EFFICIENCY OF ROCK PHOSPHATE IN THE ACID RICE SOILS OF KERALA

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Efficiency of rock phosphate in the acid rice soils of Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,

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CERTIFICATE

Certified that this thesis entitled "Efficiency of rock phosphate in the acid rice soils of Kerala" is a record of research work done independently by Kum. L. VISAKHA under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

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Phosphorus is one of the essential plant nutrients which is present in all living tissues. In terms of natural abundance and behaviour in soil plant system phosphorus differs from other plant nutrients and for this reason it has been studied more extensively. The chemical forms of phosphorus and their relative abundance in soil controls its uptake and utilization by crops. A knowledge of the amount, chemical form and distribution in soil would thus promote a workable basis for assessing the P requirements of different crops.

Though considerable amount of research in soil P has been carried out both in India and abroad, the management of P in soils for different crops still continues to be a complicated problem since the phosphate ions form a wide array of compounds of low solubility and of variable composition. The relative abundance of the iron phosphorus fractions in the soil decides the available P status of the soil. For these reasons, knowledge regarding the forms of phosphorus in different types of rice soils and the variation in availability continues to be a branch of fruitful research in the field of soil science. About 65 per cent of the total cropped area in Kerala State has been adjudged to come under the category "low" with respect to available P (Tandon 1976).

Till recently India was depending on imported rock phosphate to sustain the phosphate industry. Indigenous production of phosphate rock from the Udaipur mines began in 1969. The discovery of phosphate deposits in and around Mussoorie has also given rise to another source of rock phosphate. These rock phosphate, however, cannot be used for the manufacture of single and triple super phosphate owing to the lower content of phosphorus or due to higher amounts of $CaCO_3$ present. It has been estimated that we have more than 50 million tonnes of such phosphate rock which are not suitable for processing into commercial fertilizers, but which could be utilised as rock phosphate for direct application in acid soils.

Much information is not available on the use of Rajasthan rock phosphate in the acidic rice soils and acid laterite soils of the state. The present study is mainly intended to assess the performance of "Rajasthan" rock phosphate in the acid soils with the following objectives.

1. Response of rice in different soils to the application of Rajasthan rock phosphate
2. The pattern of changes in the phosphate fractions in the different rice soils as a result of water logging and comparing the effect of different forms of phosphates on the pattern of these changes in relation to the available P status.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Use of a rock phosphate as a phosphatic fertilizer:

Rock phosphate is known to be as a source of P fertilizer for direct application. Sedimentary rock which are substituted by carbonates and other minerals are quite reactive. The low grade phosphate rock of suitable agronomical value can be utilized for direct application.

Singh and Dutta (1974) concluded from the experiment that Udaipur and Mussoorie rock phosphate compared well with super phosphate in Kongra and Coorg soils.

Ghildayal (1975) reported that rice crop responded to Mussoorie rock phosphate better than super phosphate applied at the rate of 80 kg P_2O_5/ha.

Wright (1975) reported that the response of C-grade rock phosphate was best known when a high rate of fine material was mined into the surface soil. But in another soil the rock phosphate was inferior to super phosphate as a source of phosphorus. Prasad and Dixit (1976) have reported that in acid laterite soils of Manglore significant response to rice to the application of rock phosphate was observed. In alkaline soil of pH 7.7 super phosphate produced about 25 per cent more dry matter than rock phosphate and rock phosphate gave only slightly better yield than control. Singh et al (1976) have noticed that in a soil of pH 6.8, Mussoorie rock phosphate, Laccadive and Udaipur rock phosphates were 78, 62 and 54 per cent respectively as efficient as single super phosphate when lucerne was raised as a direct crop. Rastogi et al (1977) reported that Mussoorie rock phosphate increased dry matter yield of wheat significantly only in acid hill soils.

Natarajan (1981) and Ramasamy (1981) have reported that the application of Mussoorie rock phosphate increased the available P in neutral soils of Tamil Nadu. Nair and Aiyer (1982) stated that paddy responds to both super and Mussoorie rock phosphate were found to be equally good. Prasad et al (1982) stated that both Mussoorie and Purulia rock phosphate were effective phosphatic fertilizer for rice. They concluded that for obtaining sub optimum yield of rice under extensive agriculture phosphate rocks can be used. Narayanaswamy and Sarkar (1983) from their experiments concluded that phosphate rock has residual effect on rice and berseem and its effect was on par with that of triple super phosphate. Subramanian and Manjunath (1983) studied the response of rice, finger millet, potato etc. to super phosphate and Mussoorie rock phosphate in neutral and acid soils and concluded that response to Mussoorie phosphate with and without irrigation was similar to or better than response to super phosphate. Badrinath et al (1984) in a study to evaluate the response of super phosphate, Mussoorie phosphate and diammonium phosphate in the mid land soils of coastal Karnataka reported highest yield with super phosphate alone and it was comparable to that with a combination of MRP+SP (25+75%). Debnath and Basak (1986) in conducting experiments in terai acid soils to evaluate the fertilizer value of basic slag and two rock phosphates found that in terms of crop yield and P uptake purulia rock phosphate did not show any significant effect except in case of green gram grown as a 3rd crop after its application. Mussoorie rock phosphate increased yield and P uptake through its direct and residual effect in all the crops except rice.

Das (1987) found that Purulia rock phosphate in a 1:1 mixture with FYM was similar to that of diammonium phosphate in increasing rice yields and P uptake and its availability at various stages. Singh et al (1988) while conducting a field experiment on calcareous saline sodic sandy loam over 2 years to assess the relative performance of rock phosphate under rice wheat cropping sequence. They found that these two phosphate carriers were equally effective in increasing the yield of rice and wheat when applied alone or together.

Basak et al (1988) found that application of basic slag purulia rock phosphate, Mussoorie rock phosphate and super phosphate in a rice cropping sequence 3 weeks before transplanting showed no direct, residual or cumulative effect on paddy yield but application of the two rock phosphates after composting with rice straw or FYM increase yield and P uptake in rice.

Effect of added phosphate on the transformation of phosphate:

Debnath and Hajra (1972) studied the transformation of added water soluble P in 5 contrasting soils both under field moisture and water-logged conditions. The inorganic fraction after 24 hours were recovered in the order of Al-P > Fe-P > Ca-P. On ageing the quantity of Fe-P increased and that of Al-P decreased irrespective of soil characteristics and moisture regimes. On the whole Ca-P did not change much. Jose (1973) studied the transformation of inorganic P in soils at about field capacity and observed that in soils having pH between 7.0 and 7.6 applied P was transformed to Al-P, Fe-P and Ca-P in almost equal proportions. But in soils with Ca-P as the dominant fraction, a major part of the applied P was recovered as Ca-P Singlachar and Samaniego (1973) studied the effect of flooding and cropping on the transformation of P and reported that the P added to the acid rice soils was slowly converted to Fe-P.

Mandal and Khan (1975) studied the transformation of P in rice soils and reported that under continuous water logging and saturation treatments, the soils poor in native Al-P content recorded an initial increase in Al-P followed by a decrease and then an increase, while the soils rich in Al-P content recorded a regular decrease. Continuous water logged conditions caused a decrease in Fe-P content of very acid soils during the initial period but could not bring about any significant change in its content in near neutral soils.

Singh and Ram (1976) studied the transformation of added water soluble phosphate in some soils of Uttar Pradesh and reported that with progress of incubation there was a regular decrease in Al-P content and increase in Fe-P content in all soils between pH 6.6 and 8.9. In the recent alluvial soils there was continuous increase in Ca-P because of high content of $CaCO_3$. Mandal and Khan (1977) found that applied phosphate reported to be not utilized by the crop amounted to 60 - 70% and it was converted to unavailable Fe-P and Al-P.

Singhania and Goswami (1978) investigated transformation of applied P in rice-wheat cropping sequence in laterite soils of India and found that P applied to rice increase Al-P, Fe-P and reductant soluble P.

Sarkar et al (1979) reported that MCP and MAP in alluvial, red and laterite soils of Bengal produced mainly colloidal amorphous Fe-P and Al-P which on ageing, yielded products like octa-calcium-phosphate, varisite etc. and in some instances potassium and ammonium-taranakites, strengite etc.

Talshikar and Patel (1979) studied the rate of applied P at different stages of rice growth under water logged conditions and observed that Fe-P fractions formed the major portion of native inorganic P fraction Al-P, Fe-P and Ca-P fractions increases at both flowering and harvesting stages of rice growth while there was no appreciable increase in reductant soluble P fraction.

Sharma et al (1980) conducted an incubation study on the transformation of added P in acid soils of Himachal Pradesh and found that most of the added P was transformed to Al-P, Fe-P and very little to Ca-P at one day interval. The added P which was transformed to Al-P increases upto 7 days and later decreases slowly with time upto 90 days. The conversion of added P to Fe-P fraction increases slowly with time upto 90 days and very little was changed to Ca-P even at prolonged time intervals.

Sadanandan & Mahapatra (1972) studied the transformation of ^{32}P tagged ammonium nitrate phosphate in water logged soils and found that most of the added orthophosphates were converted to Al-P and Fe-P in all the soils.

Madhusoodanan Nair and Padmaja (1982) found that priming of rock phosphate in moist aerobic soils resulted in substantial conversion of phosphate to Fe-P and Al-P and these products increased the availability of P to rice on submergence. Regi and Jose (1985) from lab-incubation studies with Rajasthan rock phosphate, Mussoorie rock phosphate and super phosphate showed that the increase in available P content of laterite and kari soils due to application of P fertilizers did not depend on the solubility of added P fertilizers.

Gu and Wang (1986) on the transformation of super phosphate on the gleyed paddy soils found that P applied to the soil was transformed to Al-P and Fe-P at an early stage of growth, Al-P increases in the early stage and there after decreases gradually Fe-P increases continuously and Ca-P changed little.

Effect of submergence on the availability of phosphorus:

Water-logging markedly increase the availability of native and applied P as compaired to upland soils. In low land rice soils, the water and acid soluble P increase on flooding and P uptake by rice plants. Mandal and Khan (1975) reported that the availability of native soil P in and soil increased appreciably consequent to continuous water logging.

Chang (1976) noted that during submergence crystallized iron phosphates tends to change to colloidal iron phosphate through solution and precipitation resulting in its greater availability.

Mandal and Khan (1976) reported that under continuous water logging Al-P recorded an initial increase followed by a decreasing trend, while a less acid soil comparatively rich Al-P, recorded progressive decrease in continuous water logging for 110 days caused an increase in Fe-P in all the soils but did not bring about any decrease in reductant P and Ca-P decreases.

Kanwar (1976) as reported that increase in available P on submergence of a soil could be attributed to the following mechanism.

(1) Release of P from mineralisation of organic matter

(2) Reduction of insoluble ferric phosphate to more soluble ferrous phosphate (Islam and Elahi (1954)

(3) Release of occluded phosphate by reduction of hydrated ferric oxide coating (Chang and Jackson, 1958; Mahapatra, 1966)

(4) Anion exchange between clay and organic anion (Rassel, 1961)

Displacement of phosphate from ferric and Aluminium phosphate by organic anion (Mandal and Mandal (1973). Increase in solubility by hydrolysis of $Fe_3\ PO_4\ 2H_2O$ and $Al\text{-}PO_4\text{-}2H_2O$ caused by increased pH accompanying reduction of acid and strongly acid soils (Ponnamperuma 1965).

Increase in solubility of phosphate associated with the decrease in pH caused by the accumulation of CO_2 in calcareous soils (Khan and Mandal 1973).

Rajukkannu and Ravikumar (1978) studied the transformation of P in rice soils under flooded conditions and observed that consequent to flooding Fe-P and Al-P increases. Reductant P decreases and there was no change in Ca-P.

Verma and Tripathi (1982) observed that all the native inorganic P fractions increases upon water logging with maximum increase of 70.7% in Fe-P, Katyal and Venketaramayya (1983) reported that soil solution P was influenced slightly by submergence and increase due to addition of fertilizer P Mathew and Jose (1985) studied the release of available P from rock phosphate and super phosphate during incubation under submergence and observed that concentration of available P was not significantly affected by variation in the form of applied P.

