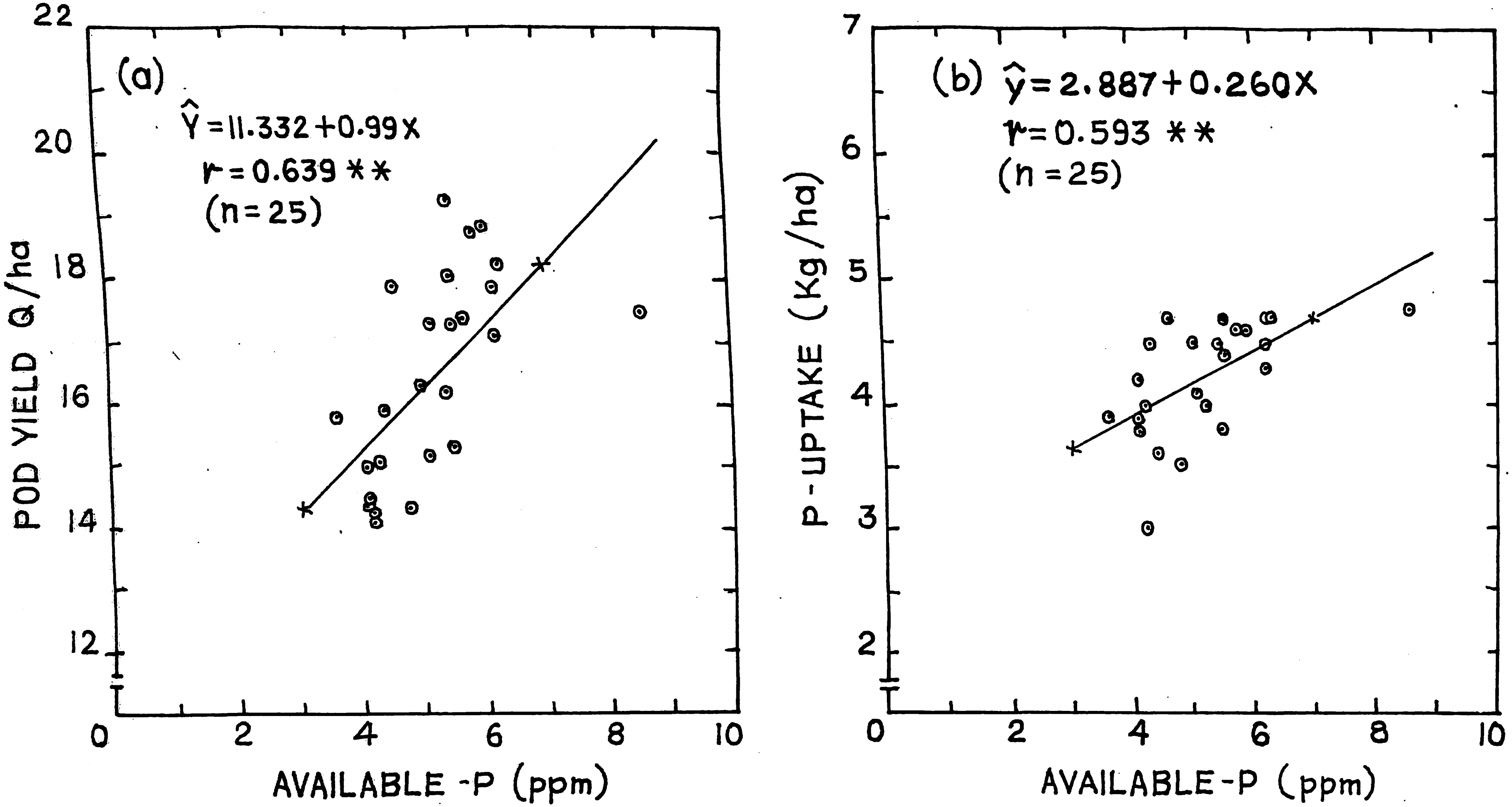

Fig.6. RELATIONSHIP OF AVAILABLE SOIL-P (BRAY'S) WITH (a) POD YIELD OF GROUNDNUT (b). P-UPTAKE AT PRE FLOWERING STAGE (TRIAL-B_2)

