USE OF CHEAPER AND EFFICIENT SOURCES OF PHOSPHATIC FERTILIZER FOR COWPEA IN RICE FALLOWS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Use of cheaper and efficient sources of Phosphatic Fertilizer for cowpea in rice fallows" 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.

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CERTIFICATE

Certified that this thesis entitled "Use of cheaper and efficient sources of phosphatic fertilizer for cowpea in rice fallows" is a record of research work done independently by Smt. OMANA, M 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

INTRODUCTION

In India the discovery of extensive rock phosphate deposits in Rajasthan, Mussoorie, Jabua, Singhbum and other locations have opened up possibilities of securing self sufficiency for fertilizer phosphorus.

However, the country's ability to secure self sufficiency depends very largely on judicious and prudent use of soluble phosphates for only such of those crops and soils for which inferior grades of rock phosphate cannot be directly applied. Inferior grade rock phosphates have been advocated on theoretical consideration for acid soils and for long duration crops such as plantation crops. In recent years evidence has been accumulated indicating the suitability of rock phosphates for acid soils. More recently results have also started coming on their usefulness in near neutral and slightly alkaline soils as well. (Saha and Sanyal, 1983 Ramasamy and Arunachalam, 1983).

The use of rock phosphate, particularly for the acid soils is recommended as desirable, since the phosphorus under these soil conditions becomes slowly available to the crop at all its growth stages. Moreover, these rocks appear to leave the soil with residual phosphorus which can benefit a succeeding pulse or rice crop. Different indigenous rock phosphates which are named after their places of origin, have appeared in the market competing with the relatively costlier superphosphate and ammonium phosphate. Farmers are left with the option to use any of these. They are at the same time desirous of knowing whether the superphosphate can be partly or fully replaced by rock phosphate for their field crops, particularly the summer crops grown in rice fallows under restricted irrigation facility. Detailed information is lacking on the use and efficiency of indigenous phosphates in the acid soils of Kerala. The selection of a cheaper and efficient fertilizer, suitable for the soil and at the same time helps in improving the crop yield is therefore felt very important. Scientific research over the years has contributed largely to expand our knowledge of the inherent characteristics and soil plant behaviour of phosphate rock and factors affecting its fertilizer efficiency. In India, the merits and demerits of direct application of ground phosphate rock to the soil has recently been investigated extensively in laboratory incubation studies, green house tests and field trials. Phosphate rock alone which is cheaper or in combination with superphosphate has been found to be nearly as effective as any other chemically processed water soluble source.

Water soluble phosphorus applied to acid soils gets fixed into more stable and difficultly available form of iron and aluminium phosphates. Calcium phosphate in phosphatic rock is less stable and gets converted into available form by the soil acidity. The practice of direct application of suitable phosphatic rocks to acid soils, therefore, provides a clue to finding out a cheaper and also an efficient, alternative source of phosphorus to crop plants.

In view of this, there is need for experimentation especially in cropping systems where the duration of component crop is short and the combination of different component crops form part of a cropping system. Thus, for example, there is need for experimentation on the comparative efficacy of these materials in different crop combinations of rice cropping system. As part of this attempt, the study has to be centered round the summer rice fallow wherein the soil conditions are entirely different from that of the dryland conditions. In summer rice fallows, pulse is being advocated as a catch crop to take advantage of the residual moisture. In view of this a suitable phosphate source has to be thought of for the summer fallow pulses including the high yielding short duration cowpea varieties which appear to be the most promising. Moreover, the phosphate rocks applied to soil may even leave residual phosphorus, which can benefit the succeeding crop. Thus, the present study is based on an attempt to assess the comparative effects of different phosphatic fertilizers on cowpea grown in rice fallow with a view to finding out a cheaper and efficient P fertilizer and to study the residual effect of these phosphatic fertilizers on the succeeding crop of rice grown in the same soil. It is hoped that the result of this study will help to highlight the significance of utilising cheaper and indigeneous sources of phosphatic fertiliser for our crops.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The literature on the various aspects of the effects of different forms of phosphatic fertilisers on pulses in general and its residual effect on a succeeding crop of paddy is reviewed.

I. Effect of phosphorus on yield characters of pulses

Ezedinma (1965) reported that increased seed yield of cowpea was obtained by combined application of 20 kg N + 40 kg P_2O_5/ha. Moolani and Jana (1965) noted that in an acid laterite soil with a high fixation capacity for phosphorus 100 kg P_2O_5/ha significantly increased the yield of grain.The yield increased from 645.2 kg/ha in control to 880.2 kg/ha with 100 kg P_2O_5/ha. Behl et al. (1969) has reported significantly increased yield of black gram due to phosphorus application. Fageria and Bajpai (1969) have indicated that the seed yield of pea was increased from 1.34 t/ha in plots with no phosphorus to 1.75 t/ha in those treated with 50 kg P_2O_5/ha. In field trials with cowpea, several combinations of P_2O_5 and K_2O were tried, but yield responses were obtained for phosphorus only (Worley et al. 1971). Malik et al. (1972) has reported that application of 60 kg P_2O_5/ha markedly increased the seed yield in cowpea. Panda (1972) found that application of phosphorus increased length of pod, average weight of seed per plant and yield of grain in green gram. Kurdikeri et al. (1975) observed highest seed yield in cowpea with the application of 22 kg P_2O_5/ha. Venugopalan and Morachan (1974) have revealed that application of phosphorus influenced the number of pods per plant in green gram. Johnson and Evans (1975) observed that cowpea yield was not affected by phosphorus application in soils where the phosphorus content was high. Dalal and Quilt (1977) found an increase in dry matter yield in pigion pea by phosphorus application. Subramonian et al. (1977) found increased number of pods per plant and number of grains per pod in cowpea due to application of 25 kg P_2O_5/ha. Ahlawat et al. (1979) reported that application of phosphorus had marked effect in increasing the yield attributes (number of pods per plant, pod length and 100 grain weight) and grain yield in cowpea. Duraisamy and Palaniappan (1979) have reported that yield components such as number of pods per plant, number of seeds per pod and thousand grain weight in green gram (Var; Co_2) was not influenced by phosphorus application. Neither grain yield nor haulm yield was affected. A linear increase in grain yield of cowpea by phosphorus application was observed by Jayaram and Ramiah (1980). Singh et al.(1982) reported that application of phosphorus increased grain and haulm yield in cowpea. Lamera and Paiva (1983) reported highest soybean yield of 1.9 t/ha with 60 kg P_2O_5/ha compared with 1.3 t/ha in control plot. Machado et al. (1983) reported that phosphorus fertilization significantly increased pigion pea seed yield. Haque et al. (1984) using 32_p in two soil types of Bangladesh, reported that application of phosphorus increased seed and haulm yield in soybean.

II. Effect of different sources of phosphorus on growth and yield of pulse crop.

Chandani and Oberoi (1956) and Khan and Malkur (1957) in their studies on manuring of sunnhemp with superphosphate at 80 lbs per acre recorded an increase in yield of green matter. Panos (1959) reported increased yield in annual legumes as a result of superphosphate application. Kanwar Singh and Tagjit Virk (1965) have reported significant increase in growth of mung by the application of 60 kg P_2O_5/ha in the form of superphosphate. Pathak (1967) has reported that application of

34 kg P_2O_5/ha as superphosphate to green gram doubled its grain and haulm yields compared to the control. When phosphorus was applied as rock phosphate the yield of green gram was increased by 90-100 per cent at higher levels. Prasad et al. (1968) showed significant yield increase in chick pea, peas, urid, mung, lentil and lathyrus by the application of phosphorus. They have also found that dicalcium phosphate was as effective as superphosphate. Mata and Sanchez (1970) have reported that yield of cowpea in triple superphosphate was higher than in single superphosphate. Motsara and Datta (1971) studied the efficiency of rock phosphate as a fertilizer for direct application to peas in acid soil and showed that rock phosphate performed better than superphosphate. From the result of a field trial on cowpea Agboola and obigbesan (1977) found that converted bone and superphosphate gave significantly higher yield than rock phosphate or basic slag. Maloth and Prasad (1977) have reported that rock phosphate was equally good as superphosphate for cowpea. Tarila et al. (1977), have reported that increasing levels of applied phosphorus enhanced growth, flower and fruit number as well as leaf number and area and earliness of flowering in cowpea. Sundaresan Nair [illegible] (1978) have shown Mussoorie phos-

phate as an efficient phosphorus fertilizer for green gram in the slightly acidic laterite soils of Kerala. Results of field trials conducted at Pattambi have indicated that the yield of cowpea was significantly increased by the application of rock phosphate when compared to that treated with superphosphate (Anon. 1979). From a field trial on an acid soil using soybean and ground nut, Mathur (1979) concluded that Mussoorie phosphate under limed condition showed better performance than under unlimed condition. Prasad and Singh (1980) have reported that for forage legumes-Cowpea and cluster beans, Mussoorie rock phosphate was only 22 per cent as effective as ordinary superphosphate. Haque et al. (1980) found that in cowpea, triple superphosphate gave higher yield than moroccan rock phosphate followed by Carolina rock phosphate and Christmas Island phosphate. Hundal (1981) has reported that efficiency of Mussoorie rock phosphate was considerably higher for the legumes-cluster beans and groundnut than for the cereal-wheat. Taneja (1981) has reported that the effectiveness of phosphocompost (rock phosphate compost) in increasing cowpea fodder yield was only 50 per cent of that of single superphosphate. However, the effect of phosphocompost was similar to that of single superphosphate in producing wheat. From the result of a field experiment using ^{32}P lebelled superphosphate, Mahajan et al. (1982) observed that grain, haulm and total dry matter yield in soybean increased significantly with increasing soil fertility. Mishra et al. (1982) have reported from the results of field trials with vigna radiata that phosphate enriched compost containing 3.13 per cent phosphorus prepared by composting cattle dung and farm waste with Mussoorie rock phosphate produced grain which was comparable to that obtained with single superphosphate. Field trials conduced by All India Coordinated Agronomic Research Project (ICAR) have indicated that in Majhera (uphills), Mussoorie rock phosphate proved superior to single superphosphate for cowpea. Subramonian and Manjunath (1983) observed that the response of Mussoorie phosphate to red gram was as good as superphosphate even under dry land conditions. Asarov (1983) in a band culture trial using $Ca\ H\ PO_4$, phosphorite, $Al\ PO_4$ as the only phosphorus source for a series of legumes, has reported that phosphorite was almost as good a source of phosphorus as $Ca\ HPO_4$ for lupinus species, sweet clover, soybean and phaseolus vulgaris at all stages of plant development except at the beginning of the vegetative stage. For serradella and fodder beans, phosphorite phosphorus was much less available. For soybean, Al PO_4 and Fe PO_4 were nearly as effective as phosphorite. For Peas, phosphorus from Al PO_4 and for phaseolus vulgaris, phosphorus from Al PO_4 and Fe PO_4 was least available. Haque et al. (1984) using ^{32}P as tracer, found that phosphorus application to two soil types of Bangladesh increased seed and haulm yields in soybean.

III. Effect of different sources of applied phosphorus concentration on the uptake of nutrients at different growth stages.