Availability of P in relation to P fractions:

Phosphate ions in the soil forms a wide array of compounds with varying solubility. According to Chang and Jackson (1957) inorganic phosphate in the soil can be fractionated into six forms (1) Saloid P (2) Al-P (3) Fe-P (4) Reductant soluble P (6) Occluded P (7) Ca-P.

Islam (1970) reported that increase in soluble P in acid soils was due to a decrease in Ca-Fe and reductant soluble phosphate concentrations than in neutral soils. P increased with decrease in Fe-P and Al-P.

Keno and Kobo (1970) observed that in normal paddy soils the main form was Fe-P and Al-P and the transformation of phosphate from ferric to ferrous type under water logged condition was remarkable.

Cholitkul and Tyner (1971) stated that in low land rice soils Fe-P was the primary source of labile phosphorus. Jose (1973) reported that labile P pool was influenced more by Al and Fe-P than Ca-P. Mandal and Chatterjee (1972) reported that the transformation of P into Al-P and Fe-P appeared to be directly related to the quantity of these inorganic forms of P already present in the soil and proportionate to the total amount of inorganic soil phosphate.

Minhas and Kick (1974) indicated that major part of added rock phosphate was transformed into water soluble and loosely bound Al-P and Fe-P fractions and become available for plant growth. Patrick et al (1974) found that flooding increased the transformation of all P sources into Fe-P fractions.

Kothandaraman (1975) reported that Al-P and Fe-P contributed to the pool of available P in acid soils. Uzu et al

(1975) reported that Al-P was the most available form of P to plants under upland conditions while Fe-P was the major available P source under flooded conditions.

Singh and Bahaman (1976) obtained an increase in available P after 10 days of incubation when clay loam and soils with pH 5.7 and organic carbon 0.9 per cent were kept water logged. They also recorded a decrease in available P after 20 days of incubation.

Kanwar and Tripathi (1977) reported that Al-P and Fe-P fractions contributed significantly to Olsen and Bray P.

Mohanty and Patnaik (1977) observed that on submerged soils the available P increased during the first 20-30 days because of the reduction of iron and manganese compounds, afterwards there was a decrease because of the precipitation as phosphates.

According to Raniperumal and Velayutham (1977), the correlation of phosphate forms with yield and P uptake by rice revealed that iron P, saloid P and Al-P were important contributing fractions. Singh and Ram (1978) attributed the increase in available P in slightly acid wet land rice soils is due to the decrease in Fe-P and Ca-P concentrations. Singh <u>et al</u> (1979) reported that P uptake by rice was from NH_4Cl, NH_4F and NaOH extractable fractions of soil P.

Menhilal and Mahapatra (1979) reported that Fe-P was the major contributor to the available phosphorus in alkaline alluvial soils with high calcium content. Nair and Aiyer (1982) investigated the relationship between available P and P fractions under water logged conditions and found that different P fractions under water logged conditions (Saloid P, Fe-P, Al-P and Ca-P)were found to be negatively correlated with a vailable P. Nair and Aiyer (1983) observed that Fe-P of the Mussoorie Phosphate tried soils increased with period of incubation and level of application of P and has no significant effect on Al-P and indicated that mussoorie phosphate compares very well with super phosphate in water logged situations and upland soils.

Nair and Aiyer (1983) found that consequent to water logging Fe-P, Al-P, Ca-P and Saloid P to water logging Fe-P, Al-P, Ca-P and Saloid P increases while reductant soluble P and occluded P decreases.

Palmer and Gilkes (1983) studied the effectiveness of aluminium-iron phosphate rock relative to super phosphate and found that rock phosphate were low in supplying available-P.

Harikrishnan Nair (1986) found that on water logging laterite alluvial soils of Vellayani registered an increase in all the inorganic P fractions. The availability percentage increase due to submergence was lowest for occluded P and highest for iron P.

Sah and Nikkelson (1986) observed significant changes in inorganic P fractions due to submergence of soils. They found that Fe-P fractions increases and Al-P fraction decreases when soil is submerged. The Ca-P fraction increases during flooding in soils that had initially high levels of Ca-P but was almost unchanged in soils with lower Ca-P. The reductant soluble fraction decreases during flooding in the soil submerged to annual flooding for rice.

Sudhir <u>et al</u> (1987) found that Al-P was more important fraction contributing towards the availability of P in soil followed by reductant soluble P and saloid P.

Gu and Wang (1988) studied the fate of addition of P carriers in gleying rice soils and found that there was a positive correlation between Olsen-P, Al-P and Fe-P.

Agarwal <u>et al</u> (1987) found that Al-P was the most important fraction contributing towards available P followed by reductant soluble P and saloid P.

Dikshit and Padihar (1988) found that the amount of available P and different phosphate fractions (Al-P, Ca-P and Fe-P) increases due to phosphate application under submerged conditions and phosphate released from Fe-P is complexed by calcium and aluminium leading to an increase in Ca-P and Al-P. Nageeb & Aiyer (1989) found that available P was positively and significantly correlated with Fe-P, Al-P, Ca-P and saloid-P and negatively and significantly correlated with reductant soluble P and occluded P.

Soil available P as influenced by rock phosphate:

Motsara and Datta (1971), Panda and Mishra (1972), Saranganath (1975) and Varadan et al (1977) reported that the application of insoluble phosphates increased the available P in acid soils.

Dashrath Singh et al (1976) stated that the effectiveness of rock phosphate in releasing available P in a slightly alkaline soil was inferior to super phosphate.

Logan, (1977) reported that P concentration in the soil solution were correlated with degree of carbonate substitution in the apatite and citrate solubility of the phosphate rocks used the acid soils under water logged conditions.

Loganathan and Nalliah (1977) determined the sodium bicarbonate extractable P in sandy loam soil 7 and 8 years after fertilizer application and reported that the downward movement of P from concentrated super phosphate was greater than that from rock phosphate.

Chien et al (1980) stated that the amounts of water extractable P in the soils treated with concentrated super phosphate or the phosphate rock decreased as P sorption capacity increased.

Hammond et al (1980) reported that partial acidulation with H_2SO_4 was effective in increasing the water soluble P level of phosphate rock. Mokwinye and Chien (1980) stated that the amount of water extractable P was higher in soils treated with partially acidulated phosphate rock or in the mixture of CSP and phosphate rock slowed down the immobilisation of water soluble P.

Bhujbal and Mistry (1981) investigated the minerological and chemical composition of nine Indian phosphate rocks and reported that the solubility of phosphate rocks incubated in an acid soil under flooded conditions increased upto the 3rd week and decreased thereafter. The maximum levels of water soluble and Bray I. Phosphorus in acid soil treated with phosphate rock were correlated with their citrate solubility.

Natarajan (1981) and Ramaswamy (1981) have reported that the application of mussoorie rock phosphate increased the available P in neutral soils.

Response of rice to rock phosphate fertilization:

Kurup and Koshy (1968) reported that Laccadive rock phosphate and super phosphate increased grain yield of rice to the same level in the acid soils of Kuttanad. Dungapatra and Datta (1969) and Chatterjee and Dhar (1969) have stated that rock phosphate was a poor source of P for rice when compared to super phosphate. Motsara and Datta (1971) observed similar effects of rock phosphate and super phosphate with paddy, wheat, maize, peas and potato in acid soils of Palampur (pH 5.1) Ranchi (pH 5.4) Ooty (pH 4.5) and Rastar (pH 5.9). This is in line with the findings of Panda (1979). Panda and Mishra (1972) observed that in a laterite soil of Orissa (pH 4) Udaipur rock phosphate in a finely ground form was an effective source of for rice.

Sahu and Dash (1972) found that the grain yield of high yielding paddy in the case of super phosphate and rock phosphate did not differ significantly with each other.

Prasad and Dixit (1976) obtained higher grain yield of rice with rock phosphate than super phosphate at 120Kg P_2O_5/ha in acid laterite soils of Manglore. Singh et al (1976) observed lower effectiveness of rock phosphate over other water soluble phosphate for paddy and wheat on soils with neutral to alkaline pH.

Ramaswamy and Raniperumal (1980) reported that the combined application of mussooriephos (75%) and super phosphate (25%) produced higher grain yield of rice similar to that of super phosphate in red soil (pH 7) of Tamil Nadu.

According to Ramaswamy (1981) mussoorie rock phosphate 100 mesh size was as effective as ordinary super phosphate for rice in a sandy clay loam soil pH (7.2). Madhusoodanan Nair and Padmaja (1982) found that priming of rock phosphate in moist aerobic soils resulted in substantial conversion of phosphate to Fe-P and Al-P and these products increased the availability of P to rice on submergence.

Ramaswamy and Arunachalam (1983) have reported that super phosphate is slightly superior to mussoorie phosphate for the main crop paddy, if a residual crop of paddy has to be raised without further application of P mussoorie phosphate would give better yield than super phosphate.

Nair and Aiyer (1983) reported an increase in grain yield of rice at 45 kg P_2O_5/ha with super phosphate and mussoorie phosphate in kari and kayal soils. In karapadom and kole soils increase in yield was obtained only at higher dose of mussoorie phosphate and super phosphate.

Field experiments conducted at RRS Moncompu (1983) to study the comparative efficiency of water soluble and acid soluble phosphate alone and in combination with pyrite showed that during punja and additional crop seasons mussoorie rock phosphate at the rate of 60 kg P_2O_5/ha and pyrite used as 1:1 mixture recorded highest grain yield.

Rabindra and Swamy Gowda (1986) evaluated rock phosphate as an alternate source of phosphorus in phosphorus deficient calcareous vertisols. Application of rock phosphate pyrite mixture (1:3) gave paddy and straw yield comparable with that of single super phosphate.

Das (1987) observed that efficiency of purulia rock phosphate admixed with FYM in 1:1 ratio was similar to that of diammonium phosphate in increasing rice yield and P uptake and its availability at various growth stages.

In a field experiment on clay loam soils to test the response of rice to rock phosphate as compared with super phosphate Mathur and Suresh (1987) observed that sources of P significantly differed in increasing the yield of rice in 2 out of 4 years but no significant difference in yield was noted among the levels of P of the same source.

Effect of sources of P on yield and plant uptake of P:

According to Shinde and Patnaik (1973) the application of ground rock phosphate is as efficient as super phosphate in respect of P uptake by rice. Sahu and Das (1972) reported an increase in uptake of P by rice with the application of rock phosphate in combination with super phosphate.

Shukla (1973) observed that P content of rice grain was not significantly affected by different sources of P. Kothandaraman [redacted] (1975) reported that phosphorus in combination with N_2 significantly incluenced the calcium content of rice grain.

Singh and Patiram (1977) have observed the highest P uptake by rice when the phosphatic fertilizers were applied in combination with farm yard manure. Ramaswamy (1978) reported that uptake of P by rice did not differ significantly for super phosphate and rock phosphate.

Chowdhary and Mian (1979) reported that an application of 90 kg N + 45 kg P_2O_5/ha gave higher yield of rice than untreated control.

Hammond <u>et al</u> (1980) observed that crop response and P uptake were both highly correlated with water solubility of the product which was increased by partial acidulation with H_2SO_4.

Ramaswamy (1981) obtained higher content and uptake of P in rice grain and straw due to residual effect of mussoorie rock phosphate.

Marwaha (1981) reported that P uptake increased significantly with rock phosphatic application.

Marwaha (1983) concluded that samples acidulated with HNO_3 proved as effective as those prepared with phosphoric acid at almost all the comparable levels of acidulation in respect of crop yield total P uptake and apparant recovery of applied P.

Reddy and Mittra (1985) found that under water logged conditions application of P together with N increased the grain yield of rice 9-14% over N_2 alone and by 27% over infertilized control. Roy and Jha (1987) studied the effect of phosphorus on low land rice yield and found that P application increased the grains yield from 3.95 t/ha without phosphorus to 4.61 t/ha with P applied basally. Najeeb (1989) found that application of Mussoorie phosphate along with green leaves recorded the highest grain yield and straw yield when compared to super phosphate and mussoorie rock phosphate alone.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation is intended to the chemical transformation of different forms of phosphatic fertilizers under cultivator's field conditions in two different soils of Kerala in relation to plant growth and yield.

As a part of the study two field experiments in cultivator's field viz. one at Vellayani in the kayal lands and another at Moncompu, upper Kuttanad area were conducted during 1988-89 puncha and 1989 virippu seasons respectively using different forms of phosphatic fertilizers at the rate of 45 kg P_2O_5/ha.