CHAPTER-V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Two field experiments namely B_1 and B_2 were conducted in the 'D' block of the Central Research Station of the Orissa University of Agriculture and Technology to test the efficiency of Mussoorie rock phosphate and its partially acidulated products as compared to triple superphosphate in cropping sequences of rice-greengram and rice-groundnut. These trials were conducted in medium land where ground water table in the rainy season comes close to the surface. The soils of both the fields are classified as Haplaquept (lateritic). The textural classes of the experimental sites are clay loam and silty loam respectively. The dominant clay mineral as identified by earlier workers is kaolinite-illite. Fair amounts of hydrous oxide clay are also present.

In the B_1 trial (soil pH 5.8) HYV paddy "Pratap" (OR-131-3-1) was grown during the kharif season in a randomised block design with 22 treatments and 3 replications. Here 7 different phosphate carriers were tested at three levels i.e. 40,80 and 120 Kg P_2O_5/ha. Rice crop received an uniform dose of 75% N/ha applied in 3 splits, 37.5% N as basal, 18.75 Kg, 15 days after transplanting and the rest 7 days before panicle initiation. Potassium was applied @ 60 Kg K_2O/ha as muriate of potash in 2 splits i.e. 30 Kg as basal and 30 Kg at 10 days before panicle initiation. The phosphatic sources were compared taking into considerations the grain yield and phosphorus uptake at panicle initiation stage. Soil samples collected from each treatment were tested for Bray's-I and Olsen's 'P'. Correlations were worked out between the phosphorus uptake and yield of grain and soil test 'P' values with phosphorus uptake and grain yield. Grain yield from the control plot which did not receive any ('P' yielded 31.8 q/ha whereas the yield from the plot receiving IFDC-702 (50% H_3PO_4 partially acidulated) was 39.9 q/ha giving an increase of 25%. However, this increase was of the order of only 4% as compared to the plot receiving triple superphosphate. Both available 'P' of soil as extracted by Bray's-I and Olsen's method had significant correlations with the grain yield and uptake of 'P' by the crop. The uptake of phosphorus at panicle initiation stage and grain yield also significantly correlated with 'r' value of 0.631.

Greengram (Hyb.12-4) was grown as the second crop under B_1 trial with residual phosphorus without any fresh 'P' application. However, 20 Kg N/ha from calcium ammonium nitrate and 20 Kg K_2O/ha from muriate of potash was applied in the furrow before sowing of greengram. This crop received one irrigation only after 40 days of germination. In this experiment yield difference due to residual effect of different sources of phosphorus in general was not significant. However, there was significant difference in yield between control and the rest. The treatments receiving IFDC-605 (acidulated with 40% H_2SO_4) and IFDC-813 (acidulated with 25% H_3PO_4) produced yield of 9.5 q/ha as against control yield of 7.9 q/ha which amounts to 20% higher yield. But this yield was only 3% more than the plot which received triple superphosphate. Such results lead to the conclusion that partially acidulated rock phosphate even with 25% H_3PO_4 is better than superphosphate for integrated phosphate supply to the soil. Excellent positive correlation was observed between uptake of phosphorus and the ultimate grain yield (r = 0.823). Available 'P' extractable by Bray's-I reagent correlated significantly with grain yield (r = 0.664) and phosphorus uptake (r = 0.583).