From a field study conducted by Marvin et al. (1953) to assess the effect of phosphorus on soybean, it was concluded that that the phosphorus content of plant increased with application of phosphatic fertilizer. Shende and Sen (1958) have reported that application of phosphorus increased nitrogen content of plant in guar. Iswaran et al. (1969) observed that plant uptake of total phosphorus, fertilizer phosphorus and soil phosphorus were significantly higher or tended to be higher in inoculated than in non-inoculated plants of vigna sinensis, phaseolus aureus and phaseolus mung by the application of 80 kg P_2O_5/ha. Belogolovtsev (1970) pointed out that in pea, application of NPK markedly increased the rate of N and K uptake between flowering and fruiting stages but did not affect phosphorus uptake. Omueti and Oyenuga (1970) indicated that application of superphosphate increased the protein content of seed in cowpea. Atanasiu (1971) has reported that phosphorus uptake in acid Ethiopion soil from citrate soluble phosphate was higher than that from water soluble phosphate. Malik et al. (1972) showed that application of phosphorus had no effect on protein content in cowpea.

Sahu and Behera (1972) have reported that in cowpea, nitrogen content in shoot, root and grain increased significantly by phosphorus manuring. Protein content of grain of cowpea was increased from 25.3 to 28.3 per cent by inoculation and application of phosphorus. From the result of the trials conducted to evaluate the effect of three phosphorus sources on ground nut, Sanchez and Mata (1972) found highest utilization of applied phosphorus from superphosphate. Gttonsikar and Miller (1975) have reported that uptake of polyphosphate in sterile system suggests direct absorption of polyphosphate by soybean plants, while under sterile reinoculated condition indicate a greater response to orthophosphate. But sterile inoculated system provided evidence for nearly twice the uptake of phosphorus by plants. Shankar Maloth and Rajendra Prasad (1976) compared the efficiency of rock phosphate and superphosphate for cowpea and reported that application of 50 kg P_2O_5/ha as superphosphate or rock phosphate almost doubled the phosphorus uptake by the summer season crop as compared to no phosphorus application. Dalal and Quilt (1977) have reported that fertilizer phosphorus significantly increased the total phosphorus uptake in pigeon pea.

Hegde and Saraf (1982) have reported that phosphorus fertilization significantly increased the nitrogen and phosphorus contents in pigeon pea and also uptake of all nutrients. From a field experiment using ^{32}P labelled superphosphate Mahajan et al. (1982) concluded that the total phosphorus uptake in soybean increased significantly with increasing soil fertility. Kang and Nangju (1983) found that phosphorus significantly increased the nitrogen content of cowpea plant. From the result of a pot trial with soybean grown in two soil types Hague et al. (1984) have reported that application of phosphorus increased seed phosphorus content and phosphorus uptake. Havlin et al. (1984) have reported that phosphorus uptake by alfaalfa was significantly increased by phosphorus fertilization on the keeth soil.

IV Comparative effects of different sources of phosphorus fertilizers

Chang and Chiang (1953) indicated that rock phosphate and superphosphate were of comparable value in acid soils but the difference in neutral and alkaline soils was quite apparent. In field trials conducted by the Fertilizer Corporation of India for comparing the effectiveness of different forms of phosphorus fertilizer including rock phosphate showed that citrate soluble sources were not inferior to water soluble forms in promoting growth and plant development (Anon., 1971). Atanasiu (1971) has reported that fertilizer containing water soluble phosphate showed a good response to the yield of plants. Moreover, Rhenania phosphate soluble in ammonium citrate has a better fertilizer effect than superphosphate in acid soils as well as on calcareons and alkaline soils. He has also reported that in Kenia and Liberia on laterite soils the citrate soluble phosphate had better effect than the water soluble forms. Mandal and Khan (1972) have reported that rock phosphate and basic slag were more effective than superphosphate for growing rice in acid soils. Dashrath Singh et al. (1976) from laboratory incubation studies have reported that the phosphorus availability of different sources of phosphate like Udaipur phosphate, Mussoorie phosphate, Laccadive phosphate deposit and superphosphate mixed with phosphobactrin spices, initially reduced upto 75 days of incubation due to incorporation of phosphorus solubilizer and afterwards increased. Reduction in available phosphorus values with the use of phosphobactrin is attributed to microbial locking up process. Pot culture experiments were carried out using different sources of phosphate, Udaipur, Mussoorie, Laccadive phosphate deposits and superphosphate on fodder crops, Dashrath Singh et al. (1976) have found that the availability coefficient ratio (ACR) was 0.6 for Udaipur, 0.75 for Mussoorie and 0.21 for Laccadive at 60 kg P_2O_5/ha level. Dashrath Singh and Mannikar (1976) compared Udaipur, Mussoorie and Laccadive rock phosphate with superphosphate, the percentage efficiency was found to be 78, 62 and 54 respectively. In a comparative study of the effectiveness of different sources of phosphatic fertilizer, Hundal and Sekhon (1976) have reported that effectiveness of nitric phosphate increased with the proportion of its water soluble fraction. Dicalcium phosphate and superphosphate were almost equal in their effectiveness. Rock phosphate was the best effective source of fertilizer phosphorus. From the result of a field trial Motsara and Datta (1976) have reported that rock phosphate proved to be as effective as superphosphate. Regarding the residual effect, rock phosphate was a better source of phosphorus than superphosphate in acid soils. From the result of a three year trial with maize and wheat on comparative efficiency of different phosphatic fertilizers, Meelu et al. (1977) have reported that on wheat wholly water soluble phosphorus sources proved equally effective and gave significantly higher yield to the extent of 13.8 to 22.5 per cent and 8.9 to 17.2 per cent over suphala (30 per cent water soluble phosphate) and nitrophosphate (50 per cent water soluble phosphate) respectively. Atanasiu et al. (1978) have reported that with a low phosphorus application (45 kg P_2O_5/ha), water soluble phosphate resulted in better maize development and higher phosphorus uptake at the beginning of growing period, water soluble and mixed phosphate gave better results during later stages of growth. With a large phosphorus application (90 kg P_2O_5/ha), the water insoluble and combined phosphate gave good results during the entire growing period. Singh and Mehrotra (1978) found that pyrites applied with superphosphate or rock phosphate gave better effect on wheat than when they were applied alone. The beneficial effects were increased in the phosphorus content of grain and moderate increase in the available phosphorus of the soil under these treatments. Mishra and Gupta (1980) have found that the response of grain yield of wheat to the application of rock phosphate was very poor. Yield response to the application of a mixture of rock phosphate plus superphosphate (1+1) was as good as to the application of superphosphate. A mixture of rock phosphate and low grade pyrites (1+2.5) was inferior to superphosphate. Dashrath Singh et al. (1979)(a) have reported that Visakhapatnam, Udaipur, Mussoorie and Laccadive Phosphates when mixed with Amjore pyrite in the ratios of 1:0.16, 1:0.2, 1:0.25, 1:0.33, 1:0.5 and 1:1 and applied to the soil of pH 7.8, with the narrowing of rock phosphate-pyrite mixture ratios, the amount of available soil phosphorus increased. Amongst different indigenous rock phosphates, Laccadive phosphate earth was superior to others. From the result of a forage cropping sequences involving berseem-guar-cowpea, Dashrath Singh et al. (1979)(b) have reported that when phosphates were applied to berseem each year and guar and cowpea were grown on the residual soil phosphorus, Udaipur, Mussoorie and Laccadive phosphates respectively were found to be 60, 66 and 67 per cent as effective as superphosphate and corresponding availability coefficient ratios were 0.50, 0.59 and 0.71 respectively. Hundal et al. (1979) have reported that the effectiveness of various sources of fertilizer phosphorus was enhanced with increase in the proportion of water soluble phosphorus. Dicalcium phosphate (dihydrate) and nitrophosphate - super phosphate of 70 per cent water solubility were almost equal in their effectiveness. Nitrophosphate of 30 per cent water solubility was the least effective source of fertilizer phosphorus. Sadanandan et al. (1979) have reported that ammonium nitrate phosphate containing 50 per cent of phosphorus in the water soluble form applied to rice was as effective as water soluble phosphate, in respect of dry matter production, phosphorus uptake and utilization of applied phosphorus. Mishra et al. (1980)(a) have shown that the response of maize to Mussoorie rock phosphate was very poor, but spectacular improvement in its efficiency occurred when it was mixed with pyrites in 1÷2.5 ratio. A mixture of Mussoorie rock phosphate and superphosphate in equal proportion on total phosphorus basis was found to be 83.1 per cent as effective as superphosphate for increasing the grain yield of maize. Mussoorie rock phosphate mixed with pyrites or superphosphate was comparable with superphosphate interms of the respone of grain yield of wheat. But Mussoorie rock phosphate used alone was significantly inferior to other three sources of phosphorus tested (Mishra et al. 1980). From the result of a field experiment to compare the efficiency of Mussoorie phosphate with ordinary superphosphate for two forage legumes - cowpea and cluster beans, and residual effect on wheat, Prasad et al. (1980) have reported that for both the forage legumes Mussoorie phosphate was only 22 per cent as effective as ordinary superphosphate. Pot culture experiment on the comparative efficiency of Mussoorie Phos and superphosphate alone and their combinations with and without farm yard manure in rice growing acid and neutral soils showed that superphosphate (100 per cent) and the combination of superphosphate (25 per cent), Mussoorie phos (75 per cent) and farm yard manure produced higher yield of rice in acid soils than in neutral soils (Ramasamy and Rani perumal (1980). Sahu and Pal (1983) have shown that under a rice - wheat farming system, physical mixture of Mussoorie rock phosphate and single superphosphate in the ratio of 50:50 at 80 kg P_2O_5/ha had greater direct and residual effect in increasing the productivity of rice and wheat in respective seasons.

V. Absorption, changes and residual effect of different sources of phosphorus

Bruce (1968) studied the effect of leaching and residual effect of superphosphate and rock phosphate under high rainfall conditions in alluvial soils and found that leaching of rock phosphate was similar to that of superphosphate. The residual effect, however, was appreciable in rock phosphate. Patnaik *et al.* (1968) from his studies using different liming and phosphorus materials on rice yield in an acidic laterite soil (pH 4.8) concluded that addition of liming materials increased the availability of applied phosphorus as measured from soil content and plant uptake. Panda and Panda (1969) have reported that short term evaluation of rock phosphate would be meaningless in case of lateritic soils as the residual effects are more important than the immediate effect. Motsara and Datta (1971) compared the effectiveness of rock phosphate and superphosphate in acid soils for the crops-rice, wheat, maize and peas and found that there were significant differences in yield. Eighty kg P_2O_5/ha as rock phosphate gave the same yield as that obtained from an equivalent doze of superphosphate in the case of paddy, wheat and maize, but greater yield was obtained in peas with rock phosphate than superphosphate. In their residual study, rock phosphate was significantly found to be better than superphosphate with respect to crop yields and residual phosphorus status of soil. From the result of a field experiment conducted on soils with varying pH from 4.5 to 5.9 Motsara and Datta (1971) found that on peas the yield due to rock phosphate was better than superphosphate. On evaluation of residual effects it was found that rock phosphate was significantly better than superphosphate, both in terms of crop yield and residual phosphate status of the soil. Lehr and Mccellan (1972) have reported good yield of rice from first crop from rock phosphate application but poor yield from second and third rice crops. This in their opinion could be attributed to the effect of residual phosphorus which was no longer in apatite form in which it was applied initially but as intermediate products of soil phosphorus interaction.