Studies on fractionation of phosphorus in relation to available P status in these two soils of the field experiments were conducted at regular intervals from planting to harvest. This was to compare the efficiency of the different forms of phosphatic fertilizers in these soils.

A. Field experiments on rice:

(i) Season: The experiment was conducted during punja 1988-89 at Vellayani and 1989 virippu at Moncompu

(ii) Site and cropping history of the experimental area.

The sites selected were the waterlogged fields in Moncompu area in upper Kuttanad and the kayal lands of Palappur at Vellayani having facilities for controlled irrigation.

(iii) Soil: The soils in the two experimental sites were lateritic loam

(iv) Variety: High yielding medium duration rice cultivar Jaya was used for the experiment

(v) Cultural practices: Recommendations given by Kerala Agricultural University package of practices (1989) were followed for the experiment

(vi) Design, spacing and plots: The experiment was laid out in a Randomised Block Design with five replications and four treatments with a plot size of 9.6 x 9.4 m and with a spacing of 15 x 10 cm.

(vii) Experimental procedure: Two field experiments in the cultivator's field viz. one at Moncompu (upper Kuttanad) and another in kayal land at Palappur Vellayani. The plots were laid out at the two locations as per the treatments, ploughed twice, puddled and levelled. The fertilizers (N_2 and K_2O) were added at the rate of 90 and 45 kg/ha respectively. N in the form of urea was applied in two splits, one at the time of planting and another 20 days after planting. K_2O was applied as muriate of potash (MOP). P_2O_5 was added at 45 kg/ha and forms as per the treatment combinations.

Treatments		Forms of P_2O_5 kg/ha	Soil type
Experiment I	P_1	No P_2O_5	Laterite loam Vellayani
	P_2	P as super phosphate	
	P_3	P as mussoorie phosphate	
	P_4	P as Rajasthan phosphate	
Experiment II	P_1	No P_2O_5	Moncompu
	P_2	P as super phosphate	
	P_3	P as mussoorie phosphate	
	P_4	P as Rajasthan phosphate	

Twenty days old rice seedlings were transplanted at the rate of two seedlings/hill. The plots were kept free from weeds. The plants were sprayed twice with Ekalux (ie. on 15th and 45th day) and once with metacid (on 75th day) 10 days before harvest irrigation was discontinued. The grains and straw were harvested at full maturity.

Basic data of the soils selected:

Mechanical analysis: ([redacted] [redacted])

Soils	Coarse % sand	File % sand	Silt %	Clay %
Vellayani kayal	22.0	27.2	14.8	36.0
Moncompu	23.3	26.5	15.2	35.0

170326

Soils

	Kayal	Moncompu
pH	5.5	5.2
Conductivity	0.07	0.05
Lime requirement tonns/ha	2.2	2.5
Organic carbon %	1.01	1.86
Total P %	0.071	0.078
Total N %	0.021	0.025
Total K %	0.062	0.064
Total Ca %	0.021	0.092
Total mg %	0.039	0.40
Available P %	0.004	0.049
Available N %	0.013	0.021
Total Fe_2O_3 %	7.98	7.38
Total alumina %	10.73	10.82

Observations:

As per the method suggested by Gomez (1972) the following growth and yield characters were studied.

1. Height of the plants: The height of plants from each of the plots was measured from ground level to the top of the highest leaf on the top of the panicle which ever was longer.

2. Panicle length: Panicles of the sampling units were removed separately and length measured in cm from the last node to the tip of the panicles

3. Yield of grain and straw: The crop was harvested at full maturity and the weight of the grain and straw were recorded

4. Thousand grain weight: Thousand grain weight was recorded for each treatments

5. Fractionation studies:

a. Effect of soil type at di ferent periods of rice growth on the available P and phosphorus fractionations in soil

The samples from each plot of the field experiments were collected at periodical intervals viz. before planting, 20 (I_1), 40 (I_2), 60 (I_3) days after transplanting and also at harvest (I_4) of the crop. The periodical samples for fractionation and available phosphorus determinations were made from each plot. The procedure suggested by Abichandani and Patnaik (1957) for taking samples from water logged rice fields was adapted for this purpose.

A weighed quantity of the moist samples to give 5 g of dry soil was used for the available P determination.

A weighed quantity of the moist sample to give 1 g of the dry soil was used for the fractionation of soil P.

The moisture content of the representative samples was separately estimated immediately on withdrawal of the sample and the exact quantity of wet soil to represent one gram for the fractionation and five gram for available P determination was taken for each sample.

Chemical analysis of plant samples:

a) Preparation of plant samples:

The plant samples collected at each sampling intervals were cleaned and dried in an air oven at 80°C. The prepared samples were kept in separate labelled bottles. The straw samples were also similarly dried. The grain was winnowed cleaned and then dried in an air oven at 80°C. The dried samples were ground in a wiley mill. The ground samples were also stored for analysis in separate labelled bottles.

b) Analytical procedure for plant samples:

The plant samples were analysed for nitrogen by the method of Poidevin and Robinson (1965) using H_2SO_4 digestion with Na_2SO_4 and calorimetric estimation with Nessler's reagent P in sulphuric acid digest was estimated by using 1 - amino 2 - naphthol 4 - sulphonic acid as a reducing agent and the phospho molybdo blue colour method using 660 mμ in a spectronic 2000 (Jackson 1967) and total potassium by flame photometer method (Black 1985).

Calcium and magnesium were determined by digesting a weighed quantity of the plant material with triple acid mixture making upto 100 ml and estimating calcium and magnesium by varsenate titration method (Cheng et al, 1952).

Soil studies:

Analytical method:

The methods followed for the analysis (physical and chemical) of soil samples are given below.

a) Mechanical analysis:

Mechanical analysis was carried out by International pipette method (Piper 1950).

b) pH: The pH was determined using a Perkin Elmer meter with a soil: water ratio of 1: 10.

c) Total phosphorus: The precipitation method of Jackson 1967.

d) Available phosphorus: The available phosphorus was extracted by Bray No.1 extractant (0.25 N HCl and 0.03 N $NH_4$7) Ammonium phospho molybdo blue colour developed was determined by the method of Dickman and Bray (1940).

e) Fractionation of soil P: The fractionation of soil P was carried out by the procedures of Chang and Jackson after Peterson and Corey described in Hesse 1976.

Statistical analysis:

The data recorded at periodical intervals were analysed statistically as follows (Gomez and Gomez).

ANOVA

Source	df
Block	4
Between sources of P	3
Error (1)	12
Between periods (I)	3
Period x treatments (I x P)	9
Error (2)	48

RESULTS

RESULTS

It is seen from the results that the plant height was significantly influenced by the application of P. However Mussoorie rock phosphate and Rajasthan rock phosphate were on par. Maximum height was recorded by super phosphate in Vellayani kayal soils. There is significant interaction of treatments with periods at Vellayani soils. In the first two periods viz. 20 days after planting and 40 days after planting no significant difference in plant height was observed with different sources of 'P'. But at later stages super phosphate was found to be more effective.

At Moncompu, no significant difference in plant height was observed with different forms of P. There is significant interaction of treatments with periods. 40 days after transplanting (I_2), treatment with super phosphate recorded less height.

Tables 3 and 4 represent the results on the number of tillers/m^2. At Vellayani, the treatment P_2 (super phosphate) produced the highest number of tillers/m^2. During the first 3 periods viz. 20, 40 and 60 days after planting no significant difference in tiller number was observed with treatments. But at harvest stage super phosphate was found to be superior to Mussoorie rock phosphate. At Moncompu, though the application of phoaphate increased the tiller number no significant difference was seen with the three sources of P.

Tables 5 and 6 represent the 1000 grain weight, number of filled grains/panicle, number of panicles/m^2 and panicle length in cm respectively at Vellayani and Moncompu soils recorded at the time of harvest. The results showed that P application had no significant effect in enhancing 1000 grain weight and number of filled grains/panicle, but influenced in enhancing the number of panicles/m^2 and panicle length (cm). Moncompu soils also recorded the same results as in Vellayani soils.

Table 7 represents the mean yield of rice grains inkg/Ha.

From the results it was seen that at both the locations the treatments helped to increase the yield of grain. However the different sources of P did not produce any significant variation in yield.

Tables 8 and 9 represent the average P content of plants. P content of the plants was significantly higher in the P treated plots. The maximum P content was seen in plants treated with super phosphate, but no significant difference was seen in plants treated with Mussoorie rock phosphate and Rajasthan rock phosphate.

Table 1. Mean tiller height (cm) (Vellayani)

	I_1	I_2	I_3	I_4	Mean I
P_1	25.16	39.86	54.86	70.84	47.68
P_2	31.02	49.30	80.42	94.14	63.72
P_3	27.60	47.14	75.00	85.70	58.86
P_4	27.12	47.58	76.18	87.78	59.65
Mean II	27.73	45.97	71.62	84.62	

CD(P) = 2.98 CD(T) = 2.33 CD(PxT) = 4.67

Table 2. Mean tiller height (cm) (Moncompu)

	I_1	I_2	I_3	I_4	Mean P
P_1	23.32	37.00	60.50	82.94	50.94
P_2	28.06	43.66	74.70	96.30	60.68
P_3	26.68	49.44	75.58	99.88	62.89
P_4	27.04	50.04	75.78	99.40	63.06
Mean T	26.28	45.03	71.64	74.63	

CD(P) = 3.02 CD(T) = 1.82 CD(TxP) = 3.64

Table 3. Effect of different phosphatic fertilizers on tillers of rice plant at Vellayani

	I_1	I_2	I_3	I_4	Mean A
P_1	265.00	515.80	727.00	915.00	605.70
P_2	330.00	699.60	904.20	1168.20	775.50
P_3	303.60	646.80	885.00	1063.80	724.80
P_4	297.20	645.80	883.80	1075.20	725.50
Mean B	298.95	627.00	850.00	1055.55	

CD(P) = 80.21 CD(I) = 47.23 CD(PI) = 94.46

Table 4. Effect of different phosphatic fertilizers on tillers of rice plant at Moncompu

	I_1	I_2	I_3	I_4	Mean I
P_1	151.00	362.80	666.80	795.40	494.00
P_2	231.00	580.20	794.00	988.40	648.40
P_3	230.60	586.60	797.60	981.60	649.10
P_4	234.20	594.60	769.60	987.80	646.50
Mean B	211.70	531.10	757.00	938.30	

CD(P) = 33.82 CD(I) = 26.03 CD(PI) = 52.06

Table 5. Effect of different phosphatic fertilizers on yield [redacted] characters of rice plant at Vellayani

	P_1	P_2	P_3	P_4	SE
1000 grain wt.(g)	19.09	21.52	20.90	20.74	0.75
No. of filled grain/panicle	88.60	106.60	94.20	94.20	3.25
No. of panicles/m^2	413.60	554.40	540.40	540.20	149.05
Panicle length (cm)	20.62	23.84	21.24	22.16	2.44