In the B_2 trial (soil pH 5.2) HYV paddy "Pratap" (OR-131-3-1) was also grown with 25 treatments and 3 replications. Since pH of this soil was somewhat more acidic than the B_1 trial plot, the sources of phosphorus chosen were different. Here again triple superphosphate was used as the standard source for comparison. But other sources included powdered raw Mussoorie rock phosphate as such and rock phosphate concentrated containing 18% and 24% total P_2O_5, respectively. Apart from partially acidulated materials minigranulated rock phosphate were also used where 8.1% H_2SO_4 and 7.7% H_3PO_4 were used as binder. There was no significant difference in the grain yield of control plot and the plots receiving ground Mussoorie rock phosphate and concentrated powdered Mussoorie rock phosphate but the yield obtained from the plot of

IFDC-702 (50% H_3PO_4 acidulated) was higher by 4.6 q/ha than the control amounting to 17% higher. This yield is only 1.7 q/ha higher than that of triple-superphosphate (5% higher). The ground rock phosphate as concentrated rock phosphate did not perform well as compared to partially acidulated sources or completely watersoluble sources because the soil was very poor in inherent fertility in respect of available 'P' and also because rice is hardly capable to extract 'P' from insoluble sources. The Bray's-I extractable phosphorus of soil had significant positive correlation with 'P' uptake by rice (r = 0.731) and grain yield (r = 0.539). Uptake of phosphorus and grain yield had also significant correlation (r = 0.533).

Groundnut (Var. AK-12-24) was grown as the test crop in the B_2 trial to test the residual effect of the phosphate sources which were applied to the HYV paddy. Nitrogen @ 20 Kg N/ha from calcium ammonium nitrate and potassium @ 20 Kg K_2O/ha from muriate of potash were applied. The crop was irrigated 3 times during the growth period in an interval of one month. In the control plot, groundnut pod yield was 14.2 q/ha which were 17.7 q/ha in IFDC-301, 17.3 q/ha in IFDC-816 and 17.3 q/ha in the plot which received ground Mussoorie rock phosphate. There was 24.6% increase in yield due to IFDC-301 as against control whereas in other treatments the increase was of the orderof 21% as compared to the control plot. It is interesting to note that there was significant differences in yield due to various treatments but difference in the pod yield due to the sources was not significant. This clearly indicates that even the minigranulated rock phosphate where 8.1 H_2SO_4 has been used as binder is good enough when a cropping sequence of rice and groundnut is taken. Interestingly the yields obtained from the plot where ground rock phosphate was applied is the same like 8.1 H_2SO_4 treated rock phosphate. There was no significant differences among the sources to build up a residual 'P' which indicates clearly that to build up a satisfactory phosphate potential cheaper source of phosphates should be preferred in such soils and cropping sequence. Since it is the question of building phosphate concentration, there was significant difference between the levels of applied phosphorus.

CONCLUSION

1. Mussoorie rock phosphate which is of sedimentary origin due to its good reactivity has been considered as one of the important sources of phosphorus for direct u se in acid soils. This has been confirmed in the present studies particularly when a cropping sequence of Rice and legume like greengram or groundnut are taken. However, the experimental data generated from this study clearly indicated that application of ground Mussoorie rock phosphate in the case of a short duration paddy is of no immediate value because rice has no good capacity to extract phosphorus from insoluble sources, unless the available native soil phosphorus is of medium or high level.

2. In the B_1 trial of the present studies IFDC-702 (50% H_3PO_4 acidulated) or IFDC-816 (25% H_3PO_4 acidulated) were equally good from the point of view of grain yield, because these materials had both water soluble and citrate soluble sources of phosphorus to benefit the rice crop. This is also true in the B_2 trial even at pH 5.2 where these materials could prove their efficiency as far as rice is concerned. When the second crop of greengram and groundnut are taken into consideration IFDC-816 (25% H_3PO_4 acidulated) was good enough. Therefore, one could conclude that 25% acidulation with H_3PO_4 is preferable looking at the cost of manufacture.

When grain yields of rice and greengram or rice and groundnut in totality are taken into consideration IFDC-605 (40% acidulation with H_2SO_4) and IFDC-301 (mini-granulated with 8.1% H_2SO_4) are preferable respectively. In other words long range effect of partial acidulation of rock phosphate with H_2SO_4 is good particularly when a legume is a test crop which has the capacity of extracting phosphorus from insoluble sources.