Rajendra Prasad and Govil (1973) studied the residual effect of phosphate applied to sorghum on the succeeding crop of wheat in a field experiment during 1968-69 and 1969-70. The residual effect was significant and more with triple superphosphate than with rock phosphate. Mishra et al. (1978) recommended Mussoorie rock phosphate as a better source of phosphorus for maize on acid soils compared to superphosphate. However, the residual effect of both the sources was similar on a succeeding wheat crop. Monkwunye (1975) revealed that rock phosphate had a better residual effect on subsequent crops than superphosphate. Motsara and Datta (1976) have reported that rock phosphate proved to be as effective as superphosphate. The residual effects of fertilizer phosphorus (evaluated by crop response and available phosphorus content of soils) suggest that rock phosphate is a better source of phosphorus than superphosphate in acid soils. From the field trial carried out at three locations in Nigeria with maize as the main crop, followed by vigna unguiculata, Atanasiu et al. (1978) reported that with a low phosphorus application (45 kg P_2O_5/ha), water soluble phosphate resulted in better maize development and higher phosphorus uptake at the beginning of the growing period whereas water soluble and mixed phosphate gave better result during later stages of growth. With larger phosphorus application (90 kg P_2O_5/ha), the water insoluble and combined phosphate gave good result during the entire growing period. Combined phosphates (partly water soluble and partly insoluble) produced highest maize yield and greatest phosphorus uptake. All phosphate types had a good residual effect on the yield and phosphorus uptake of Vigna ungui-culta. Mishra et al. (1978) have reported that the response of grain yield of wheat to the application of rock phosphate was very poor in first and second year (1974-75 and 1975-76). However, the response to the application of a mixture of rock phosphate and superphosphate (1+1) was as good as that of application of superphosphate. Mishra et al. (1980)(a) have showed that the response of maize (Zeamays Linn.) to Mussoorie rock phosphate alone was poor but spectacular improvement in its efficiency occurred when it was mixed with pyrites in the ratio 1:2.5. A mixture of Mussoorie rock phosphate and super-phosphate in equal proportion on total phosphorus basis was found to be more efficient in increasing the grain yield of maize. With regard to its residual effect on wheat, the differences among phosphorus sources were much less compaired to the direct effect on maize. From the result of a field experiment conducted at the Indian Agricultural Research Institute, New Delhi, Prasad and Singh (1980) have reported that for forage legumes-cowpea and cluster beans, Mussoorie rock phosphate was only 22 per cent as effective as ordinary superphosphate and it had no significant residual effects on wheat. Ramaswamy (1981) has reported that as a direct effect, superphosphate recorded slighly higher paddy production and larger phosphorus uptake than rock phosphate while residual effects the two sources were statistically on par. Tanija et al. (1981) studied the direct and residual effect of rock phosphate compost in legumes. The effect was similar to that of superphosphate on wheat grain yield. Phosphocompost produced a better residual effect on seed yield and phosphorus uptake in *Vigna radiata*, than with superphosphate. Mussoorie phos proved superior to single superphosphate for soybean. And Mussoorie phos produced better residual response in wheat than single superphosphate (Anonymous, 1983). Natarajan et al. (1983) studied the residual effect of rock phosphate on black gram which was grown after finger millet. In acid soils Mussoorie rock phosphate was very effective in maintaining the residual effect and in neutral red soil this effect was considerable only when it was combined with farm yard manure. Ramasamy and Arunachalam (1983) have reported that superphosphate is slightly superior to Mussoorie phos for the main crop of paddy. If a subsequent crop of paddy has to be raised without further application of phosphorus, Mussoorie phos would give better yield than superphosphate application. Considering the total phosphorus uptake of both the crops together it was observed that there was no significant difference between the two forms of fertilizers at the same level of phosphorus. When cost factor of fertilizer is considered, the application of Mussoorie phos for a neutral soil capable of giving consecutive crops could be cheaper. Sahu et al. (1983) have reported that under rice-wheat farming system, physical mixture of Mussoorie rock phosphate and single superphosphate in the ratio of 50:50 at 80 kg P_2O_5/ha had greater direct and residual effect on increasing the productivity of rice and wheat in respective seasons.

VI. Effect of sources and levels of phosphorus on soil fertility status

Marvin et al. (1953) have shown an increase in the level of soil phosphorus due to the application of different forms of phosphorus such as superphosphate, double superphosphate, calcium metaphosphate, fused tricalcium phosphate and dicalcium phosphate containing radio active phosphorus. From the result of a trial on the release of phosphorus from insoluble phosphatic materials in acid low land rice soils, Mandal and Khan (1972) showed that within 15 days of application more than 86 per cent of the phosphorus added as superphosphate was converted to unavailable form. The rock phosphate maintained a high amount of available phosphorus in the soil than superphosphate.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was undertaken to assess the comparative effects of different sources of phosphate fertilizer on pulse crop - cowpea, grown in summer rice fallow with a view to finding out the cheaper and efficient source of phosphatic fertilizer. The residual effect of phosphorus from different sources was also studied by raising a succeeding paddy crop in the following kharif season.

Experimental site

The field experiment was carried out in a farmer's field at Kalliyoor, near the College of Agriculture, Vellayani.

CROPPING HISTORY OF THE FIELD

Prior to the starting of the field experiment, a double crop of rice in the virippu (first crop) and mundakan (second crop) seasons of the year followed by a pulse crop in summer was the general pattern of cultivation prevailing in the area. The crops raised during the three seasons received the fertilizers according to the package of practices recommendations of the Kerala Agricultural University.

SOIL

The soil of the experimental site was sandy loam in texture and had the following chemical composition:

pH	5.0
TSS	0.10 mmhos/cm
Total nitrogen	0.08 per cent
Total phosphorus	0.02 per cent
Total potassium	0.173 per cent
Available nitrogen	327 kg/ha
Available phosphorus	11.80 kg/ha
Available potassium	58.6 kg/ha

The field experiment was conducted in two stages. The first experiment was carried out using cowpea as the test crop grown in summer and the second was with rice grown during the succeeding kharif.

EXPERIMENT I (COWPEA)

MATERIALS

Grain type Cowpea variety C 152 was used in this trial. The variety is a medium duration, bushy and moderately high yielding which matures between 65 and 80 days depending on climatic condition. The seed required for the experiment was procured from the Department of Agriculture, Kerala.

Urea analysing to 46 per cent N, superphosphate analysing to 16 per cent P_2O_5, rock phosphate (Madhya Pradesh) analysing to 27.5 per cent P_2O_5, Mussoorie phosphate analysing to 20 per cent P_2O_5, Rajasthan phosphate (Udaipur) analysing to 16 per cent P_2O_5 and muriate of potash analysing to 60 per cent K_2O were used in the experiment.

METHODS

The experiment was laid out in March 1984 in a randomised block design with five treatments and four replications. The lay out of the experiment is presented in Fig.1. All the plots except T_1 (control) received a uniform dose of N P K at 20:30:10 kg/ha which is the recommended package of practice for cowpea. The treatment T_1 received N, P and K at 20:0:10 kg/ha. The treatments T_2, T_3, T_4 and T_5, however, differed only in the form of phosphatic fertilizers used. Accordingly the following were the treatments:

T_1 - Control (without P)

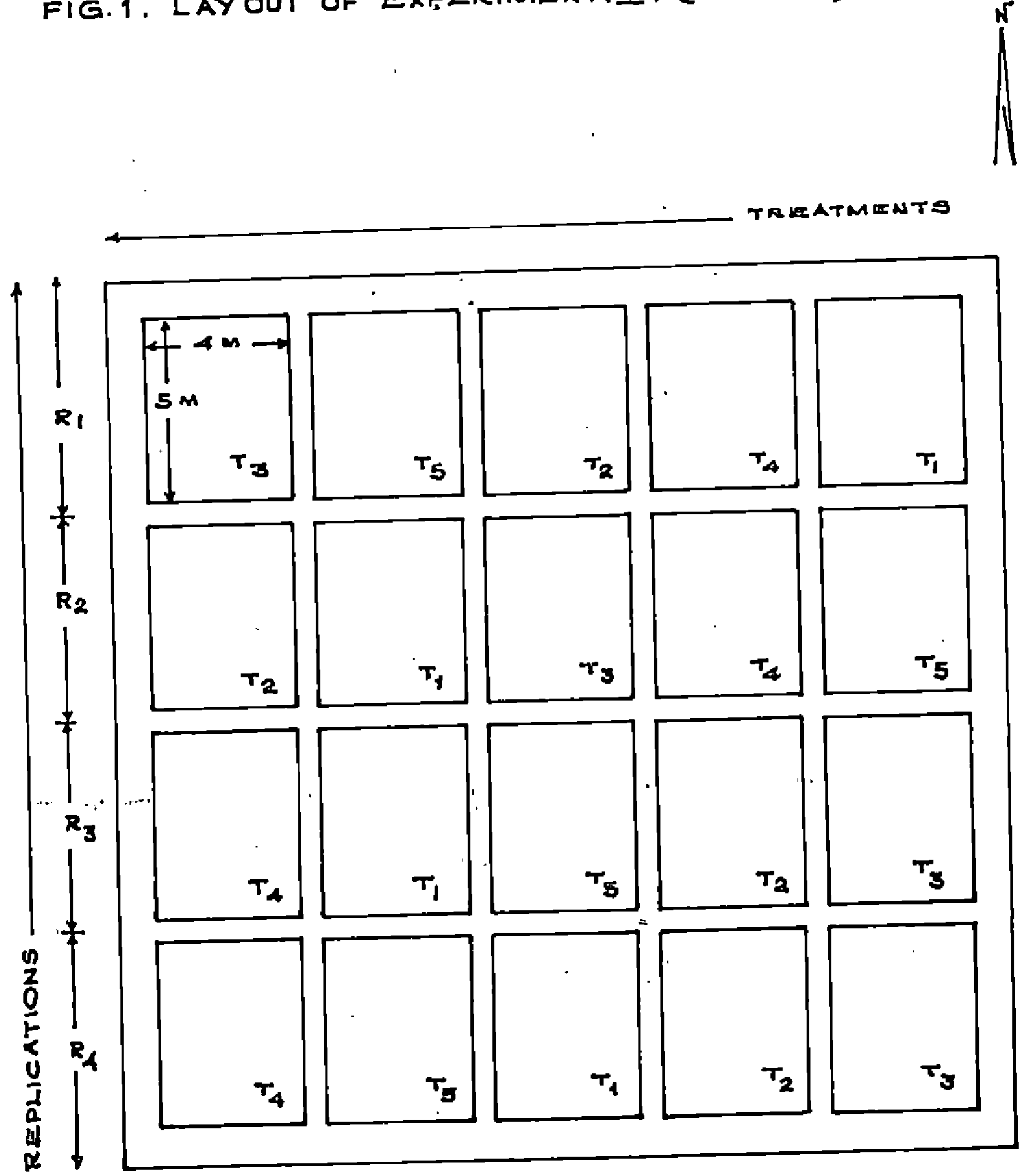
T_2 - P as superphosphate

T_3 - P as Rock phosphate (Madhya Pradesh)

T_4 - P as Mussoorie phosphate

T_5 - P as Rajasthan phosphate (Udaipur)

FIG.1. LAYOUT OF EXPERIMENT. I. (COWPEA)



Plot size was maintained at 5x4 m and the spacing followed was 25 cm between rows and 15 cm between plants, with one plant per hill.

One row all around the plot was provided as border row. Leaving the border row, the next row of plants was considered as the destructive row for sampling of plants and chemical analysis. The net plot size of each treatment was 4X3.4 m.

The land was dug twice and stubbles were removed, clods were broken and the field was levelled properly. It was then laid out into plots and blocks as per the experimental design.