MEAN YIELD IN kg/Ha AT VELLAYANI

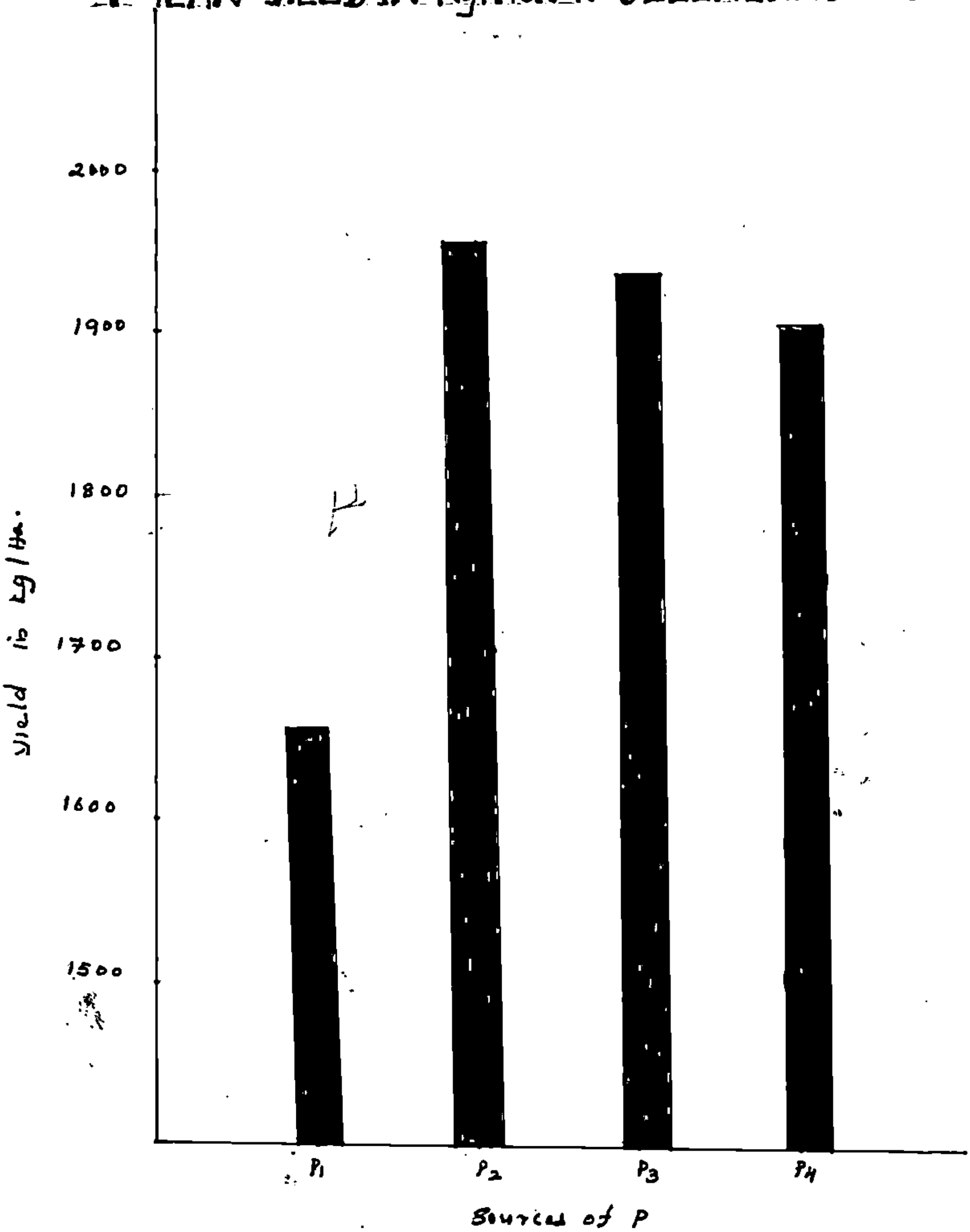


Table 6. Effect of different phosphatic fertilizers on the yield ~~attributes~~ characters of rice plant at Moncompu

	P_1	P_2	P_3	P_4	SE
1000 grain wt.(g)	18.53	19.77	20.29	19.81	0.77
No. of filled grains/panicle	88.00	95.80	93.80	94.40	2.05

	P_1	P_2	P_3	P_4	CD
No. of panicles/m^2	398.40	475.20	480.40	482.20	51.34
Panicle length (cm)	20.66	24.86	24.48	23.50	2.08

Table 7. Mean yield of rice grains in kg/ha at Vellayani and Moncompu

Locations	Treatments		Yield of grain (kg/ha)
Vellayani	P_1	No phosphorus	1651
	P_2	Super phosphate	1957
	P_3	Mussoorie phosphate	1934
	P_4	Rajasthan phosphate	1911
	SE		
Moncompu	P_1	No phosphorus	1640
	P_2	Super phosphate	2070
	P_3	Mussoorie phosphate	2065
	P_4	Rajasthan phosphate	2055
	SE		

MEAN YIELD IN kg/Ha AT MONCOMPU

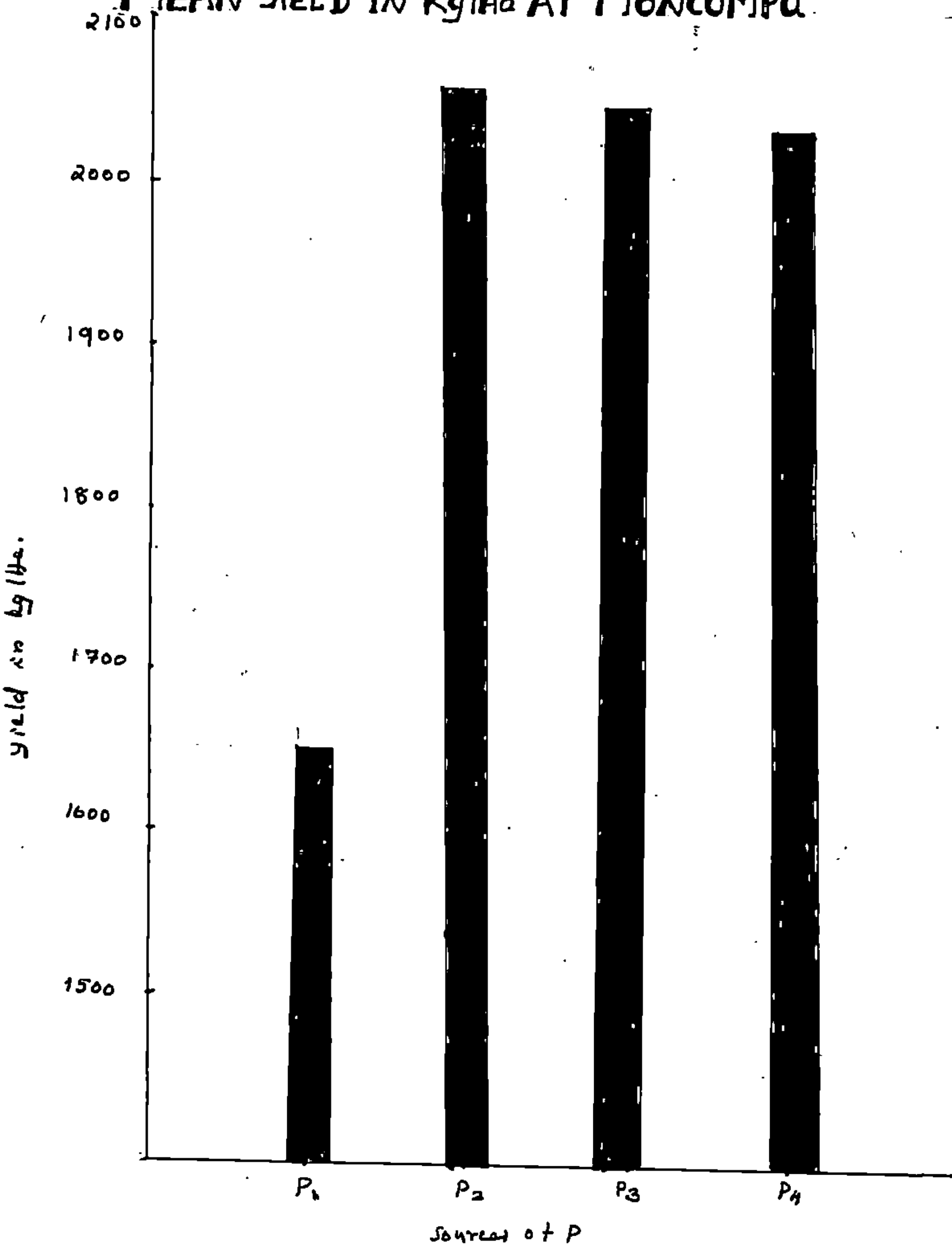


Table 8. Average P content (%) of rice plants (Vellayani)

	I_1	I_2	I_3	I_4	Mean P
P_1	0.42	0.48	0.26	0.09	0.31
P_2	0.52	0.53	0.28	0.12	0.36
P_3	0.46	0.50	0.27	0.10	0.33
P_4	0.45	0.51	0.27	0.10	0.34
Mean I	0.46	0.51	0.27	0.10	

CD(P) = 0.0044 CD(I) = 0.0053 CD(PxI) = 0.0105

Table 9. Average P content (%) of rice plants (Moncompu)

	I_1	I_2	I_3	I_4	Mean P
P_1	0.40	0.46	0.25	0.09	0.30
P_2	0.50	0.49	0.27	0.12	0.35
P_3	0.49	0.52	0.27	0.13	0.35
P_4	0.49	0.52	0.27	0.12	0.36
Mean I	0.47	0.50	0.27	0.12	

CD(P) = 0.0065 CD(I) = 0.0083 CD(PxI) = 0.0166

Though at 20 DAT, 40 DAT and at harvest super phosphate was found to produce good results, at 60 DAT three sources were found to be on par.

At Moncompu, maximum P content was observed in plants treated with Rajasthan rock phosphate followed by Mussoorie rock phosphate and super phosphate. At 20 DAT, 60 DAT and at harvest different sources of P showed no significant difference in P content. But 40 DAT, P content in plants treated with super phosphate was significantly low.

Tables 10 and 11 respectively represent the percentage composition of grain and straw in respect of N, P, K, Ca and Mg. In both the experimental locations the treatments with different forms of phosphates tend to increase the phosphorus content of grain and straw. In general, the treatments with the phosphatic fertilizers increase both the Ca and Mg content of grain and straw. The increase is much more marked with Calcium.

Tables 12 and 13 respectively represent the average total phosphorus content (ppm) at Vellayani and Moncompu soils respectively. At Vellayani total P content in soil significantly increased with the application of P. Maximum was recorded by super phosphate which was on par with Mussoorie phosphate. Total P content was not significantly different between soils treated with Mussoorie rock phosphate and Rajasthan rock phosphate with increase in time there is a progressive reduction in total P.

Table 10. Average N, P, K Ca and mg Content of grain

Treatments	Locations	N %	P %	K %	Ca %	Mg %
P_1	Vellayani	1.09	0.26	0.88	0.78	0.16
P_2		1.12	0.32	0.87	0.83	0.20
P_3		1.12	0.31	0.88	0.84	0.20
P_4		1.11	0.32	0.87	0.83	0.21
	Moncompu					
P_1		1.05	0.29	0.86	0.74	0.19
P_2		1.10	0.32	0.89	0.86	0.23
P_3		1.13	0.32	0.88	0.85	0.21
P_4		1.12	0.32	0.88	0.85	0.22

Table 11. Average N, P, K, Ca and mg Content of straw

Treatments	Locations	N %	P %	K %	Ca %	Mg %
P_1	Vellayani	0.87	0.14	1.90	0.94	0.17
P_2		0.94	0.16	1.87	0.97	0.19
P_3		0.93	0.15	1.89	0.96	0.19
P_4		0.92	0.14	1.87	0.95	0.19
P_1	Moncompu	0.86	0.47	2.01	0.88	0.15
P_2		0.96	0.16	1.97	0.95	0.16
P_3		0.95	0.16	1.90	0.95	0.17
P_4		0.94	0.16	1.91	0.95	0.17

Table 12. Average total P content (ppm) in soil (Vellayani)

	I_1	I_2	I_3	I_4	Mean P
P_1	741.08	685.48	643.88	628.28	674.93
P_2	790.56	737.88	685.48	669.48	720.85
P_3	770.84	716.64	666.36	650.24	701.02
P_4	761.84	710.96	660.40	642.12	693.83
n	766.08	712.74	684.03	647.78	

CD(P) = 19.94 CD(I) = 3.63

Table 13. Average total P content (ppm) in soil (Moncompu)

	I_1	I_2	I_3	I_4	Mean P
P_1	821.02	791.70	762.58	746.92	780.55
P_2	841.46	814.76	788.52	776.40	805.28
P_3	837.56	811.34	788.64	778.74	804.07
P_4	842.40	811.62	789.54	779.32	805.71
Mean I	835.61	807.36	782.32	770.35	

CD(P) = 11.39 CD(I) = 10.62

But at Moncompu soil no significant difference in total P content was seen with different forms of P. There is a progressive reduction in total P with time.

Tables 14 and 15 respectively represent the average available P content (ppm) at the two experimental locations. Maximum available phosphorus content was recorded from plots treated with super phosphate. No significant difference was observed between the other two sources of P viz. Mussoorie rock phosphate and Rajasthan rock phosphate with respect to available P. At 40 and 60 DAT available P was not significantly different and maximum available P was recorded at 40th day. Similar results were observed for available soil P at Moncompu also. With respect to period also similar results were observed.