3. From correlation studies of Bray's-I and Olsen's extractable phosphorus from soil with that of phosphorus uptake and grain yield one could conclude that both the extractants are dependable when soil pH is not highly acidic, however, Bray's-I extractant should be preferred for soil testing when the pH of the soil is of the order of 5.0.

In general, the acid lateritic soils have a high phosphate fixing capacity and therefore, it is not economically feasible to build up a satisfactory phosphate potential in such soils by application of completely water soluble phosphate sources. However, from the point of view of integrated phosphate supply to crops in sequence it is possible to meet the challenge by addition of large doses of less expensive indigenous rock phosphate. To meet the requirement of acidic, neutral and slightly alkaline soils and for varieties of cropping sequences partial acidulation of rock phosphate to various degree is probably the answer to economise the cost on phosphatic fertiliser.

Since the indigenous rock phosphate of our country have hardly any utility of being converted to watersoluble sources due to heavy expenditure of the process it is all the more necessary for the soil scientists and agronomists to perfect the technology of the direct use of rock phosphate wherever feasible.

****

BIBLIOGRAPHY

CHAPTER - VI

BIBLIOGRAPHY

1. Anderson, D.L.; Kussow, W.R.; Corey, R.B. (1985) " Phosphate rock dissolution in soil: Indications from plant growth". Soil Sci.Soc.Am.J. 49: 918 - 925.

2. Bailey, L.D.; Spratt, E.D. and Read D.W.L. (1977) " Residual effect of phosphate fertilization". Can.J.of Soil Sci. 57: 263 - 270.

3. Bhujbal, B.M., Mistry, K.B.; (1981) " Characterisation of major Indian phosphate rock, their dissolution and availability in acid soils" . Bull. Bhava Atomic Res.Centre, Bombay 46 pp.

4. Biddappa, C.C. and Perur, N.G. (1978) " Dynamics of phosphorus transformation in laterite soils of Mysore". Mysore J.Agril. Sci. 12: 91 - 94.

5. Biddapa, C.C. and Sankaram, V. (1981) " Relationship of Olsen's P and inorganic P fractions in the river alluvial soil of Cuttack". J.Ind. Soc. Soil Sci. 29: 281 - 282.

6. Bouyoucos, G.J. (1962) "Hydrometer method improved for making particle size analysis of soils" Agron.J. 54: 464 - 465.

7. Bray, T. and Kurtz (1945) " Determination of total, organic and available forms of phosphorus in soil. Soil Sci. 59: 39 .

8. Chakravarty, S.N. and Kar, A.K. (1970)
"Effect of waterlogging on redox potential, available P and pH of some Indian soils ". J.Ind.Soc.Soil Sci. 13.

9. Chapman, H.D. (1965)
"Cation Exchange Capacity" In methods of Soil Analysis Part-II. Ed. C.A. Black Ag.No.9. Am.Soc.of Agro.Madison, Wisconsin, U.S.A.

10. Chatterjee, S.C., Guha, A.; and Ghosh, S.K.(1968)
" Characterisation of phases formed in acidulated rock phosphate and their estimation by X-ray diffraction method". Technology India (5) 92 - 97.

11. Chatterjee, S.C.; Sircar, A.K.; and Ghosh, S.K. (1970)
" A study on the acidulation of Indian rock phosphates in the preparation of SSP " . Technology: India (7) 286-291.

12. Chaudhury, M.L. and Mishra, B.; (1980)
"Factors affecting transformation of rock phosphate in soils". J.Ind.Soc.Soil Sci. 28: 295 - 301.

13. Chaveri, J.G. and Black, C.A. (1976)
Theory of the solubility of phosphate rock". Iowa St. J.Sci. 41: 77-95.

14. Chien, S.H. (1977)
" Dissolution rates of phosphate rocks". Soil Sci.Soc.Am.J. 41: 656 - 657.

15. Chien, S.H. and Black, C.A. (1976)
" Free energy of formation of carbonate apatites in some phosphate rocks". Soil Sci. Soc. Am.J. 40: 234 - 239.