Lime @ 250 kg/ha was applied to all the plots at the time of first digging. Half the dose of nitrogen and full dose of phosphorus and potassium were applied as basal. The remaining nitrogen was applied 20 days after sowing.

Seeds after uniform treatment with rhizobium culture were dibbled at the rate of two seeds per hole at the prescribed spacing. The seeds were then covered with a thin layer of soil. A light irrigation was also given.

Germination was satisfactory. One week after emergence, the crop was thinned to one plant per hill. The crop was given two weedings followed by hoeing. Second irrigation was given 15 days after sowing and third at the time of flowering.

Two sprayings were given with ekalux (0.03 per cent) to control pea aphids.

The general condition of the crop was satisfactory through out the period of growth.

The dry pods from the net plot were picked thrice, viz, on 68th, 75th and 80th day, sun dried, threshed plot wise and the yield of grain and bhusa recorded separately.

BIOMETRIC STUDIES

Five plants were selected at random from each treatment for recording periodical observations. The following observations were recorded:

Growth characters

Growth characters such as the height of the plant, number of leaves per plant and the number of branches per plant were recorded at three stages, viz. on 20th day after sowing, at flowering and at harvest. For uptake studies the dry weight of five whole plants removed from the destructive row, at each of the three stages was recorded after properly drying in the air.

Yield and yield attributes

Pods collected from the observational plants were counted separately and average taken.

The average length of ten pods selected randomly from each treatment was measured.

Pods used for measuring the length were threshed separately and the number of seeds in each pod was counted and average worked out.

Dry weight of all the seeds from the observational plants were recorded and the average worked out.

Hundred seeds were selected randomly in each plot, and the weights were recorded.

Yield of grain obtained from each plot was recorded separately.

After the pods were picked from treatment, the plants were uprooted, air dried uniformly and weighed as bhusa yield.

The sample plants were air dried and then dried to constant weight in an air-oven maintained at 70 $\pm$ 5°C for 48 hours. Dry matter production was worked out from each treatment.

Pods harvested from each plot were threshed and the shelling percentage was worked out.

CHEMICAL STUDIES

Soil analysis

Soil samples from individual plots at 20 days after sowing, at flowering and at harvest stages were separately collected and analysed for pH, total and available forms of nitrogen, phosphorus and potassium.

Before sowing the crop and at harvest, total nitrogen and potassium were also estimated in the soil samples. The pH was measured in a 1:2.5 soil suspension using Perkin Elmer pH meter. Total nitrogen was determined by modified micro Kjeldahl method (Jackson, 1967), available nitrogen by alkaline potassium permanganate method (Subbiah and Asija), total phosphorus by perchloric acid method (Jackson 1967), available phosphorus by Bray's reagent No.1 (0.03 NH_4F in 0.025 N HCl) method (Jackson, 1967), total potassium using E E L Flame photometer (Jackson, 1967) and available potassium by ammonium acetate method (Jackson, 1967).

Plant analysis

The samples were dried at 80°C in an air-oven and powdered in an electrical grinder and used for chemical analysis. The plant, grain and husk samples were separately analysed for N, P_2O_5, K_2O, Ca and Mg.

Total nitrogen content of the plant, grain and husk were determined by modified micro Kjeldahl method (Jackson, 1967).

The contents of P, K, Ca and Mg were determined in the triple acid extract. Phosphorus was estimated colorimetrically by ammonium vandate method (Jackson, 1967), potassium using a EEL Flame photometer (Chopra and Kanwar, 1976) and Ca and Mg using a Perkin Elmer Atomic Absorption Spectrophotometer.

Uptake studies

The total uptake of nitrogen, phosphorus, potassium, calcium and magnesium at 20 days after sowing, at flowering and at harvest stages was calculated based on the content of these nutrients in the plant, grain and bhusa and their total dry weight.

EXPERIMENT II (PADDY)

MATERIALS

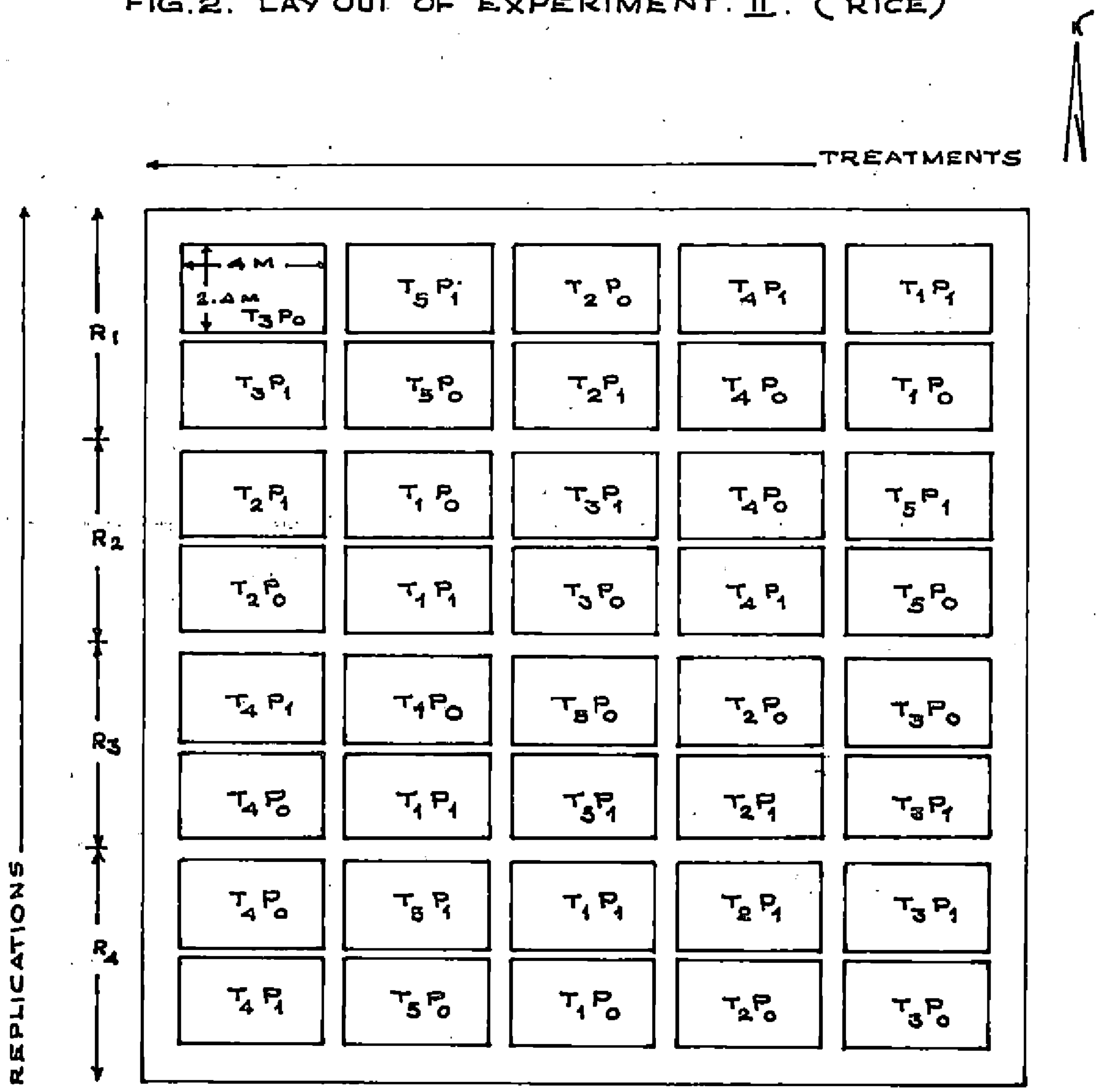
Jaya, a medium duration, high yielding paddy variety was used as the test crop for studying the residual effect of phosphorus from the different sources of phosphatic fertilizers applied to the soil under Experiment I (Cowpea).

METHODS

The experiment was laid out in a split plot non-factorial structural design with four replications. For this, each plot after the harvest of cowpea crop under experiment I was divided into two subplots. One subplot received phosphorus in the form of superphosphate (P_1) and in the other subplot phosphorus was skipped (P_0). The lay out of the experiment is given in Fig.2.

For raising the nursery 100 kg farm yard manure was applied to 50 m^2 of wet land and was prepared well. Four kilograms of pre-germinated paddy seeds were sown in the seed bed.

FIG. 2. LAY OUT OF EXPERIMENT. II. (RICE)



Twenty main plots in the field used under experiment I was dug thrice, puddled, levelled and were divided into forty subplots, each plot having an area of 4x2.4 m (9.6 sq.m). Provision already given for the irrigation and drainage under experiment I was retained. Controlled irrigation was maintained.

Lime @ 350 kg/ha was applied basally to all the plots at the time of first ploughing and the field was flooded with water. The water was drained off after twenty four hours. Farmyard manure at the rate of 5 t/ha was applied basally and incorporated in to the soil.

To one subplot in each of the twenty plots under Experiment I, phosphorus was applied at the rate of 45 kg P_2O_5/ha in the form of superphosphate (16 per cent P_2O_5) before the last ploughing. N and K_2O were applied in the form of urea (46 per cent N) and muriate of potash (60 per cent K_2O) respectively, to all the forty plots at the uniform rate of 90:45 kg/ha as prescribed in the package recommendations. Half the nitrogen and potash were given as basal application, the balance was applied as top dressing at the time of panicle initiation. Twenty eight days old healthy seedlings were used from the nursery for transplanting. Two plants per hill with a spacing of 20x15 cm were transplanted. Hand weeding was done twice to control the weeds. Plant protection measures were taken as and when required. Three sprayings were given with ekalux and metacid against pests. Thirty days after transplanting, 250 kg lime/ha was applied as top dressing. The general stand of the crop was good throughout the period. It was noticed that the flowering was early and more uniform in the superphosphate treated plots.

The field was harvested at full maturity. Each plot was harvested, threshed and dried separately. Wet weights and dry weights of grain and straw were separately recorded. Representative samples of the grain and straw and also soil from each subplot were collected, dried and preserved for analysis.

Biometric Studies

The following observations relating to the growth and yield characters of the plant were recorded from each treatment.

Third and fifth rows in each plot were marked out from both sides as sample rows. Twelve hills were marked at random from the sample row and the height of the tallest plant in the hills from the ground level to the tip of the longest leaf was measured at active tillering stage and at harvest and recorded.

Total number of tillers per hill from the observational plants was recorded at active tillering stage and at harvest.

YIELD AND YIELD ATTRIBUTES

Length of panicle from the neck node to the tip of the apical grain of the panicles in the twelve observational plants were measured.

Number of filled grains per panicle was recorded by taking the average count from twelve panicles.

Number of unfilled grains per panicle was averaged out from twelve panicles.

One thousand grains were counted from the random samples drawn from the winnowed and cleaned produce and weight recorded.

The field was harvested at maturity leaving the border strips of three rows on the four sides of each sub plot. The dry weights of grain and straw were taken, converted into kg/ha and recorded.

CHEMICAL STUDIES

Soil analysis

The composite soil samples were collected at harvest from individual subplots. Total and available N, P and K were determined by standard procedures as described under experiment I.

Plant analysis

The plant samples were oven dried at 70°C and powdered. N, P, K, Ca and Mg were estimated by the analytical methods described under experiment I.

STATISTICAL ANALYSIS

The data relating to different characters of the cowpea crop under experiment I and the rice crop under experiment II were analysed. Important correlations were also worked out.