Tables 16 and 17 respectively represent the average Fe-P fraction (ppm) at the two experimental locations. Maximum Fe-P fraction was recorded by super phosphate treated plots. The two rock phosphate sources were found to be on par. There is significant difference in Fe-P content with respect to periods and maximum Fe-P content was recorded at 40th day. At Moncompu also super phosphate recorded highest Fe-P content and the two rock phosphate sources were found to be on par. Here also maximum Fe-P content was recorded at 40th day. At Moncompu there is significant interaction of treatments with periods. Here the effectiveness of super phosphate tend to decrease with time. Super phosphate is found to be more effective in increasing the Fe-P content during the early stages compared to harvest stage.

Table 14. Average available P (ppm) content in soil (Vellayani)

	I_1	I_2	I_3	I_4	Mean P
P_1	44.40	48.80	47.20	47.20	46.90
P_2	50.00	61.20	57.60	53.60	55.60
P_3	49.20	54.80	54.00	50.00	52.00
P_4	48.80	56.40	54.80	50.00	52.50
Mean I	48.10	35.30	53.40	50.20	

CD(P) = 2.77 CD(I) = 2.78

Table 15. Average available P content (ppm) in soil (Moncompu)

	I_1	I_2	I_3	I_4	Mean P
P_1	50.80	53.40	56.20	51.20	52.90
P_2	55.40	61.60	62.00	61.80	60.20
P_3	54.80	60.60	61.80	60.40	59.40
P_4	55.00	61.00	60.80	62.00	59.70
	54.00	59.20	60.20	58.90	

CD(- .92 CD(I) = 2.05

Different P fractions at Vellayani soil

Fig. III. Fe-P

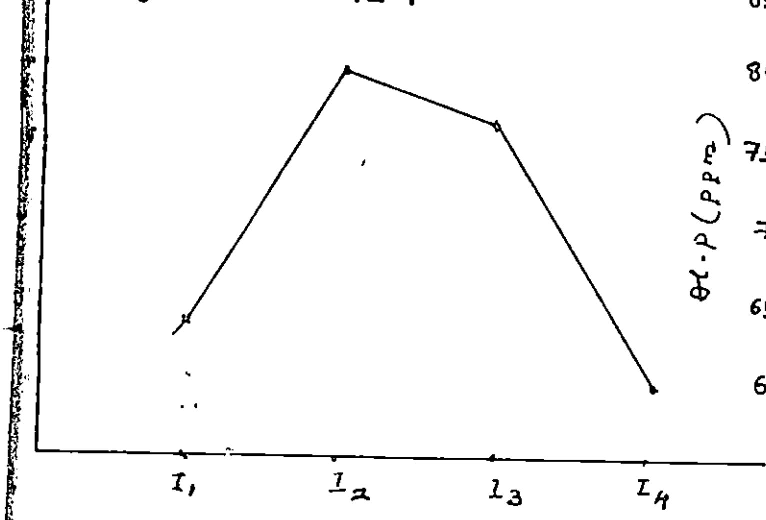
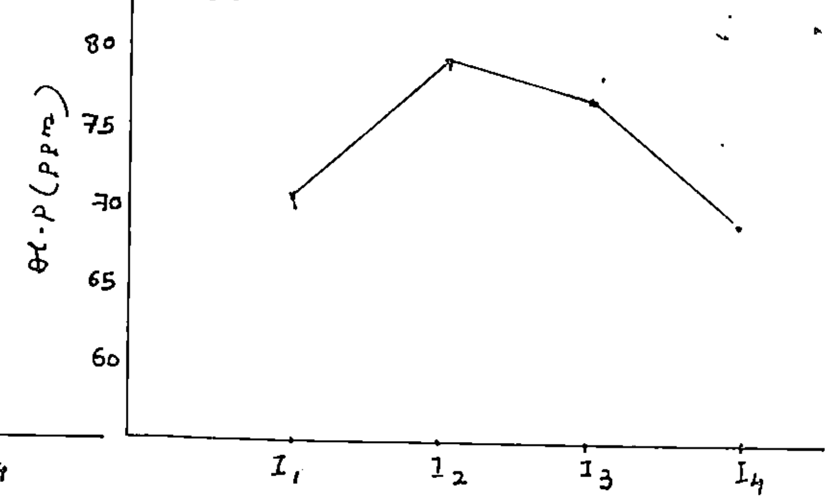
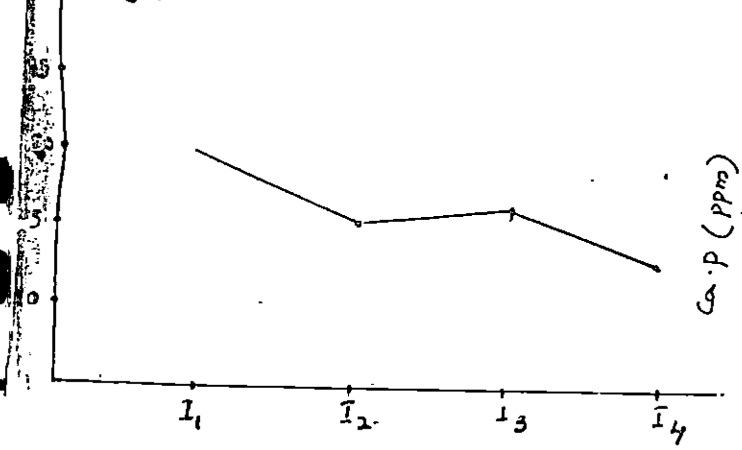


Fig IV Al-P



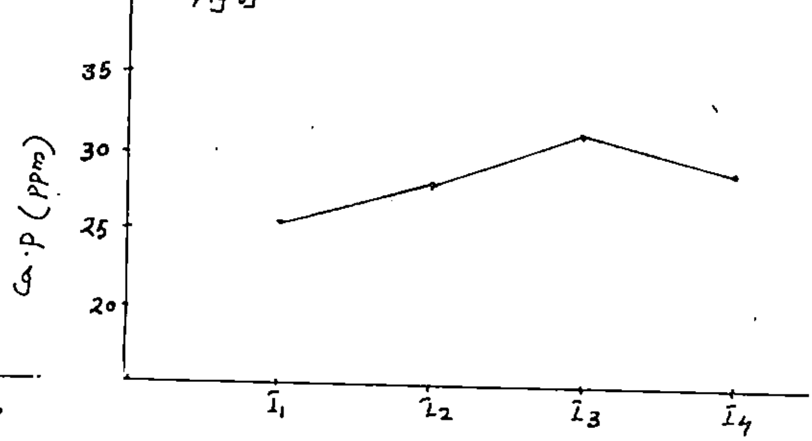
Reductant-Soluble-P

Fig. V



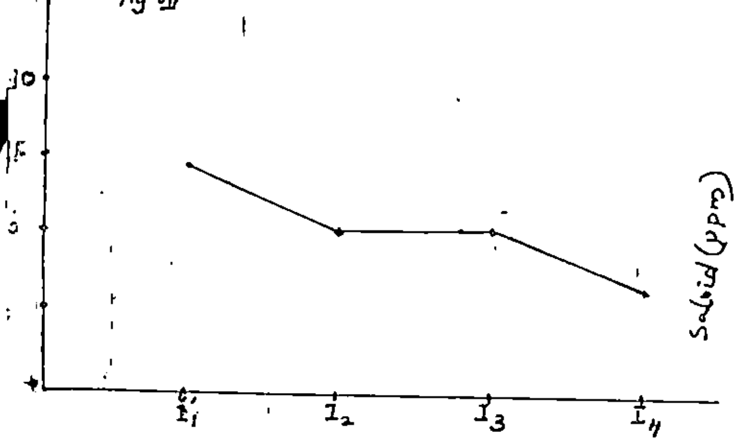
Ca-P

Fig VI



Occluded P

Fig VII



Saloid-P

Fig. VIII

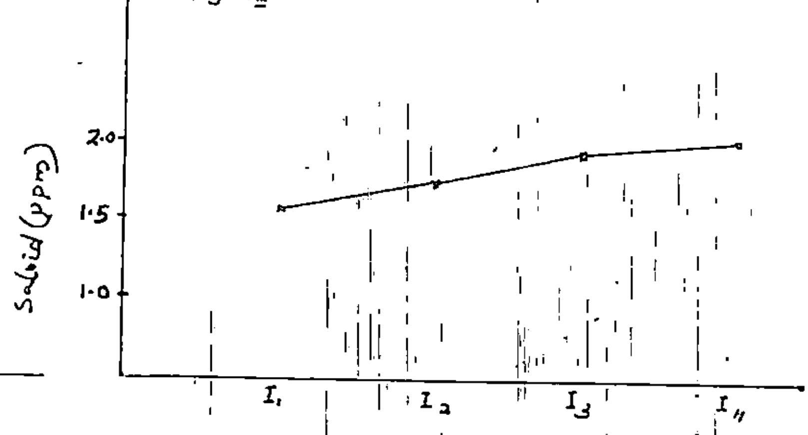


Table 16. Average Fe-P fraction (ppm) (Vellayani)

	I_1	I_2	I_3	I_4	Mean P
P_1	116.12	132.18	129.38	107.17	121.21
P_2	134.48	151.44	147.28	126.38	139.89
P_3	122.10	140.24	136.40	117.40	129.03
P_4	122.50	140.52	136.04	116.74	128.95
Mean I	123.50	141.10	137.28	116.92	

CD(P) = 2.06 CD(I) = 1.48

Table 17. Average Fe-P fraction (ppm) (Moncompu)

	I_1	I_2	I_3	I_4	Mean P
P_1	124.48	138.42	135.56	117.50	128.99
P_2	145.20	167.34	161.22	135.32	152.77
P_3	139.02	158.38	158.10	131.62	146.78
P_4	139.62	159.38	157.34	130.64	146.74
Mean I	137.08	155.88	153.05	128.77	

CD(P) = 1.46 CD(I) = 1.78 CD(PxI) = 3.56

Tables 18 and 19 respectively represent the average Al-P fraction (ppm) at the two experimental locations. Super phosphate is found to be significantly superior to the rock phosphates in enhancing the Al-P fraction at the two experimental locations. There is significant difference in Al-P content with respect to periods. There is an increase in Al-P content from 20th to 40th day and thereafter there is a decline and maximum Al-P content was recorded at 40th day irrespective of the locations. At Moncompu there is significant interaction between treatment and periods. During the earlier periods viz. 20 DAT, super phosphate was found to be more effective, but at later stages there is no significant difference between the sources.

Tables 20 and 21 respectively represent the average reductant soluble P content (ppm) in soils at the two locations. At Vellayani soil, phosphatic treatments tend to enhance the reductant P content of the soil. But there is no significant difference between the three forms. There is significant difference in reductant soluble P with respect to periods only during the initial period super phosphate was found to be significantly superior in enhancing the reductant soluble P. At Moncompu also similar results were observed. Here significant interaction of treatments with period is observed. During the initial periods viz. 20 DAT and 40 DAT super phosphate tend to increase the reductant soluble P content of the soil more ompared to rock phosphate.

Table 18. Average Al-P fraction (ppm) Vellayani

	I_1	I_2	I_3	I_4	Mean P
P_1	67.34	77.18	74.16	67 [illegible]3	71.54
P_2	72.22	81.32	78.20	[illegible]0	75.53
P_3	70.40	80.18	76.28	69.28	74.03
P_4	71.18	81.22	76.34	69.22	74.49
Mean I	70.29	79.98	[illegible]6.24	69.[illegible]	

CD(P) = 1.11 CD(I) = 1[illegible]

Table 19. Average Al-P fraction (ppm) Moncompu

	I_1	I_2	[illegible]	I_4	Mean P
P_1	78.66	85.50	8[illegible] 70	[illegible]	81.18
P_2	87.58	96.40	9[illegible].56	88.40	91.48
P_3	82.50	93.88	91.54	87 [illegible]	88.86
P_4	84.00	93.20	91.24	[illegible]	88.81
Mean I	83.19	92.25	[illegible].01	84.91	

CD(P) = 2.13 CD(I) = 1.7[illegible] CD(PxI[illegible] 3 [illegible]5

Tables 22 and 23 represent the [illegible]ge occluded P content (ppm) at the two loca[illegible]ons. At both the locations the treatments significantly increase the occ[illegible]d P content of the soil. But all the three source of P (P_2, P_3 and P_4) were found to be on par. At both the locations there is a significant decrease in occluded 'P' with increase in period and maximum accluded-P was recorded at 20 DAT and least during harvest. Interaction of P with intervel is also found to be significant at Moncompu. During the initial stages (20 DAT and 40 DAT) super phosphate significantly increase the occluded-P content of the soil. But at later stages there is no significant difference between the sources.