16.Chien, S.H. and Hammond, L.L. (1978)
"A comparison of various laboratory methods for predicting the agronomic potential of phosphate rocks for direct application" Soil Sci.Soc.Am.J. 42 : 935 -939.

17. Chu, C.R.; Moschler, W.W. and Thomas, G.W. (1962)
" Rock phosphate transformation in acid soils".
Soil Sci. Soc. Am.Proc. 26: 476 - 478.

18. Debnath, N.C.; Basak, R.K. (1984)
"Efficiencies of some RP and basic slag as phosphatic fertilizer for Rice,Wheat and Greengram in acid lateritic soils of W.B.".
Indian J.of Agril.Sc. 54: 722 - 726.

19. Dhillon, N.S.; Sindhu, A.S.; Dev, G.(1979)
" Prediction of response to phosphorus application by rice and wheat in soils of Punjab".
J.Ind. Soc.Soil Sci. 27: 88.

20. Ellis, R.M.; Quaddor, R.A.; and Truog, E. (1955)
" Rock phosphate availability as influenced by soil pH" . Soil Sci. Soc.Am.Proc. 19:484-487.

21. Espedo, W.G. (1968)
" Changes of inorganic fractions of phosphorus with equilibration time in flooded and moist soils, resulting in P availability to Nato rice seedling". Diss. Abstract B 29, 1542-43.

22. Ghosh, P.C.; (1965)
"Fertilizer and crop production in the Eastern India".
Thorns publication, Calcutta.

23. Graham, E.R. (1955)
" Availability of natural phosphates according to energy changes". Soil Sci. Soc. Am.Proc.19:26-29.

24. Gupta, M.L. and Nayar, K. (1972)
" Inorganic phosphorus transformation in Dhankar soils". J.Ind. Soc. Soil Sci. 20(4)337-44.

25. Holford, I.C.R. (1980)
" Effect of phosphate buffer capacity on critical levels and relationship between soil test and labile phosphate".
Aust. J.Soil Res. 18: 405 - 414.

26. Hsu, P.H.; and Jackson, M.L.; (1960)
" Inorganic phosphate transformation by chemical weathering in soils as influenced by pH".
Soil Sci. 90: 16-24.

27. Hundal, H.S., Deol, P.S. and Sekhon, G.S. (1977)
" Evaluation of some sources of fertilizer phosphorus in two cycles of a paddy wheat cropping sequence".
J.of Agric. Sci.Camb. 88: 625 - 630.

28. Jackson, M.L. (1958)
"Soil chemical analysis". Prentice Hall Inc. Englewood Cliffs, Newjersey.

29. Jackson, M.L. (1962)
" Soil Chemical Analysis" Constable and Company Ltd.1962 Edition.

30. Juo, Anthony, S.R. and Ellis, G.(1967)
" Chemical and physical properties of Iron and Aluminium phosphates and their relation to 'P' availability". Soil Sci. Soc.Am.Proc.32(2)216-24.

31. Khanna,S.S. and Mahajan, K.R. (1971)
" A Study of the behaviour of added phosphate in soils of variable physico-chemical properties".
Proceeding Int. Symp. on Soil Fertility, Evalu. New Delhi. Ind. Soc.of Soil Sci. 1: 725 - 736.

32. Khasweh, F.E. and Doll, E.C.; (1978)
The use of phosphate rock for direct application to soils". Adv. Agron. 30: 159-206.

33. Laxminarasingham, C.R. and Krishnamurthy (1978)
" Study of phosphorus soil test for different rice soils". Madras Agril. J. 65: 725.

34. Lehr, J.R. and Mc Clellan G.H., (1972)
" A revised laboratory reactivity scale for evaluating phosphate rocks for direct application"
Bull. Y-43 TVA, Muscle Shoals.