RESULTS

RESULTS

The results of the field experiment to find out the use of cheaper source of phosphatic fertilizer for cowpea grown in rice fallow and to find out the residual effect of applied phosphorus on a subsequent crop of paddy are presented in this chapter under Experiment I and Experiment II respectively.

Experiment I (Cowpea)

Growth characters

The data on the mean height of cowpea recorded at three growth stages viz. twenty days after sowing, at flowering and at harvest are presented in Table 1 and the analysis of variance in Appendix I. At twenty days after sowing there was significant difference between the height of plants receiving different sources of phosphatic fertilizer. Maximum height of 19.6 cm was observed in plants which received superphosphate. This was significantly higher than the other treatments T_3, T_4 and T_5 which were on par. Height of plants in control plot (14.4 cm) was significantly lower than the other treatments except T_5 which was on par. The same trend

Table No.1 Mean height and dry weight of per plant at different growth stages of cowpea

Treatments	Twenty days after sowing		Flowering stage		At harvest	
	Height of plant (cm)	Dry weight of plant (g)	Height of plant (cm)	Dry weight of plant (g)	Height of plant (cm)	Dry Weight of plant (g)
T_1	14.40	1.86	34.05	5.95	40.55	10.65
T_2	19.60	5.05	41.05	7.18	49.55	11.00
T_3	16.80	2.95	39.05	6.13	46.20	10.35
T_4	16.55	2.30	38.90	6.30	45.90	10.48
T_5	15.65	2.33	35.10	6.05	42.95	10.73
CD (0.05)	2.1	1.47	3.57	NS	3.51	NS

was seen at the flowering stage and at the time of harvest.

The data on mean dry weight of plants recorded at three stages of growth of cowpea are presented in Table 1 and analysis of variance in Appendix II. At twenty days after sowing the dry weight of plants (5.05 g) which received superphosphate was statistically higher than all the other treatments, which were on par. The lowest value was recorded in the control plot (1.86 g). However, data on plant dry weight at the flowering stage showed no significant difference due to treatments. Maximum dry weight was recorded by T_2 (7.18 g) followed by T_4, T_3 and T_5 in order. The lowest value was obtained from control plot (5.95 g). At the harvest stage also, no statistically significant differences could be seen in the dry weight of plants between the different treatments. However maximum dry weight was obtained in superphosphate treatment T_2 (11 g) followed by T_5, T_4 and T_2.

The data on the number of leaves per plant recorded at the three growth stages were analysed. The mean values are presented in Table 2. The analysis of variance is given in Appendix III. At twenty days after sowing the number of leaves per plant in superphosphate treatment was higher

Table No.2 Mean of number of leaves and branches per plant at different growth stages of cowpea

Treatments	Twenty days after sowing		Flowering stage		At harvest	
	No. of leaves	No. of branches	No. of leaves	No. of branches	No. of leaves	No. of branches
T_1	6.75	0.150	13.75	1.075	18.75	1.200
T_2	12.00	0.725	20.00	2.300	25.00	2.600
T_3	10.75	0.475	17.00	1.975	20.00	1.975
T_4	10.75	0.475	18.00	2.000	22.00	2.000
T_5	10.75	0.475	17.00	1.975	20.00	1.975
CD (0.05)	2.427	0.212	3.312	0.396	3.597	0.334

(12 nos.) than in all the other treatments. All these were on par. Lowest value was obtained from control plot (6.75 nos.) which was significantly lower than all other treatments. At the flowering stage also, a higher number of leaves was recorded in super phosphate treated plants compared to other treatments. However, the difference between the treatments was not significant. The least estimate was obtained in the control plot. At harvest stage a significant increase in the number of leaves was obtained in the superphosphate treated plants (25 nos.) compared to other treatments. A significantly lower value was obtained for the control plants (18.75 nos.).

Data on the mean number of branches per plant at three stages of growth of cowpea are presented in Table 2 and analysis of variance in Appendix IV. At twenty days after sowing, the number of branches per plant as affected by the different sources of applied phosphorus was significantly different. The highest value was obtained in T_2 (0.725 nos.) and the lowest value in control (0.15 nos.). The treatments T_3, T_4 and T_5 were on par. At flowering stage also, there was significant difference due to different sources of phosphorus applied. Mean number of branches per plant in T_2 (2.3 nos.) was significantly superior to T_3, T_4 and T_5 which were on par.

A significantly lower estimate was obtained in the control (1.075 nos.). Similar observation could be recorded in T_2 at the harvest stage also.

Yield and yield attributes

The mean number of pods per plant recorded are presented in Table 3 and analysis of variance in Appendix V. A closer examination of the mean values revealed significant difference in the number of pods per plant due to different sources of phosphate applied. Number of pods per plant in superphosphate treatment (9.13 nos.) was significantly superior to rock phosphate treatments viz. T_4, T_5 and T_3 which were on par. A lower value was obtained for the control plot.

The data on the mean pod length are furnished in Table 3. Analysis of variance is presented in Appendix V. Pod length in all the treatments were on par, ranging between 13.9 cm in T_5 to 14.48 cm in T_1.

The mean number of grains per pod are presented in Table 3 and the analysis of variance in Appendix V. Maximum number of grains per pod was obtained in the superphosphate treatment (14.2 nos.). However, all treatments were on par.

Table No.3 Mean of number of pods per plant, length of pod, number of grains per pod, grain weight per plant and hundred grain weight in cowpea

Treatments	No. of pods per plant	Length of pod (cm)	No. of grains per pod	Grain weight per plant (g)	Hundred grain weight (g)
T_1	6.50	14.48	13.80	4.5	8.18
T_2	9.13	14.18	14.20	6.25	8.05
T_3	7.63	14.38	13.40	5.20	8.18
T_4	7.88	14.03	13.60	5.55	8.23
T_5	8.00	13.90	13.85	5.50	8.05
CD (0.05)	0.847	NS	NS	0.569	NS

Data on the mean grain yield per plant are presented in Table 4 and analysis of variance in Appendix V. The per hectare yield of grain computed from the net per plot data is presented in Table 4 and the analysis of variance in Appendix VI. Yield of grain in superphosphate treated plant was significantly superior to T_4, T_5 and T_3 which were on par. A lower yield was estimated from control.

The analysis data on mean value of hundred grain weight are presented in Table 3 and the analysis of variance in Appendix V. Hundred grain weight in all the treatments were statistically on par. The value ranged between 8.05 g in T_2 to 8.23 g in T_4.

Bhusa yield and shelling percentage observed in each treatment were determined at the time of harvest. The mean values in terms of tons/hectare are presented in Table 4 and abstract of analysis of variance given in Appendix VI. The results revealed that the effect due to different sources of phosphatic fertilizers on bhusa yield and shelling per centage were not significantly different. Bhusa yield varied from 1.65 t/ha in T_2 to 1.7 t/ha in T_4 and shelling per centage varied from 69.75 in T_5 to 70.55 in T_4.

Table No.4 Mean yields of grain, bhusa, shelling per centage and dry matter production of cowpea

Treatments	Grain yield t/ha	Bhusa yield t/ha	Shelling per centage	Dry matter production in t/ha
T_1	0.474	1.771	69.875	2.245
T_2	0.658	1.648	70.075	2.305
T_3	0.548	1.703	69.925	2.249
T_4	0.584	1.718	70.550	2.300
T_5	0.582	1.677	69.750	2.262
CD (0.05)	0.051	NS	NS	NS

Observation on total dry matter production was recorded at the time of harvest and mean values obtained are given in Table 4. The abstract of analysis of variance is given in Appendix VI. Dry matter production was highest in T_2(2.305 t/ha followed by T_4, T_3 and T_5.

Soil analysis

The analytical data on the soil samples collected at the three stages of sampling viz. twenty days after sowing, at flowering and at harvest stages are given in Tables 5(a) and 5(b) and the abstract of analysis of variance in Appendix VII to XI. The pH of soil at twenty days after sowing was found to be significantly higher in Mussoorie phosphate and rock phosphate (Madhya Pradesh) treatments over the others which were on par. The values ranged from 5.3 in superphosphate treatment to 5.8 in Mussoorie phosphate. The pH of soil at flowering stage was lowest in the superphosphate treatment following by control. The three rock phosphate treatments were all on par. The pH of the soil at harvest stage was lowest in the superphosphate treatment and control which were on par. Significantly highest pH was recorded in Mussoorie phosphate treatment and this was on par with rock phosphate (Madhya Pradesh).

Table No.5(a) Mean values of pH, available nitrogen, available phosphorus and exchangeable potassium content of soil at different growth stages of cowpea

	pH			AV.N (kg/ha)			AV.P_2O_5 (kg/ha)			AV. K_2O (kg/ha)		
Treatments	Twenty days after sowing	Flowering stage	At harvest	Twenty days after sowing	Flowering stage	At harvest	Twenty days after sowing	Flowering stage	At harvest	Twenty days after sowing	Flowering stage	At harvest
T_1	5.5	5.3	5.1	206.75	197.50	209.75	26.93	25.90	25.64	58.38	77.95	106.17
T_2	5.3	5.0	5.1	390.25	270.75	264.00	61.55	46.21	34.56	92.73	63.16	120.96
T_3	5.7	5.6	5.5	324.50	248.25	235.00	28.85	42.01	46.08	64.50	63.17	118.27
T_4	5.8	5.8	5.7	326.00	247.25	236.00	35.90	45.21	49.37	61.82	69.89	79.29
T_5	5.5	5.6	5.4	313.25	222.25	239.00	27.57	38.61	39.75	67.19	41.66	96.77
CD (0.05)	0.225	0.295	0.247	150.85	NS	12.043	6.321	2.044	4.003	8.809	16.959	NS

- 50 -

Table No.5(b) Mean values of total nitrogen and potassium at harvest and total phosphorus content of soil at different growth stages of cowpea

Treatments	Total N Per cent	Total P_2O_5 (Per cent)			Total K_2O (Per cent)
	At harvest	Twenty days after sowing	Flowering stage	At harvest	At harvest
T_1	0.0792	0.018	0.0154	0.0105	0.165
T_2	0.0817	0.042	0.0365	0.0269	0.165
T_3	0.0820	0.042	0.0323	0.0270	0.165
T_4	0.0820	0.045	0.0315	0.0266	0.163
T_5	0.0820	0.030	0.0258	0.0256	0.163
CD (0.05)	0.00012	0.00061	0.0001	0.00017	NS

Available nitrogen content of the soil at twenty days after sozing was found maximum in T_2 (390 kg/ha). The values for T_2, T_3, T_4 and T_5 were on par and the lowest estimate was obtained from control plot (207 kg/ha). Available nitrogen content of the soil at flowering stage was found highest value in superphosphate treatment (271 kg/ha) and lowest in control (198 kg/ha). The other treatments T_3, T_4 and T_5 were on par. Between these treatments there was no significance. At harvest a significantly higher available nitrogen content of the soil was estimated in T_2 (264 kg/ha) over to T_3, T_4 and T_5 which were on par.

At twenty days after sowing, application of superphosphate resulted in a significant increase in the available phosphorus content (61.55 kg/ha) of soil compared to the other sources of phosphorus. In the other treatments,the values varied from 27.57 kg/ha in T_5 to 35.9 kg/ha in T_4. At flowering stage the effect due to different sources of applied phosphorus on available phosphorus content of the soil was significant for the various treatments. Maximum value was obtained in T_2 (46.21 kg/ha) which was on par with T_4. Treatments T_3 and T_5 were significantly lower than T_2 and T_4. A least estimate was obtained in control plot (25.9 kg/ha). At harvest a significantly lower value of available phosphorus content of soil was estimated for the control plot (25.64 kg/ha). The highest value was associated with T_4 (49.37 kg/ha) followed by T_3, T_5 and T_2. At this stage a slight decrease in available phosphorus content was obtained in T_2 (34.56 kg/ha).