Tables 24 and 25 represent the average calcium-P content (ppm) of the soil at 2 locations super phosphate significantly increase the Ca-P content of the soil. There is no significant difference between the rock phosphate in enhancing the Ca-P content. There is a significant increase in Ca-P from 20th day to 60th day after which there is a decrease. Maximum Ca-P was recorded on the 60th day.

At Moncompu the phosphate treatments significantly increase the Ca-P content of the soil. But all the three sources of P were found to be on par. There is a significant increase in Ca-P with period from 20th to 60th day and there after it remains more or less steady. Interaction between the P and time is also found to be significant with increasing period the effectiveness of rock phosphate in producing Ca-P tend to decrease.

Tables 26 and 27 represent the average saloid-P content at the 2 locations.

Table 20. Average reductant - Soluble P (ppm) Vellayani

	I_1	I_2	I_3	I_4	Mean P
P_1	28.48	24.46	24.46	21.30	24.67
P_2	31.24	27.30	27.44	24.32	27.57
P_3	30.48	27.20	27.28	24.18	27.28
P_4	30.68	26.52	27.20	24.22	27.15
Mean I	30.22	26.37	26.60	23.51	

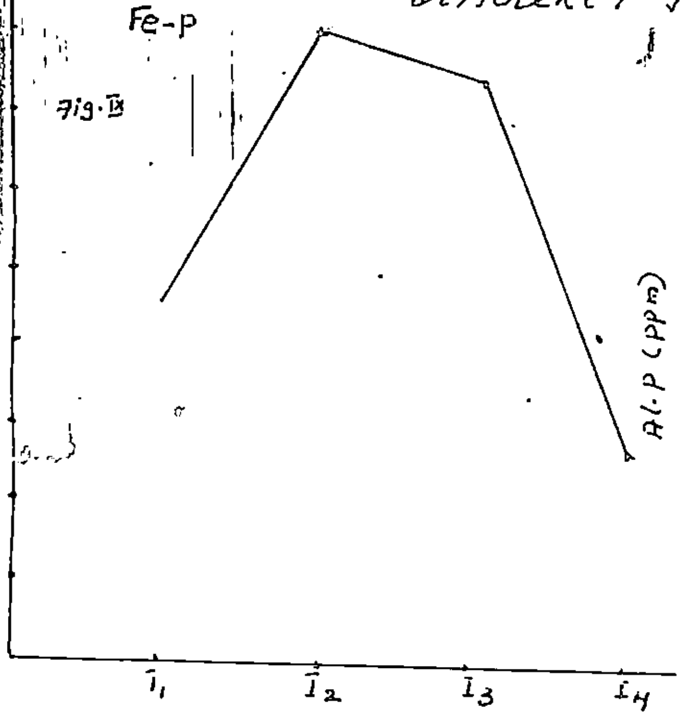
CD(P) = 0.79 CD(I) = 1.01

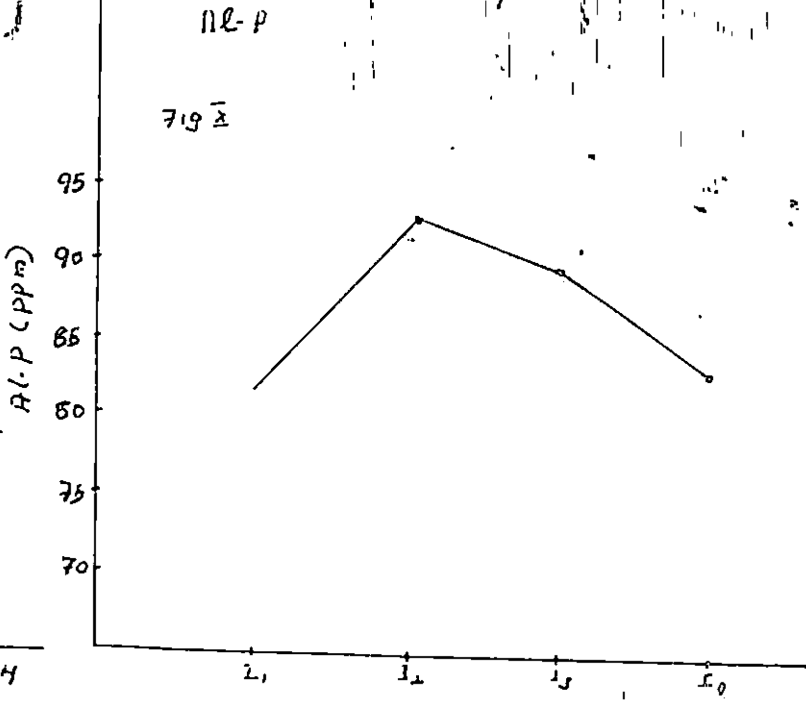
Table 21. Average reductant - Soluble P (ppm) Moncompu

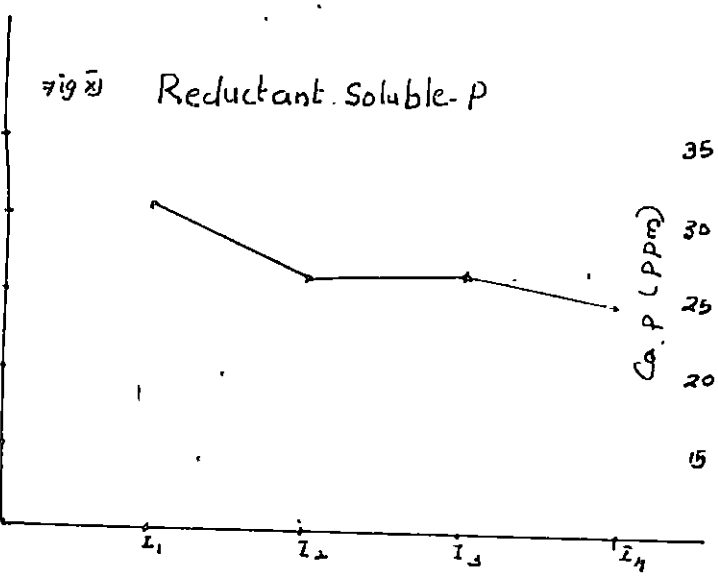
	I_1	I_2	I_3	I_4	Mean P
P_1	33.72	29.48	29.50	26.58	29.82
P_2	37.78	33.52	33.70	29.62	33.65
P_3	35.16	32.44	32.58	28.48	32.16
P_4	34.64	32.26	32.70	29.28	32.22
Mean I	35.33	31.93	32.12	28.49	

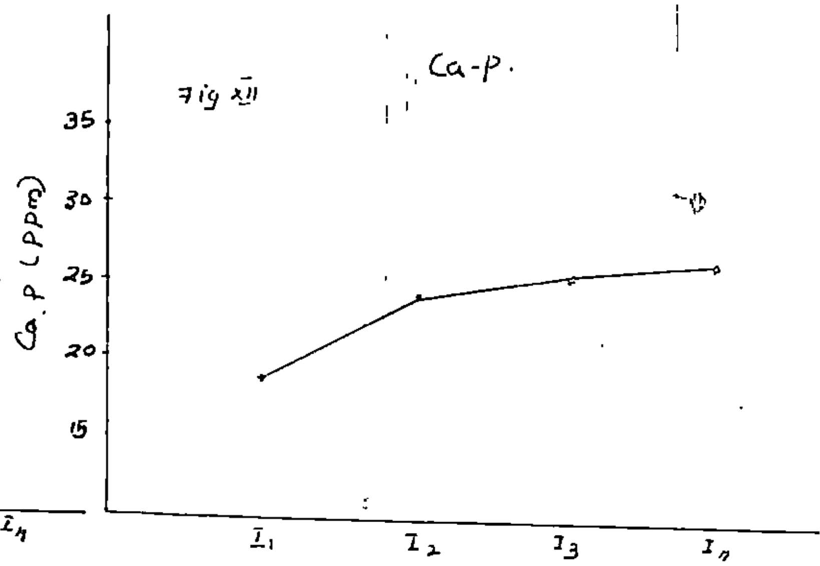
CD(P) = 1.76 CD(I) = 1.36 CD(PxI) = 2.73

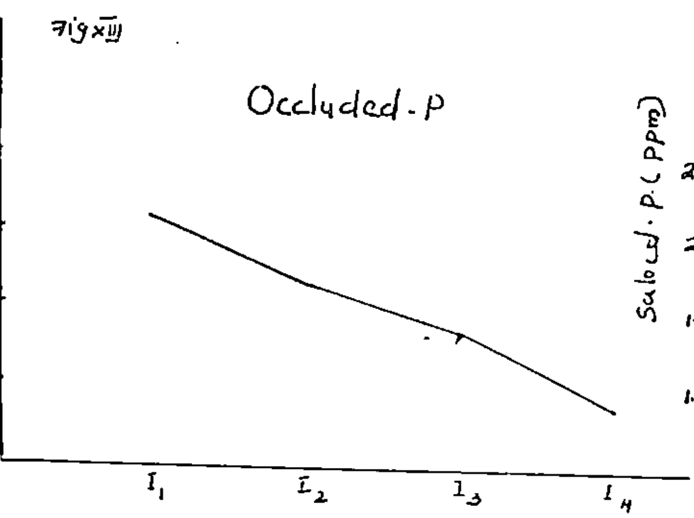
Different P. fractions at Noncompusoil











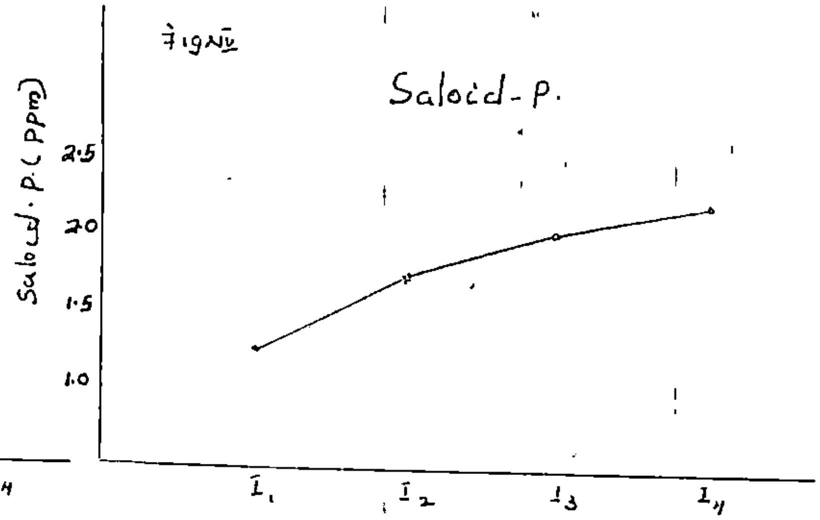


Table 22. Average occluded P content (ppm) of the soil (Vellayani)

	I_1	I_2	I_3	I_4	Mean P
P_1	22.38	19.56	18.40	17.38	19.43
P_2	26.32	22.16	21.18	19.46	22.23
P_3	24.52	21.52	20.26	18.38	21.17
P_4	25.16	21.20	20.40	19.24	21.50
Mean I	24.59	21.11	20.06	18.62	

CD(P) = 1.16 CD(I) = 1.007 CD(PxI) =

Table 23. Average occluded P content (ppm) of the soil (Moncompu)

	I_1	I_2	I_3	I_4	Mean P
P_1	23.55	20.44	16.58	18.48	18.51
P_2	26.40	23.60	19.48	14.58	21.05
P_3	25.70	22.44	18.48	13.66	20.07
P_4	24.54	22.80	18.24	13.32	19.72
Mean I	25.05	22.32	18.19	13.76	

CD(P) = 1.41 CD(I) = 1.29 CD(PxI) = 2.58

Table 24. Average Ca-P content (ppm) in soil (Vellayani)

	I_1	I_2	I_3	I_4	Mean P
P_1	18.32	20.38	22.34	20.24	20.32
P_2	29.52	31.30	38.92	33.26	33.25
P_3	27.40	30.40	35.16	30.28	30.81
P_4	28.18	30.58	35.42	31.24	31.25
Mean I	25.86	28.17	32.96	28.76	

CD(P) = 1.86 CD(I) = 0.92

Table 25. Average Ca-P content (ppm) in soil (Moncompu)

	I_1	I_2	I_3	I_4	Mean P
P_1	18.36	20.56	22.52	23.46	21.22
P_2	20.36	24.68	26.48	27.58	24.78
P_3	19.58	23.52	26.34	26.38	23.96
P_4	19.54	23.42	25.52	26.48	23.74
Mean I	19.46	23.05	25.22	25.98	

CD(P) = 1.31 CD(I) = 1.50 CD(PxI) = 3.01

At both the locations, the treatments, and periods have significant effect in enhancing the saloid P content super phosphate is found to be significantly superior over the 2 rock phosphates and the 2 rock phosphates were found to be on par.