35. Mackay, A.D., Syers,J.K. (1984)
" A comparison of 3 soil testing procedure for estimating the plant availability of P in soil receiving phosphate rock".
Newzealand Jor. of Agril. Research 27: 231-45.

36. Mandal, L.N. and Khan, S.K. (1972)
" Release of phosphorus from insoluble phosphatic materials in acidic low land rice soils".
J.Ind. Soc.Soil Sci. 20(1): 19-25.

37. Mandal,L.N.; and Chatterjee, G.N. (1972)
" Transformation of applied water soluble phosphate in latosolic low land Rice Soils".
J.Ind.Soc. Soil Sci. 20(4): 343-353.

38. Mandal, L.N. and Khan, S.K. (1977) $ " Transformation of fixed phosphorus in soils under waterlogged conditions". J.Ind.Soc.Soil Sci.25: 122-128.

39. Mandal,L.N. and Khan, S.K. (1975)
Influence of moisture regimes on the transformation of inorganic phosphates in Rice Soil".
J.Ind.Soc.Soil Sc. 23: 31-33.

40. Marwaha, B.C., Kanwar, B.S.; Tripathy, B.R. (1981)
" Direct and Residual effect of Mussoorie rock phosphate in wheat maize rotation."
Ind.J.Agril.Sci. 51(12) 870-74.

41. Marwaha, B.C. (1983) "
" Efficiency of nitric acid and phosphoric acid acidulated rock phosphate in wheat - blackgram cropping system ".
J.Ind.Soc.Soil Sci. 31(4) 539 - 44.

42. Marwaha, B.C. (1984)
"Partially acidulated rock phosphate as a source of fertilizer phosphorus with special reference to high P-fixing acid soils - a review".
Proc.of the Ind.Nat. Sci.Aca.49(5) 436 - 66.

43. Marwaha, B.C.; Kanwar, B.S. and Tripathi, B.R.(1983) "Responsiveness of some Indian rock phosphates to acidulation with phosphoric and Nitric acids". J.Ind.Soc.Soil Sci. 31: 328 - 330.

44. Marwaha, B.C. (1986) Direct and residual effect of Mussoorie rock phosphate on soybean growing sequence with wheat in acid alfisol. Ind.J.of Agr.Science 56(3) 101-106.

45. McLean, E.O. and Wheeler, R.W.; (1964) " Partially acidulated phosphate rock as a source of phosphorus to plant". Soil Sci. Soc.Am.Proc.28: 545-550.

46. McLean, E.O and Balam, B.S. (1967) " Partially acidulated rock phosphate as a source of phosphorus to plants". III. Uptake by corn from different calcium status. Soil Sci. Soc.Am.Proc. 31: 811-814.

47. McLean,E.O., Logan, T.J.; (1970) "Source of phosphorus for plant growth in soils differing in P-fixation tendency". Soil Sci.Soc.Am.Proc.34: 907 - 911.

48. McLean, E.O. (1965) Aluminium in Methods of Soil analysis. Part-II. Ed. C.A. Black Ag.No.9, Am.Soc.of Ag.Madison, Wisconsin, U.S.A.

49. Mishra, U.K. and Panda, N. (1969) "Evaluation of partially acidulated rock phosphate in a laterite soil". Ind.J.Agri.Sci. 39: 353 - 361.

50. Mishra, B.; Kumar, P. and Dwivedi, G.K.(1985) "Effectiveness of Indian rock phosphate in acid soils" J.of Ind.Soc.Soil Sci. 33: 574-80.

51. Mokwunye, A.V. and Chien, S.H.; (1980)
"Reactions of partially acidulated phosphate rock with soils from the tropics"
Soil Sci.Soc.Am.J. 44: 447 - 482.

52. Motsara, M.R.; and Datta, N.P. (1971)
" Rock phosphate as a fertilizer for direct application to acid soils".
J.Ind.Soc.of Soil Sci. 19(1) 107-113.