The exchangeable potassium content of the soil in the superphosphate treatment (92.73 kg/ha) at twenty days after sowing was significantly higher than in the three rock phosphate treatments which were on par. However, at flowering stage its content in control (77.95 kg/ha) was significantly higher than in all the other treatments. At harvest, all the treatments were on par and the value varied from 79.29 to 120.96 kg/ha.

Total nitrogen content of the soil after harvest of cowpea showed significantly lower estimate in the control plot compared to treated plots. The total nitrogen content in T_2 was lower than in other treatments T_3, T_4 and T_5 which were on par.

At twenty days after sowing, a significantly higher value for total phosphorus content was estimated in T_4 (0.045 per cent) followed by T_2, T_3 and T_5. However, T_2 and T_3 were on par and were significantly higher than T_5. A significantly lower estimate was obtained in control plot (0.018 per cent). The effect due to different sources of phosphatic fertilizer on the total phosphorus content of the soil at flowering stage was also significant. At that stage, the total phosphorus content of the soil in control was significantly lower than in other treatments. The total phosphorus content of soil in T_2 (0.04) per cent was significantly higher than in T_3 followed by T_4 and T_5 which were on par. At harvest, total phosphorus content of soil in the control plot (0.011 per cent) was significantly lower than in all the other phosphate treatments. Treatments T_2 and T_3 were on par. Between T_4 and T_5 there was significance. Highest value was estimated in T_3.

The total potassium content of the soil in all the plots, after harvest were found to be on par.

Plant analysis

The mean values for the nutrient content of cowpea at the three stages of growth viz. twenty days after sowing, at flowering and at harvest stages are presented in Table 6 (a) and 6 (b) and the analysis of variance in Appendix XII to XVI.

Table No.6(a) Mean values of nitrogen, phosphorus and potassium content of plant sample at different growth stages of cowpea

Treatments	N (per cent)			P_2O_5 (per cent)			K_2O (per cent)		
	Twenty days after sowing	Flowering stage	At harvest	Twenty days after sowing	Flowering stage	At harvest	Twenty days after sowing	Flowering stage	At harvest
T_1	1.90	1.80	1.50	0.84	0.26	0.30	0.90	0.92	0.53
T_2	2.40	2.43	2.30	1.16	0.82	0.69	0.90	0.69	0.53
T_3	2.25	2.17	1.95	1.10	0.65	0.57	0.94	0.77	0.57
T_4	2.30	2.13	1.90	1.09	0.69	0.63	0.91	0.74	0.51
T_5	2.30	2.19	1.95	1.08	0.70	0.58	0.95	0.79	0.47
CD(0.05)	0.273	0.154	0.169	0.077	0.100	0.058	NS	0.044	0.058

Table No.6(b) Mean values of calcium and magnesium content of plant sample at different growth stages of cowpea

Treatments	Ca (per cent)			Mg (per cent)		
	Twenty days after sowing	Flowering stage	At harvest	Twenty days after sowing	Flowering stage	At harvest
T_1	0.81	0.82	0.41	0.49	0.73	0.66
T_2	0.84	0.84	0.42	0.71	0.98	0.78
T_3	0.78	0.83	0.39	0.57	0.92	0.77
T_4	0.83	0.83	0.38	0.59	0.97	0.74
T_5	0.86	0.81	0.39	0.59	0.94	0.74
CD (0.05)	NS	NS	NS	0.090	0.138	0.116

Nitrogen content of plants determined at twenty days after sowing was higher in T_2 (2.4 per cent) than in T_3, T_4 and T_5. All treatments were on par. Lowest estimate was obtained in control (1.9 per cent). At flowering stage, the nitrogen content of plants in T_2 (2.4 per cent) was significantly higher than in T_3, T_4 and T_5 which were on par. Lowest estimate was obtained from control (1.8 per cent). At harvest, the nitrogen content in control (1.5 per cent) was significantly lower than in all the treatments. T_3, T_4 and T_5 were statistically on par. Significantly higher estimate was obtained in T_2 (2.3 per cent).

The phosphorus content of plants in the treated plots at twenty days after sowing were significantly superior over the control. T_2 recorded the highest value (1.16 per cent) followed by T_3 and T_4 which were on par. At the flowering stage, the phosphorus content of plants in the control was significantly lower than that in the treated plants. Phosphorus content of plants in superphosphate treatment (0.82 per cent) was significantly superior over the other rock phosphate treatments which were on par. At harvest, the phosphorus content of untreated plants was significantly lower than in treated plants. All treatments were statistically on par. The value ranged from 0.57 per cent in T_3 to 0.69 per cent in T_2.

The potassium content of various treatments at twenty days after sowing, showed no significant difference and the values were between 0.95 per cent in T_4 and 0.9 per cent in T_1. At the flowering stage the potassium content of plants in control (0.92 per cent) was significantly superior over the treatments. Between the treatments, the rock phosphates were significantly superior over superphosphate. The potassium content of plants at harvest showed no significance between the different treatments.

The calcium content of the plant in the different treatments determined at twenty days after sowing, at flowering and at harvest showed no significance.

The magnesium content of plant determined at twenty days after sowing was significantly higher in the superphosphate treatment and was found to vary from 0.57 per cent to 0.59 per cent. At flowering, the magnesium content of plant in all the treatments were uniform and ranged between 0.92 per cent in T_3 to 0.98 per cent in T_2. Least estimate was obtained in control plot (0.73 per cent). At harvest, the magnesium content of plants in all the treatments were on par. Its content in the control plot (0.66 per cent) was significantly lower than in T_2 and T_3.

Nutrient content of cowpea grains

The mean values of the dutrient content of cowpea grains are presented in Table 7 and abstract of analysis of variance is given in Appendix XVII.

The nitrogen content of cowpea grains in T_2 (3.2 per cent) was higher than in T_3, T_4 and T_5 which were on par. A lowest estimate was obtained in control (2.6 per cent).

The phosphorus content of cowpea grains in treatment T_3 was significantly lower than in T_2 and T_5. However, T_2 (1.25 per cent) was superior to T_1, T_3, T_4 and T_5. The treatments T_3 and T_4 were on par. T_4, T_5 and T_1 were also on par.

The contents of potassium, calcium and magnesium in the grain was not found to be influenced by the treatments.

Experiment II (Rice)

The mean values for the height of plants recorded at the maximum tillering stage are presented in Table 8 and the

Table No.7 Mean values of nitrogen, phosphorus, potassium, calcium and magnesium content of cowpea grains

Treatments	N (per cent)	P_2O_5 (per cent)	K_2O (per cent)	Ca (per cent)	Mg (per cent)
T_1	2.60	1.01	0.64	0.03	0.39
T_2	3.20	1.25	0.62	0.03	0.39
T_3	2.90	0.86	0.65	0.04	0.38
T_4	2.80	0.96	0.66	0.04	0.39
T_5	2.90	1.08	0.66	0.04	0.39
CD (0.05)	0.162	0.167	NS	NS	NS

Table No.8 Height of plant at maximum tillering stage of paddy (cm)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	27.00	29.75	32.00	32.00	32.00	30.55
P_1	28.50	31.00	33.50	33.50	33.25	31.95
Mean	27.75	30.38	32.75	32.75	32.63	

CD (0.05) for comparison of main plot means 1.248

CD (0.05) for comparison of main sub plot means 0.656

CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment } 1.467

abstract of analysis of variance in Appendix XVIII. Plant height was more or less uniform in treatments $T_3 P_0$, $T_4 P_0$ and $T_5 P_0$. The treatments T_3P_1, T_4P_1 and T_5P_1 also followed the same trend, but these values were higher than those for the respective P_0 treatments. A significantly lower value was estimated in T_2P_0 (29.75 cm) and in T_2P_1 (31 cm). The control plot in both cases ie., T_1P_0 (27 cm) and T_1P_1 (28.5 cm) gave the least estimate of plant height. Maximum height (33.5 cm) was obtained from the treatment which received rock phosphate (T_3P_1) and Mussoorie phosphate (T_4P_1) in the earlier cowpea crop. Control plot recorded the lowest plant height.

Mean values of the number of tillers per plant are presented in Table 9 and the abstract of analysis of variance in Appendix XVIII. The number of tillers per plant was more or less uniform in the P_0 treatments, i.e., treatments which received no phosphorus for the rice crop. Uniformity was observed in the P_1 treatments also. However, these values were significantly higher. Maximum mean number of tillers per plant (5.9) was obtained in T_4P_1 and minimum of 4.65 in T_1P_0.

Mean values of the plant height at harvest are given in Table 10 and abstract of analysis of variance in Appendix

Table No.9 Number of tillers at maximum tillering stage of paddy

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	4.65	5.63	5.73	5.75	5.70	5.49
P_1	4.93	5.78	5.80	5.90	5.88	5.66
Mean	4.79	5.70	5.76	5.83		

CD (0.05) for comparison of main plot means	0.158
CD (0.05) for comparison of sub plot means	0.060
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.143

Table No.10 Height of plant at harvest stage of paddy (cm)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	62.50	65.25	67.00	69.25	69.50	66.70
P_1	65.00	68.25	71.50	72.00	71.75	68.70
Mean	63.75	66.75	69.25	70.63	70.63	

CD (0.05) for comparison of main plot means	1.204
CD (0.05) for comparison of sub plot means	0.883
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	1.974

XVIII. A significantly low value for plant height at harvest was estimated in T_2P_0 and T_2P_1 over the other treatments. Between T_2P_0 and T_2P_1, the latter showed significant increase. The control plot in both cases (P_1 and P_0) gave lowest values with a significant increase in P_1 over P_0. Other treatments indicated more or less uniform height. Maximum plant height (71.75 cm) was obtained in T_5P_1 and least estimate (62.5 cm) in T_1P_0.

Data on the mean number of productive tillers per plant are given in Table 11 and abstract of analysis of variance given in Appendix XVIII. The number of productive tillers was uniform in all the P_0 treatments except control. The same trend was observed in P_1 treatments also. A significantly lower value was estimated in T_2P_1. Control plots T_1P_0 and T_1P_1 gave the least estimates of 4.75 nos. and 6.25 nos. respectively. Between P_0 and P_1 there was significance. Maximum productive tillers (8.5 nos.) was obtained in T_5P_1 and minimum (4.75 nos.) in control.

In general, it was seen that the treatments which received a normal basal dressing of phosphatic fertilizer for rice showed more height and more number of tillers both at maximum tillering and harvest stages compared to the plots

Table No.11 Number of productive tillers per plant

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	4.75	6.25	6.25	6.75	6.50	6.10
P_1	6.25	7.00	8.00	8.00	8.50	7.55
Mean	5.50	6.63	7.13	7.38	7.50	

CD (0.05) for comparison of main plot means	0.679
CD (0.05) for comparison of sub plot means	0.567
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	1.268

where there was only residual effect of phosphorus and no separate basal application of phosphorus for the rice crop was given.