All the phosphatic fertilizer treatments were found to be superior over control. There is a progressive increase in saloid P from 20th day till harvest. Irrespective of the locations super phosphate recorded the highest saloid P at harvest.

Table 26. Average saloid P content (ppm) Vellayani

	I_1	I_2	I_3	I_4	Mean P
P_1	1.26	1.46	1.68	1.82	1.55
P_2	2.06	2.20	2.38	2.36	2.25
P_3	1.50	1.70	1.76	1.88	1.71
P_4	1.44	1.74	1.74	1.78	1.67
Mean I	1.57	1.78	1.89	1.96	

CD(P) = 4.63 CD(I) = 8.05

Table 27. Average saloid P content (ppm) Moncompu

	I_1	I_2	I_3	I_4	Mean P
P_1	1.22	1.36	1.66	1.60	1.46
P_2	1.52	2.16	2.46	2.50	2.16
P_3	1.40	2.82	1.94	1.96	1.78
P_4	1.34	1.76	1.86	1.88	1.71
Mean I	1.37	1.78	1.98	1.99	

CD(P) = 0.11 CD(I) = 0.10 CD(PxI) = 0.20

DISCUSSION

DISCUSSION

Response of rice to the application of Rajasthan rock phosphate in two different rice soils of Kerala was studied through well laid out fields experiments in cultivator's field the experiments were laid out in cultivator's field due to the non response to P in many of the fields of experimental stations in the state. The results of the experiments are discussed below.

At the two experimental sites selected a significant increase in plant height was obtained for the different forms of P tried. At both the locations viz. Vellayani and Moncompu super phosphate recorded the highest plant height. Between the forms of rock phosphate tried there is no significant difference at Moncompu. But at Vellayani super phosphate is found to be superior to rock phosphate. The effect on plant height is mainly due to the effect on nitrogen applied and phosphorus has got only limited effect in deciding plant height ([redacted]) [redacted] Barnes et al 1986). Between forms of P tried there can not be significant variation in plant height because both the forms of P tried contain the same amount of total P. P fixation as it is water soluble in the case of super phosphate could not be reflected in plant height because the soil contains a medium level of native P. However between the three forms of phosphates tried and with that of control there is significant difference in plant height. This may be due to the non availability of native P for the growth of the crop. There are reports of P application to response to increase in plant height in acid soils of this type (Nair and Aiyer 1982). At Moncompu significant difference between forms of P tried is noted. In the initial period of plant growth super phosphate has got a significant effect over rock phosphates. With increase in time the difference in response to [redacted] different forms of P get nearly equalised. As the pH is in the acidic range with increase in time highest response is noted for P_3 and P_4. This is in concurrence with the earlier findings of Ghildayal (1975) Rastogi et al (1977).

In the case of tiller number at both the locations, the treatments, periods and their interactions are found to be significant. At Vellayani super phosphate produces the highest number of tillers/m^2. As this is a water soluble form and the soil is also around pH 5.5, the super phosphate might have been able to give the highest tiller number/m^2. The treatments with Mussoorie rock phosphate and Rajasthan rock phosphate (P_3 and P_4) are on par in deciding the tiller number. There are reports that between forms of P tried the same trend is usually obtained

Ensminger et al (1967) and Minhas et al (1974) also reported that since the soil is of pH 5.5 response to the applied P is enhanced in the laterite and kayal soils and this might have been the reason why (P_2) gave the highest result. At Moncompu as the soil is in a more acidic range of pH (5.2) due to the fixation of soluble applied phosphates and as the period progresses response might have got reduced. The P_2 treatment even though initially it gave good results in plant height and tiller number however decreased in its response with time and ultimately rock phosphate treatments P3 and P4 gave the highest tiller number. This is because P fixation might not have interfered in the case of rock phosphate treatments. Instead gradual solubilisation of the rock phosphate might have taken place.

In respect of yield components (Table 5 and 6) studied it is seen that the application of three forms of phosphates significantly increase these components which get reflected in the yield. At both the locations the results showed that treatments have no effect on 1000 grain weight, number of panicles/m^2 and panicle length. Only in the case of number of filled grains per panicle treatment has any significant effect. This may be due to the reason that the experiment under study was with soils of pH (5.1 and 5.5) and of average P status

(0.08 & 0.09%). There are reports that as the P availability is in the medium range response to the applied P cannot be expected (David, 1964; and Raheja, 1966). This might have resulted in the lack of significant effect on applied P in determining the yield parameters.

The results of yield of grain and straw at the two locations viz. Vellayani and Moncompu shows significant effect of treatments. Rice response to the application of P especially in soils deficient in P (Davide, 1964) Roy and Jha (1987). Between forms of P there is no significant difference with respect to yield. This is in concurrence with the findings of Shinde and Patnaik (1973), Shukla (1973) Singh and Datta (1974) Nair and Aiyer (1982). In kayal soils even though growth and yield parameters shows varying effect on treatments, in the case of yield the response is much more clear. This may be due to the seasonal effect. The crop has been raised during the rainy season and ended during the period in which water logging was not there in the field. A rainy season usually enhances the available P level in kayal soils. This might have contributed to the non significant effect between the treatments for growth and yield characters of rice. The rock phosphate treatments (P3 and P4) gave the highest yield.

However between super phosphate and rock phosphate treatments there was no significant effect. This is in agreement with the findings of Mehrotra (1966 and 68), Kurup and Koshy (1968), Shinde and Patnaik (1973), Singh and Dutta (1974), Chowdhary and Mian (1979), Subramanian and Manjunath (1983).

Results of P content of plants during different periods at the two experimental locations (Table 8 and 9) reveals the significant effect of treatments and periods. In Vellayani super phosphate is found to be significantly superior over the two forms of rock phosphates whereas in Moncompu all the three forms are on par. Higher P content in rice plants were obtained with the application of super phosphate than with rock phosphate. This is in agreement with the findings of Motsara and Datta (1971). At Moncompu since the pH is less than that at Vellayani, there is likely to be greater fixation of P from water soluble forms of P fertilizers viz. super phosphate than from rock phosphate. This might be the reason for the non significant effect of the forms of P tried even though during the initial period super phosphate gave a higher response than the other two phosphates. At Vellayani since the availability of P from super phosphates is more it shows a higher P content of plants with super phosphate. This might be due to the reason that P fixation have not interfered much at Vellayani compared to Moncompu because the pH is slightly higher than that at Moncompu.

Results of the percentage content of N, P, K, Ca and Mg of grain and straw at both the locations shows an increase in percentage component of these elements with treatments. Control plot has received both N and K. P2, P3 and P4 has received N, P and K. N, P, K application to the soil might have contributed to the increase in N, P, K content of both grain and straw. The same trend is also noted for Ca and Mg. The P applied to the soil is in the form of super phosphates and rock phosphates both contains calcium. This might have contributed to the increase in percentage of calcium. Rock phosphate tried also contain small amounts of trace elements and magnesium. This coupled with pH of the soil might have contributed to the increase in percentage Ca and Mg. Shukla (1973) observed that P content of rice grain was not significantly affected by different sources of P. Lutz (1974) stated that the application of P increases N, P, K, Ca and Mg concentrations. Kothandaraman et al (1973) stated that P in combination with nitrogen significantly influenced the Ca content of rice grain.

The results on total P_2O_5 content at both the locations show that periods and treatments have a significant effect in deciding the total P status of the soil. Treatment P1 shows the least level of P_2O_5 in the soil and P_2 shows the highest level of P_2O_5. This was closely followed by P3 and P4. Total P_2O_5 shows a progressive gradual decrease. Maximum decrease was noted on the 60th day. Between forms there is no significant difference. The requirements of phosphorus especially during the initial stages of growth, root formation and development is met from the available P_2O_5 of the soil reserves Maximum plant growth takes place on the 60th day after transplanting that is after panicle initiation stage. It is at this stage that the plant requires highest P. The increasing requirement of P is met from the release of P from rock phosphate treatments P3 and P4. In the case of P2 where initially water soluble super phosphate has been added, 90% of it undergoes reversion. However from the reverted phosphate gradually P is released which is taken up by root interception. Total P level in the soil get reduced and become minimum on the 60th day. Between forms of P there is no significant difference because all the three forms contain the same level of total P_2O_5.

Available P status (Bray No. 2) Table 14 and 15 is found to increase with submergence and there are reports that the available P increases with submergence. Results shows that treatments and periods have a significant effect in deciding the available P_2O_5 content. The available P_2O_5 level is found to increase gradually and the highest level is obtained on 60th day. Basak and Battacharya (1962) observed an increase in available P with water logging of rice soils upto flowering stage. Gupta (1973) in his studies on the behaviour of simple forms of phosphates had observed a similar release of available P upto 50th day. The available P_2O_5 level is found to increase gradually and highest level is obtained on 60th day after transplanting beyond which it shows a decline. Basak and Battacharya (1962) observed an increase in available P upto tillering stage (60th day) and a decline beyond this stage. The increase in available P level is noted in the case of water logging and is reported by workers like Gupta (1973). Initial increase in available P. P status was attributed partly to the addition of phosphatic fertilizers to the soil and partly to the solubilization of unavailable forms of P. Initial increase in available P level and then a decline after attaining a peak value has been attributed to the fact that mild reducting condition which make the Fe_2O_3 to become more active and sorb the 'P' which might have been released by the mineralisation of organic P. There are reports to show that soils with high organic P take much prolonged time for the attainment of a peak available P status on water logging. Water logging also increase Fe-P and Al-P in soil. The peak level of Fe-P and Al-P and Ca-P has been obtained on 60th day after transplanting. These fractions have direct contributing effect in deciding the available P of the soil (Najeeb 1989). Present study also shows a gradual increase and the peak values attains during 40th and 60th day respectively at Vellayani and Moncompu after which it shows a slight decline. Between the forms the same trend is followed. The super phosphate being a water soluble phosphate gave highest available P content initially. However with period the available P content reached almost the same level as in T3 and T4 due to the operation of fixation mechanism. This is in concurrence with the earlier findings of SarangaNath (1975) Nair and Aiyer (1978).

From the results of Fe-P at both the locations it is clear that there is a gradual increase in Fe-P fraction from the initial period to the 40th day and the highest level is achieved at 40th day, beyond which it shows a gradual decrease. Treatment has also got a significant effect in increasing the Fe-P fraction water logging itself can increase the Fe-P level in soils. There are reports that water logging increase Fe-P fraction in soils. [(Mahapatra and Patrick, (1969); Singh and Singh, (1976); Mandal and Khan (1976); Nair and Aiyer (1983), and Sah and Nikkelson (1986).] Soils rich in Al-P show significant effect in Fe-P on continuous water logging. Mahapatra and

Patrick (1939), Singh and Singh (1976), however found that in increase in Fe-P in alluvial soils till flowering and harvesting. The results of the present study is in concurrence with findings of the above workers. The increase in Fe-P is attributed to the reduction of ferric forms to ferrous forms. The super phosphate treatment shows the highest Fe-P fraction level on 40th day is almost maintained till 60th day eventhough it shows a decline almost same levels of Fe-P that are attained in the soils with P3 and P4 and there is no significant difference between P3 and P4 which are rock phosphates. From the available P status of the soils of the present study, it is clear that by the 40th day, the available P level was found to be highest. This synchronizes with peak periods of available P status and also peak periods of uptake of P by rice. This again is in confirmity with findings of Saranganath et al (1976), Menhilal and Mahapatra (1979), Nair (1976), Najeeb (1989).