53. Olsen, S.R.; Cole, C.W.; and Dean, L.A. (1954)
" Estimation of available P in soil by extraction with $NaHCO_3$" . USDA circular 21: 154.

54. Olsen, R.A. (1975) " Rate of dissolution of phosphates from minerals and soils". Soil Sci. Soc. Am. Proc. 39: 634 - 639.

55. Panda, D. and Panda, N. (1969)
"Evaluation of mixture of ground rock phosphate and superphosphate in lateritic soils"
J.Agric, O.U.A.T.

56. Panda, N.; and Mishra, U.K.; (1970)
" Use of partially acidulated rock phosphate as a possible means of minimising phosphate fixed in acid soils"
Plant and soil 33 : 225 - 235.

57. Panda, N.; and Mishra, S.N.; (1972)
" Use of rock phosphate as phosphate carrier for Red and lateritic soil".
Proc.Nat. Acad.Sci. 293 - 295.

58. Panda, N. and Panda, D.; (1968)
" Evaluation of raw and partially acidulated rock phosphate on lateritic Rice Soil"
M.Sc.(Ag.) Thesis, O.U.A.T.

59. Panda, N. and Gunansingh, R. (1978)
"Evaluation of rock phosphate for paddy in lateritic soil". M.Sc.(Ag) Thesis, OUAT.

60. Patnaik, S.; Sarangmath, P.A.; and Shinde, B.N.(1974) " Increasing efficiency of citric acid soluble phosphate and rock phosphate for growing rice". Fert. News, 19: 46-50.

61. Piper, C.S. (1950
Soil and Plant analysis. Inter Science Publishers. Inc.N.Y.

62. Prabhudesai, S.S.; Kadrekar, S.B. (1984) "Reaction products from fertilizer phosphorus in lateritic soils of Konkan region". J.Ind.Soc.Soil Sci. 32(I) 52-56.

63. Raheja, P.C.; and Bains, S.S.; (1960) " Effect of residual phosphorus on crop production". I.C.A.R. review series Bulletin No.30.

64. Raj, B. and Van, A. (1980) "Phosphate supplying power of rock phosphate in an Oxisol".Plant and Soil 56(I) 97-104.

65. Robinson, G. (1950) " The Colorimetric determination of Aluminium on silicate mineral" Jr.Sci. Food Agril. 1: 59 - 63.

66. Sanchez, S.L.F. , Owen, B.E.J.; (1978) " Comparison of phosphate sources in an oxisol in the eastern plains of Columbia". Revista, Inst.Colomb. Agro.pec. 13(4) 641-648.

67. Sarangmath, P.H.; Shinde, B.N.; and Patnaik, S.(1977) " ^{32}P tracer studies on the method of increasing the efficiency of citric soluble and insoluble phosphate for Rice in acid Soils" Soil Sci. 124 (I) 40-44.

68. Sarkar, D. and Sarkar, M.C.; (1982) "Efficiency of Mussoorie rock phosphate for rice in acid soil of Assam". J.Ind.Soc.Soil Sci. 30(I) 48-52.

69. Scott, H.O. (1941)
"Colorimetric Estimation of Iron with Sodium salicylate" Analyst.66: 142.

70. Sdobnikova, O.V. (1980)
"The use of phosphatic fertilizer in the USSR". Proc.of Fert. Assoc.of Ind.Seminar Part-II. Agril. Sci. 11-13.

71. Seatz, L.F. and Stanberry, C.O. (1963)
"Fertilizer technology and usage". Soil Sci. Soc.Am.Proc.24: 177-181.

72. Sharma, P.K.; Bhumbla, D.R.; Kaistha, B.L.(1980)
"Available P in relation to some soil properties and the efficiency of the methods for its extraction in the soils of Himachal Pradesh". Agrochimica 24 (213) 102-107.

73. Sharma, P.K.; Tripathi, D.R. (1984)
" P availability indices in relation to P fraction in some Himalaya acid soils". J.of I.S. on S.S. 32(2) 292-298.