Yield and yield attributes

Data on the mean values of length of panicle are given in Table 12 and the abstract of analysis of variance in Appendix XIX. Length of panicle was found more or less unform in all the treatments except the two control plots. Between P_0 and P_1 there was significance. The maximum length (20.65 cm) was obtained in T_5P_1 and least (18.98 cm) in control. A significantly lower value was estimated in T_1P_0 which was on par with T_2P_0 and T_1P_1.

Data on the mean values of filled grains per panicle are presented in Table 13 and the abstract of analysis of variance in Appendix XIX. Number of filled grains per panicle was found on par in the sets of treatments T_2P_0 and T_3P_0, T_3P_0 and T_4P_0 and T_4P_0 and T_5P_0. The treatments T_3P_1, T_4P_1 and T_5P_1 were also on par. However, maximum number of filled grains (107.5) was obtained in T_3P_1 and least (84) in T_1P_0. A significantly lower value (89.25) was estimated in T_2P_1. The control plots T_1P_0 and T_1P_1 gave least estimates of 84 and 84.5 filled grains/panicle respectively.

Table No.12 Length of panicle (cm)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	18.98	19.33	19.65	19.73	19.75	19.49
P_1	19.18	20.23	20.43	20.50	20.65	20.20
Mean	19.08	19.79	20.04	20.11	20.20	

CD(0.05) for comparison of main plot means	0.456
CD(0.05) for comparison of sub plot means	0.274
CD(0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.613

Table No.13 Number of filled grains per panicle

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	84.00	88.75	91.50	94.5	95.50	90.85
P_1	84.50	89.25	107.50	104.50	105.00	98.15
Mean	84.25	89.00	99.50	99.50	100.25	

CD (0.05) for comparison of main plot means	3.895
CD (0.05) for comparison of sub plot means	3.130
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	6.999

Data on the mean values of number of unfilled grains per panicle are presented in Table 14 and the abstract of analysis of variance in Appendix XIX. Number of unfilled grains per panicle was more or less similar in the P_0 and P_1 treatments of different rock phosphates, with significant difference between P_0 and P_1. A significantly higher value was estimated in the superphosphate treated plots. Maximum estimate was obtained in control plots. In general, the P_1 set of treatments gave lesser number of unfilled grains per panicle. The number of unfilled grains ranged between 5 and 11.5 with maximum in T_1P_0 and minimum in T_4P_1 and T_5P_1.

Table 15 gives mean values of thousand grain weight of different treatments. The abstract of analysis of variance is given in appendix XX. Thousand grain weight was more or less uniform in the P_0 and P_1 treatments of different rock phosphates with significant difference between P_0 and P_1. A significantly low value was estimated in the P_0 and P_1 treatments of superphosphate. The control plot gave the least value.

In general, the treatments which received normal basal application of phosphatic fertilizer for the rice crop showed increased panicle length, higher number of filled grains per

Table No.14 Number of unfilled grains per panicle

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	11.5	8.75	7.50	7.00	7.00	8.36
P_1	9.75	6.75	5.25	5.00	5.00	6.35
Mean	10.63	7.75	6.38	6.00	6.00	

CD (0.05) for comparison of main plot means	1.141
CD (0.05) for comparison of sub plot means	0.912
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	2.039

Table No.15 Thousand grain weight (g)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	27.98	28.70	29.23	29.33	29.73	28.99
P_1	28.60	29.48	30.35	30.28	30.35	29.81
Mean	28.29	29.09	29.79	29.80	30.04	

CD (0.05) for comparison of main plot means 0.306

CD (0.05) for comparison of sub plot means 0.164

CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment 0.367

panicle and increased thousand grain weight compared to the plots where there was only a residual effect of phosphorus and no separate basal application of phosphorus made for rice.

Mean values of the grain yield are presented in Table 16 and the abstract of analysis of variance in Appendix XX. Grain yield of paddy was more or less uniform in the different rock phosphate treatments. The treatments T_3P_0, T_4P_0 and T_5P_0 were found on par. T_4P_1 and T_5P_1 were also on par. Highest yield of 3996 kg/ha could be recorded from the Mussoorie phosphate treatment of P_1, and this was followed by Rajasthan phosphate treatment of P_1 and rock phosphate (Madhya Pradesh) treatment of P_1 in the order. The yield increase of grain on account of Mussoorie rock phosphate was significant. The superphosphate treatments of P_0 and P_1 gave lower grain yields. All the P_1 set treatments gave significantly higher grain yield than P_0 set.

Data on the mean weight of straw are presented in Table 17 and the analysis of variance in Appendix XX.

Yield of straw was more or less uniform in the P_0 and P_1 treatments of the different rock phosphates. Between P_0 and P_1 sets there was significant difference. A significantly

Table No.16 Mean yield of grain (kg/ha)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	2706.25	3001.75	3810.50	3814.50	3810.00	3428.60
P_1	3229.50	3380.75	3915.00	3996.25	3995.00	3703.30
Mean	2967.88	3191.25	3862.75	3905.38	3902.50	

CD (0.05) for comparison of main plot means	71.078
CD (0.05) for comparison of sub plot means	42.031
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	93.982

Table No.17 Mean yield of straw (kg/ha)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	3290.25	3390.00	3785.00	3754.50	3737.00	3610.30
P_1	3325.00	3410.00	3919.75	3935.00	3920.00	3705.00
Mean	3307.63	3400.00	3852.38	3844.75	3853.50	

CD (0.05) for comparison of main plot means	138.40
CD (0.05) for comparison of sub plot means	75.12
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	167.968

higher value was estimated in the rock phosphate treatments as compared to superphosphate. These values were on par. Highest straw yield of 3935 kg/ha was recorded in the Mussoorie phosphate treatment of P_1.

In general, the treatments which received normal basal application of phosphate fertiliser for the rice crop registered higher yields of grain straw when compared to the treatment where there was only a residual effect of phosphorus.

Soil analysis at harvest

Mean values of pH of soil are presented in Table 18(a) and the abstract of analysis of variance in Appendix XXI. The pH of the soil after harvest of paddy was found on par in sets of treatments T_1P_0, T_2P_0 and T_5P_0; T_3P_0 and T_4P_0; T_3P_0 and T_5P_0; T_1P_1, T_2P_1, T_4P_1 and T_5P_1 and T_3P_1 and T_4P_1. Between P_0 and P_1 there was slight increase in pH in treatments T_1, T_2 and T_3. Maximum pH of 5.3 in the soil could be recorded in T_4P_0 and T_3P_0. In general, all the treatments could record more or less uniform pH.

Data on the mean values of available nitrogen content in the soil at harvest are presented in Table 18(b) and the abstract of analysis of variance in Appendix XXII. Available

Table No.18(a) pH of soil after harvest of paddy

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	5.0	5.0	5.2	5.3	5.1	5.12
P_1	5.1	5.1	5.3	5.2	5.0	5.14
Mean	5.05	5.05	5.25	5.25	5.05	

CD (0.05) for comparison of main plot means 0.13

CD (0.05) for comparison of sub plot means 0.074

CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment } 0.165

Table No.18(b) Available nitrogen content of soil after harvest of paddy in kg/ha

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	248.0	254.0	254.5	262.0	248.0	253.3
P_1	253.0	248.0	252.0	254.0	247.5	250.9
Mean	250.5	251.0	253.25	258.0	247.8	

CD (0.05) for comparison of main plot means	4.56
CD (0.05) for comparison of sub plot means	3.06
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	6.842

nitrogen content in the soil was found uniform in sets of treatments T_1P_0 and T_5P_0 , T_2P_0 and T_3P_0. T_1P_1, T_3P_1 and T_4P_1 and T_2P_1 and T_5P_1. Between P_0 and P_1 there was significance. Maximum content of 262 kg/ha could be recorded in T_4P_0. It could be seen that P_1 set of treatments gave less available nitrogen content in the soil compared to the corresponding P_0 set.

Data on the mean values of the available phosphorus content in the soil at harvest are presented in Table 18(c) and the abstract of analysis of variance in Appendix XXII. Available phosphorus content in the soil was found uniform in the different rock phosphate treatments of P_0. Uniformity was noted in T_3, T_4 and T_5 treatments also of P_1. In all these treatments, a significant increase over the superphosphate treatments was recorded on the available phosphorus content in the soil. Highest phosphorus content (89.6 kg/ha) in the soil was obtained in Mussoorie phosphate treatment for cowpea followed by basal phosphorus application for rice. In general, treatments which received normal basal application of phosphatic fertilizer for rice showed significantly higher available phosphorus content compared to these plots in which phosphorus was skipped.

Table No.18(c) Available phosphorus (P_2O_5) content in soil after harvest of paddy (kg/ha)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	23.1	61.6	75.8	75.0	73.1	60.91
P_1	56.1	81.5	89.1	89.6	87.1	80.68
Mean	39.6	71.5	80.5	82.3	80.1	

CD (0.05) for comparison of main plot means	4.494
CD (0.05) for comparison of sub plot means	2.902
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	6.489

Data on the mean values of exchangeable potassium content of the soil at harvest are presented in Table 18(d) and the abstract of analysis of variance in Appendix XXII. Exchangeable potassium content in the soil was more or less uniform in treatments T_2P_0, T_4P_0 and T_5P_0. The treatments T_1P_1, T_2P_1 and T_3P_1 also followed the same trend. The values varied from 42.95 kg/ha in T_4P_1 to 120.93 kg/ha in T_1P_0. In general, the P_1 treatments showed less of exchangeable potassium content in the soil compared to P_0 treatments.

Data on the mean values of total nitrogen content in the soil are presented in Table 18(e) and the abstract of analysis of variance in Appendix XXIII. Total nitrogen content was statistically similar in treatments T_2P_0, T_3P_0 and T_5P_0. The same trend was observed in T_1P_1, T_2P_1, T_3P_1, T_4P_1 and T_5P_1. The value ranged from 0.0756 per cent in T_1P_0 and T_5P_0 to 0.0790 per cent in T_2P_1. The highest value was obtained in T_5P_0 (0.0808) and the lowest in T_1P_0 (0.0745).

Data on the mean values of total phosphorus in the soil at harvest are presented in Table 18(f) and the abstract of analysis of variance in Appendix XXIII. The total phosphorus content in the soil was significantly different due to different treatments and the values varied from 0.0111 per cent in

Table No.18(d) Exchangeable potassium (K_2O) content in soil after harvest of pady (kg/ha)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	120.93	83.28	47.00	71.00	73.88	79.26
P_1	52.40	67.15	60.45	42.95	75.23	59.64
Mean	86.66	75.21	53.73	57.08	74.55	

CD (0.05) for comparison of main plot means 26.482

CD (0.05) for comparison of sub plot means 6.983

CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment 15.614

Table No.18(e) Total nitrogen content in soil after harvest of paddy (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.0745	0.0789	0.0790	0.0756	0.0808	0.0776
P_1	0.0756	0.0790	0.0767	0.0767	0.0756	0.0767
Mean	0.0751	0.0790	0.0779	0.0762	0.0782	

CD (0.05) for comparison of main plot means	0.00037
CD (0.05) for comparison of sub plot means	0.00038
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.00085

Table No.18(f) Total phosphorus (P_2O_5) content in soil after harvest of paddy (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.0111	0.0206	0.044	0.0486	0.0395	0.0322
P_1	0.0269	0.0363	0.0504	0.0592	0.0506	0.0447
Mean	0.0190	0.0285	0.0458	0.0539	0.0451	

CD (0.05) for comparison of main plot means	0.00026
CD (0.05) for comparison of sub plot means	0.00019
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.00042

T_1P_0 to 0.0486 per cent in T_4P_0 and 0.0269 per cent in T_1P_1 to 0.0592 in T_4P_1. A high value was obtained in T_4P_0 (0.0486 per cent) and also in T_4P_1 (0.0592 per cent) and a lower value in T_2P_0 (0.0206 per cent) and also in T_2P_1. (0.0363 per cent). Least estimate was obtained in both the control plots. In general, the treatment which received normal phosphorus for the rice crop showed more total phosphorus content compared to the phosphorus skipped plots.