At both the locations the treatments and periods have significant effect on the Al-P content of the soil. Maximum Al-P content is attained on the 40th day beyond which it shows a decline.

Mandal and Khan (1975) showed that under continuous water logging Al-P increased upto 20th day later decreased upto 60th day and again increased in soils poor in Al-P while in soils rich in Al-P it progressively increased. The results of the present study, however are at variance with the observation of Mandal and Khan in that initially there is a progressive increase upto 40th day beyond which there is a decrease irrespective of the initial Al-P level. This is in concurrence with the findings of Nair (1978), Najeeb (1989).

The results of reductant soluble P at both the locations show a progressive decrease with period. At both the locations the treatments and periods are found to be significant. The decrease is due to the mild reducing condition that makes Fe_2O_3 more active and sorb greater quantities of P which might have been released by mineralisation of organic P or by solubilization of Ca-P. This is in concurrence with the findings of Mahapatra (1968) and Patrick (1971).

The treatment P2 being water soluble initially gave higher reductant soluble P level. But the other two forms both being tri-calcium-phosphates gave initial low level of reduced P. With increase in period, due to change in Fe_2O_3 of soil due to water logging between forms of P there is no significant difference in reductant soluble P. This is also observed with soils of control plots where they do not receive any additional P. Similar progressive decrease in reductant P has been observed by Mahapatra and Patrick (1971), Nair Aiyer (1978) and Najeeb (1989).

In the case of occluded P at both the locations, the treatments and periods are found to be significant. Between P2, P3 and P4 there is no significant difference. The highest level for occluded P is noted for P2. The water logging and the resulting reduced condition that prevails in the soil coupled with the formation of Fe_2O_3 in the soil might have occluded the available P formed from the treatments and resulted in highest level of occluded P. The occluded P level shows a progressive decrease with periods and the decrease is due to the more solubilization effect of Fe_2O_3 due to the reduced condition of water logging. This is in agreement with the findings of Mahapatra and Patrick (1971), Nair Aryer (1978), Najeeb (1989). This pattern was followed irrespective of soil types similar results are obtained by Nair (1978).

The data on Calcium P content of the soil at Vellayani reveals a progressive increase of Calcium P upto 60th day and beyond which it shows a gradual decrease. The calcium P level in P1 also shows a gradual increase and maximum increase is obtained at 60th day after transplanting. This is mainly due to the effect on water logging and also plant root activity. This is in agreement with the findings of Gupta (1971). Mandal and Khan (1977) observed a gradual increase in Calcium P fractions in soils rich in Ca-P Najeeb (1989) also observed similar increase in Ca-P. Most of the phosphatic fertilizers used in the present study contain Ca-P and hence the observations of the above workers are confirmed.

Results on Ca-P at Moncompu shows a progressive increase with periods. The treatment (P1) which receives no P is inferior to P2, P3 and P4. The trend is common in all the treatments. This may be partly due to water logging and partly due to solubilising effect of native Ca-P in soil as well as added Ca-P in the form of phosphates. CO_2 released by microbial activity, solubilises the phosphate and made available and these by Ca-P level in the soil increases. Most of the fertilizers used for the present study also contain Ca-P. This pattern of progressive increase with period is also reported by Mandal and Khan (1977), Sundaresan Nair (1979).

All the phosphatic fertilizer treatments increase the saloid P fraction in both the soils. The initial higher level of saloid P was noted in the case of super phosphate treatment. This is due to the fact that super phosphate being water soluble caused the rise in the level of saloid fraction. But in the case of P3 and P4 both [redacted] rock phosphates, being not water soluble might not have effected the contribution to the rise in level of saloid P. Water logging itself in general can increase the saloid P level of the soil. However maximum saloid P level was noted at 60th day after planting. At this stage all the phosphatic fertilizer treatment contribution to the saloid P were almost at the same level. This is because at this period, the dissolution of the applied rock phosphate results and thereby contribution to saloid P by all other forms were almost on par.

Effect of water logging:

Water logging in general increase the Fe-P fraction in both the soils and attain a maximum level at 40th day. Differences in the soil do not bring about changes in the duration of water logging for the attainment of maximum value of Fe-P fraction. In the case of Al-P also peak values were obtained at 40th day irrespective of soil type. It is significant to note that Gupta (1971) also observed increase in Fe-P, Al-P and Ca-P. In the case of reductant soluble P and occluded P there is a progressive decrease with water logging till harvest soil types do not affect this pattern.

The increase in Fe-P, Ca-P and Al-P are in general due to the decrease in reductant - P, and occluded - P. The dissolution of the applied Ca-P also indirectly leads to an enhancement of the Fe-P fraction.

Similar progressive decrease in reductant-P and occluded P has been observed by Mahapatra and Patrick (1971).

Calcium-P fractions also increases with increasing periods of incubation reaching a peak value on the 60th day beyond which it tends to decrease. In this pattern soils do not introduce much variation and the results are in agreement with those of Gupta (1971) Nair and Aiyer (1979). Mandal and Khan (1977) observed a gradual increase in Ca-P fractions in soils rich in Ca-P. Most of the phosphatic fertilizers used in the present study contain Ca-P and hence the observations of Mandal _et al_ (1977) are confirmed.

The available P status (Bray No: 2) is found to increase with submergence reaching a peak value on the 40th and 60th day respectively at Vellayani and Moncompu beyond which it gradually declines. Similar increase in available P and subsequent decrease have been reported by workers like Gupta (1971). Basak and Bhattacharya (1962) had observed in the rice soils of Bengal a 64 per cent increase in available P upto tillering stage (30 days) which was maintained till pre flowering stage (60 days) beyond which it declines. Mandal and Khan (1975) however observed increase in available P upto 110 days. Thus there is variation in the period of submergence required for the attainment of the peak value in available P in different soils as reported by different workers mentioned above soil to soil variation are partly responsible for this, which was partly confirmed by the results of the present study.

Fe-P fraction in the different soils are enhanced by the phosphatic fertilizer treatments. The highest Fe-P was recorded by super phosphate. At Moncompu all the phosphatic treatments including mussoorie rock phosphate and Rajasthan rock phosphate significantly enhance the Fe-P fraction whereas the treatments have not significantly enhance the Fe-P fraction at Vellayani.

All the phosphatic fertilizer forms do not significantly increase the Al-P fraction over control. But there is considerable variation in behaviour at the two locations. The treatments significantly enhance the Al-P fraction at Moncompu than at Vellayani. This might be due to the initial higher level of P content and also lower pH at Moncompu compared to Vellayani.

However Al-P fractions are also some extent enhanced by addition of phosphatic fertilizer Yuvan et al (1960) showed that when p^{32} containing mono-calcium-phosphate is applied to water logged soils 80 per cent of the added phosphate could be recovered as Fe-P and Al-P.Gupta (1971) observed enhancement of Fe-P and Al-P fraction by the application of mono calcium phosphate to water logged soils. However such an enhancement is observed to be more pronounced with respect to Fe-P than to Al-P in the present study.

Reductant and occluded P continuously decrease with period of water logging and application of phosphatic fertilizer affect to some extent this decrease. The treatments behaved congenially over the two locations viz. Vellayani and Moncompu in enhancing the reductant soluble P and occluded P. The fact that Fe-P has been adjudged as the most dominant form and the observation that Fe-P and Al-P fractions increase at the expense of reductant P and occluded P explains the response in rice fields obtained in such soils.

In general, the treatments with phosphatic fertilizers enhance the calcium P fraction in at two locations. All the three phosphatic treatments behaved congenially over the two locations in enhancing the Ca-P fraction. This might be because both the locations have almost the same level of initial active calcium content. Water logging the soils which have already fixed P as Ca-P according to Mandal et al (1977) show a gradual increase particularly if the soils are rich in native Ca-P. Since the present study is with fertilizer treatments containing Ca-P the observed increase in Ca-P corroborates the findings of Mandal et al (1977).

With continuous water logging saloid P fractions increases upto 60th day. This trend is unaffected by the application of phosphatic fertilizers of different forms. However, the highest saloid P levels have been observed in super phosphate treatments. Similar increase in saloid P fractions due to water logging has also been worked by workers like Gupta (1967) and Sahay et al (1971).

It has to be pointed out from the present study peak periods of available P with peak fractions contributing towards available P are achieved by the 40th day. To synchronize peak available P with peak periods of uptake of P by rice crop, in situations where it is possible rock phosphate may be applied 10 to 15 days prior to planting. Using P^{32} Saranganath et al (1976) have also suggested such a shifting of application of rock phosphates in water logged soils.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Investigations were conducted to assess the suitability of Rajasthan rock phosphate for rice in two acid rice soils viz. Vellayani kayal soil and Moncompu soil respectively. The study also included a study on fractionation of the soil P collected at periodical intervals from these two locations for the different forms of P. The results are summarized below:

1. At both the locations a significant increase in height of plants, number of tillers, panicle length, thousand grain weight etc. was obtained by the application of phosphatic fertilizers over control. But between the different phosphatic forms no significant difference could not be observed.

2. In both the locations application of rock phosphate both Rajasthan rock phosphate as well as Mussoorie rock phosphate has been found to be as good as super phosphate in enhancing the yield of rice grain.

3. In both the locations the treatments with different forms of P increased the P content of grain and straw. This indicates that, the rock phosphates applied in acid soils while increasing the yield significantly increase the P content in plants also. In general, the treatments with phosphatic fertilizers increase both the Ca and Mg content of grain and straw. The increase is much more marked in the case of calcium.

4. At both the locations the total P content of the soil is found to be significantly enhanced by the phosphatic fertilizer treatments. The highest total P content was recorded 20 days after transplanting and there is a progressive decrease in total P with time.

5. At Vellayani, super phosphate is found to be significantly superior to the other two rock phosphates in enhancing the available P status of the soil. But there is no significant difference between the two forms of rock phosphates in enhancing the available P. At Moncompu all the phosphatic treatments ie. super phosphate, mussoorie rock phosphate and Rajasthan rock phosphate were found to be equally good in enhancing the available P. The difference in response might be due to the difference in pH of the two soils. The highest available P content was recorded at 40th day at Vellayani and on 60th day at Moncompu. Thus there is variation in the period of submergence required for the attainment of peak value in available P in the two soils. Soil to soil variation is partly responsible for this.

6. Fe-P fraction of the soils treated with phosphatic fertilizers increase with period. Maximum Fe-P was recorded by super phosphate. However between the two rock phosphates there is no significant difference. Maximum Fe-P was recorded at 40th day of water logging. At Moncompu all the phosphatic fertilizer treatments significantly enhance the Fe-P content.

/ All the phosphatic fertilizer forms significantly increase the Al-P fraction over control. But there is considerable variation in the behaviour at the two locations. The treatments significantly enhance the Al-P level at Moncompu than at Vellayani. The peak Al-P was recorded at 40th day at both the locations.

There is a progressive decrease in reductant soluble P and occluded P as the period progresses. The pattern was followed irrespective of soil types. The progressive decrease in reductant soluble P is accelerated by phosphatic fertilizer treatment in kayal and Moncompu soils. Same is the case with occluded P.

The treatments with phosphatic fertilizers increase the Calcium P fractions in all the soils. Application of Mussoorie rock phosphate and Rajasthan rock phosphate as well as super phosphate enhance the Ca-P fraction. There is not much difference between the locations in enhancing the Ca-P fraction with respect to the treatments.

Saloid P fraction reach a peak value by 60 days of water logging. The results of the present study indicate that Rajasthan rock phosphate compares very well with super phosphate and Mussoorie rock phosphate under water logged situations. Its lower cost will substantially contribute towards reducing the input cost of phosphates under acid rice soil conditions. The studies on the pattern of dissolution give an indication that its solubilization and conversion to more available forms can be put to greater advantage in the growing of a rice crop by synchronising the peak period of utilization of phosphate by the rice crop with the peak period of availability by shifting the basal application of rock phosphate by about 10 to 15 days perior to transplanting or sowing, in situations where such a practice is feasible.

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