74. Shinde, B.N.; Sarangmath, P.A. and Patnaik, S.(1978)
"Efficiency of HCl and H_2SO_4 acidulated rock phosphate for rice on acid soil". Plant and Soil 50(3): 575-584.

75. Sood, R. and Marwaha, B.C. (1983)
" Study of the decomposition of Mussoorie rock phosphate with nitric acid as related to the time and method of acidulation" Proc. of Ind.National. Sci. Aca.49(6) 697-701.

76. Subramanian, C.K.; Manjunath, K.T. (1983)
"Response to Mussoorie phosphate in Karnataka soils". Indian Journal of Agril.Chemistry 16(3) 81-86.

77. Walkley, A.; and K.A. Black (1934)
An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37: 29 - 38.

78. Yost, R.S., Kamprath, E.J. (1982)
"Availability of RP and measured by an acid tolerant pasture grain and extractable 'P'."
Agronomy Journal 74 (3) 462-68.

****
****
**
*

APPENDIX

APPENDIX

TABLE-1

CORRELATION COEFFICIENT (r) AND REGRESSION EQUATION SHOWING THE RELATIONSHIP BETWEEN THE VARIABLES CORRELATED (TRIAL-B_1)

	Variables correlated X	vs. Y	df (n-2)	'r'	Regression equation
Fig. (1a)	1. Available 'P' (Olsen's)	Grain yield of rice	20	0.706**	Y = 32.02 + 1.124X
Fig. (1b)	2. Available 'P' (Bray's-I)	Grain yield of rice	20	0.517*	Y = 34.644 + 0.920X
Fig. (2a)	3. Available 'P' (Olsen's)	Uptake of 'P' by rice	20	0.740**	Y = 8.612 + 0.458X
Fig. (2.b)	4. Available 'P' (Bray's-I)	Uptake of 'P' by rice	20	0.522*	Y = 9.734 + 0.362X
	5. 'P' uptake by rice	Grain yield of rice	20	0.631**	Y = 20.226 + 1.620X
Fig. (3a)	6. Available 'P' (Bray's-I)	Grain yield of greengram	20	0.564**	Y = 8.247 + 0.260X
Fig. (3.b)	7. Available 'P' (Bray's-I)	Uptake of 'P' by greengram	20	0.583**	Y = 1.37 + 0.144X
	8. Uptake of 'P' by greengram	Grain yield of greengram	20	0.823**	Y = 6.297 + 1.540X

* Significant at 5% level

** Significant at 1% level

APPENDIX

TABLE-2

CORRELATION COEFFICIENT (r) AND REGRESSION EQUATION SHOWING THE RELATIONHSIP BETWEEN THE VARIABLES CORRELATED (TRIAL-B_2)

	Variables correlated X	vs. Y	df (n-2)	'r'	Regression equation
Fig.(4.a)	1. Available 'P'(Olsen's)	Uptake of 'P' by Rice	23	0.676**	Y = 8.377 + 0.407X
Fig.(4.b)	2. Available'P'(Bray's-I)	Uptake of 'P' by rice	23	0.731**	Y = 8.780 + 0.425X
Fig.(5.a)	3. Available 'P'(Olsen's)	Grain yield of rice	23	0.473*	Y = 23.564 + 0.81X
Fig.(5.b)	4. Available'P'(Bray's-I)	Grain yield of rice	23	0.539**	Y = 24.147 + 0.888X
	5. Uptake of 'P' by rice	Grain yield of rice	23	0.533**	Y = 12.137 + 1.513X
Fig.(6.a)	6. Available 'P' (Bray's-I)	Pod yield of groundnut	23	0.639**	Y = 11.332 + 0.99X
Fig.(6.b)	7. Available 'P'(Bray's-I)	Uptake of 'P' by groundnut	23	0.593**	Y = 2.887 + 0.260X
	8. Uptake of 'P' by groundnut	Pod yield of groundnut	23	0.752**	Y = 5.211 + 2.689X

* Significant at 5% level.

** Significant at 1% level.