Data on the mean values of total potassium content in the soil at harvest are presented in Table 18(g) and the abstract of analysis of variance in Appendix XXIII. With regard to the total potassium content in the soil there was no significant difference between treatments.

Plant analysis

Mean values of nutrient content of paddy grain are presented in Table 19(a) and the abstract of analysis of variance in Appendix XXIV.

Nitrogen content of paddy grain was found satistically similar in the set of treatments T_2P_0 and T_4P_0 and T_3P_0 and T_5P_0. Maximum nitrogen content of 2.37 per cent could be

Table No.18(g) Total potassium (K_2O) content in soil after harvest of paddy (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.155	0.160	0.155	0.158	0.156	0.157
P_1	0.168	0.153	0.158	0.158	0.153	0.158
Mean	0.167	0.155	0.156	0.158	0.155	

CD (0.05) for comparison of main plot means	0.012
CD (0.05) for comparison of sub plot means	0.014
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.031

Table No.19(a) Nitrogen content of paddy grain (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.995	1.233	1.325	1.200	1.338	1.218
P_1	1.220	2.258	2.368	2.200	2.100	2.029
Mean	1.107	1.745	1.846	1.700	1.719	

CD (0.05) for comparison of main plot means	0.047
CD (0.05) for comparison of sub plot means	0.034
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.076

obtained in the rock phosphate treatment in which phosphorus was supplemented to the rice crop. In general, the P_1 treatments showed more nitrogen content of grain compared to the corresponding P_0 treatments.

Mean values of the phosphorus content of grain are presented in Table 19(b) and the abstract of analysis of variance in Appendix XXIV. Phosphorus content of grain was found on par in the sets of treatments T_3P_0, T_4P_0 and T_5P_0 and in T_3P_1, T_4P_1, and T_5P_1. Between P_0 and P_1, the latter showed significant increase. Among the P_1 set of treatments, maximum content of 0.87 per cent could be recorded in the rock phosphate (Madhya Pradesh) treatment, followed by Mussoorie phosphate which was found on par. A significantly low value was obtained in T_2P_0 (0.491 per cent) and T_2P_1 (0.767 per cent). In general, the treatment which received normal basal dressing of phosphatic fertilizer for rice showed significantly higher content of phosphorus in the grain compared to the treatments which were benefitted by only the residual effect of phosphorus earlier applied to cowpea.

Mean values of potassium content of grain are presented in Table 19(c) and the abstract of analysis of variance in Appendix XXIV. Potassium content was more or less uniform

Table No.19(b) Phosphorus (P_2O_5) content in grain (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.424	0.491	0.597	0.580	0.573	0.533
P_1	0.658	0.767	0.865	0.847	0.813	0.790
Mean	0.541	0.629	0.731	0.714	0.693	

CD (0.05) for comparison of main plot means	0.056
CD (0.05) for comparison of sub plot means	0.028
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatments	0.063

Table No.19(c) Potassium (K_2O) content of paddy grain (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.170	0.180	0.140	0.140	0.140	0.154
P_1	0.160	0.170	0.160	0.150	0.135	0.155
Mean	0.165	0.175	0.150	0.145	0.138	

CD (0.05) for comparison of main plot means	0.036
CD (0.05) for comparison of sub plot means	0.095
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.212

in all the treatments and varied from 0.135 per cent in T_5P_1 to 0.18 per cent in T_2P_0. The treatments under P_1 and P_0 showed no significant difference in the potassium content.

Mean values of the content of calcium and magnesium in grain are presented in Table 19(d) and 19(e) and the abstract of analysis of variance in Appendix XXIV. A similar trend as in the case of potassium could be recorded in the contents of calcium and magnesium in the grain.

Data on the mean nitrogen content of paddy straw in the different treatments are given in Table 20(a) and the abstract of analysis of variance in Appendix XXV. A more or less uniform content of nitrogen in paddy straw could be recorded in T_2P_0, T_3P_0 and T_5P_0 and in T_3P_1, T_4P_1 and T_5P_1. Between P_0 and P_1 there was significant increase. A significantly higher content of nitrogen (1.78 per cent) was found in the superphosphate treatment (T_2P_1).

Data on the mean values of phosphorus content in straw are presented in Table 20(b) and the abstract of analysis of variance in Appendix XXV. Phosphorus content of paddy straw was found more or less similar in all the rock phosphate treatments.

Table No.19(d) Calcium content of paddy grain (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.0096	0.0093	0.0110	0.0138	0.0115	0.0109
P_1	0.0120	0.0113	0.0098	0.0118	0.0110	0.0011
Mean	0.0109	0.0103	0.0104	0.0125	0.0112	

CD (0.05) for comparison of main plot means	0.005
CD (0.05) for comparison of sub plot means	0.002
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.004

Table No.19(e) Magnesium content of paddy grains (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.221	0.219	0.223	0.224	0.218	0.221
P_1	0.208	0.217	0.224	0.220	0.218	0.217
Mean	0.214	0.218	0.223	0.222	0.218	

CD (0.05) for comparison of main plot means	0.012
CD (0.05) for comparison of sub plot means	0.241
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.539

Table No.20(a) Nitrogen content of paddy straw (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	1.050	1.200	1.200	1.275	1.175	1.180
P_1	1.388	1.775	1.650	1.625	1.600	1.608
Mean	1.219	1.488	1.425	1.450	1.388	

CD (0.05) for comparison of main plot means	0.069
CD (0.05) for comparison of sub plot means	0.052
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.116

Table No.20(b) Phosphorus (P_2O_5) content of paddy straw (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.207	0.321	0.438	0.398	0.361	0.352
P_1	0.242	0.410	0.545	0.514	0.555	0.446
Mean	0.224	0.366	0.491	0.456	0.458	

CD (0.05) for comparison of main plot means	0.084
CD (0.05) for comparison of sub plot means	0.026
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.058

In general, the plots which received normal basal application of phosphate fertilizer for rice showed higher nitrogen and phosphorus contents in straw compared to the plots where there was only residual effect of phosphorus with no basal application of phosphorus given to paddy.

Data on the mean values of potassium content of paddy straw are presented in Table 20(c) and the abstract of analysis of variance in Appendix XXV. Potassium content of paddy straw was found on par in the set of treatments T_1P_0 to T_5P_0 and in T_3P_1, T_4P_1 and T_5P_1. A significantly higher potassium content could be obtained in T_1P_1 (1.03 per cent).

Data on the mean values of calcium and magnesium contents of paddy straw are presented in Table 20(d) and (e) and abstract of analysis of variance in Appendix XXV. No significant difference in the calcium and magnesium contents of straw could be obtained in the different treatments.

Correlation study

The values on simple correlation coefficient worked out between the yields and phosphorus contents of cowpea

Table No.20(c) Potassium content of paddy straw (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.93	0.80	0.85	0.77	0.93	0.86
P_1	1.03	0.95	0.88	0.79	0.77	0.88
Mean	0.98	0.87	0.86	0.78	0.85	

CD (0.05) for comparison of main plot means	0.171
CD (0.05) for comparison of sub plot means	0.051
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.114

Table No.20(d) Calcium content of paddy straw (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.224	0.226	0.233	0.242	0.241	0.233
P_1	0.214	0.224	0.226	0.232	0.230	0.225
Mean	0.219	0.225	0.229	0.237	0.235	

CD (0.05) for comparison of main plot means	0.018
CD (0.05) for comparison of sub plot means	0.114
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.255

Table No.20(e) Magnesium content of paddy straw (per cent)

	T_1	T_2	T_3	T_4	T_5	Mean
P_0	0.243	0.265	0.266	0.249	0.249	0.254
P_1	0.265	0.276	0.270	0.265	0.241	0.263
Mean	0.254	0.270	0.268	0.257	0.245	

CD (0.05) for comparison of main plot means	0.033
CD (0.05) for comparison of sub plot means	0.186
CD (0.05) for comparison of 2 sub plot means with the same level of main plot treatment	0.416

grain, paddy grain and other characteristics are presented in Table 21. Grain yield of cowpea was positively and significantly correlated at one per cent level with the height of cowpea plant at twenty days after sowing, number of pods per plant, available phosphorus content of soil at twenty days after sowing, at flowering (five per cent only) and at harvesting stages. Phosphorus content of cowpea grain and available phosphorus content of soil at twenty days after sowing were positively and significantly correlated at one per cent levels. The yield of paddy grain was positively and significantly correlated at one per cent level with the available phosphorus content of the soil after the harvest of paddy, height of plant at maximum tillering and harvesting stages, number of tillers at maximum tillering and harvesting stages, length of panicle, number of filled grains per panicle and thousand grain weight.

Table No.21 Values of simple correlation coefficient

Sl. No.	Characters correlation		Correlation coefficient
1	Cowpea grain yield	x Height of cowpea plant, twenty days after sowing	0.529
2	Cowpea grain yield	x Number of pods per plant	0.979
3	Cowpea grain yield	x Average P_2O_5 content of plant, twenty days after sowing	0.665
4	Cowpea grain yield	x Average P_2O_5 content of plant at flowering stage	0.504
5	Cowpea grain yield	x Average P_2O_5 content of plant at harvesting stage	0.696
6	P_2O_5 content of cowpea grain	x Average P_2O_5 content of soil twenty days after sowing	0.558
7	Paddy grain yield	x Average P_2O_5 content of soil after harvest of paddy	0.844
8	Paddy grain yield	x Height of paddy plant at maximum tillering stage	0.857
9	Paddy grain yield	x Height of paddy plant at harvesting stage	0.843
10	Paddy grain yield	x Number tillers at maximum tillering stage of paddy	0.776
11	Paddy grain yield	x Number of tillers at harvest stage of paddy	0.620
12	Paddy grain yield	x Length of panicles	0.670
13	Paddy grain yield	x Number of filled grains per	0.728
14	Paddy grain yield	x 1000 grain weight	0.869

DISCUSSION

DISCUSSION

The present investigation was carried out in a farmer's field at Kalliyoor with a view to find out the effect of different sources of phosphate on growth, yield and quality of cowpea grown in the summer rice fallows. The residual effect of applied P in the soil was studied by raising a rice crop in the same field in the subsequent season. The observations on growth factors viz. height of plant, dry weight of plant, number of leaves per plant and number of branches per plant; yield and yield parameters as well as soil analysis for pH, N, P, K and uptake of nutrients like N, P, K, Ca and Mg at three different stages of plant growth were also made.

EXPERIMENT I (Cowpea)

I. Growth characters:

The data furnished in Tables 1 and 2 and bar diagrams in fig. 3, 5 and 6 have revealed significant differences in the height, number of leaves and number of branches per plant at all the three growth stages by the application of different sources of phosphates. The application of superphosphate has strengthened the root system enabling the roots to absorb more

FIG. 3. EFFECT OF DIFFERENT SOURCES OF APPLIED PHOSPHORUS ON PLANT HEIGHT AT THREE GROWTH STAGES OF COWPEA Viz. 20 DAYS AFTER SOWING, FLOWERING AND AT HARVEST

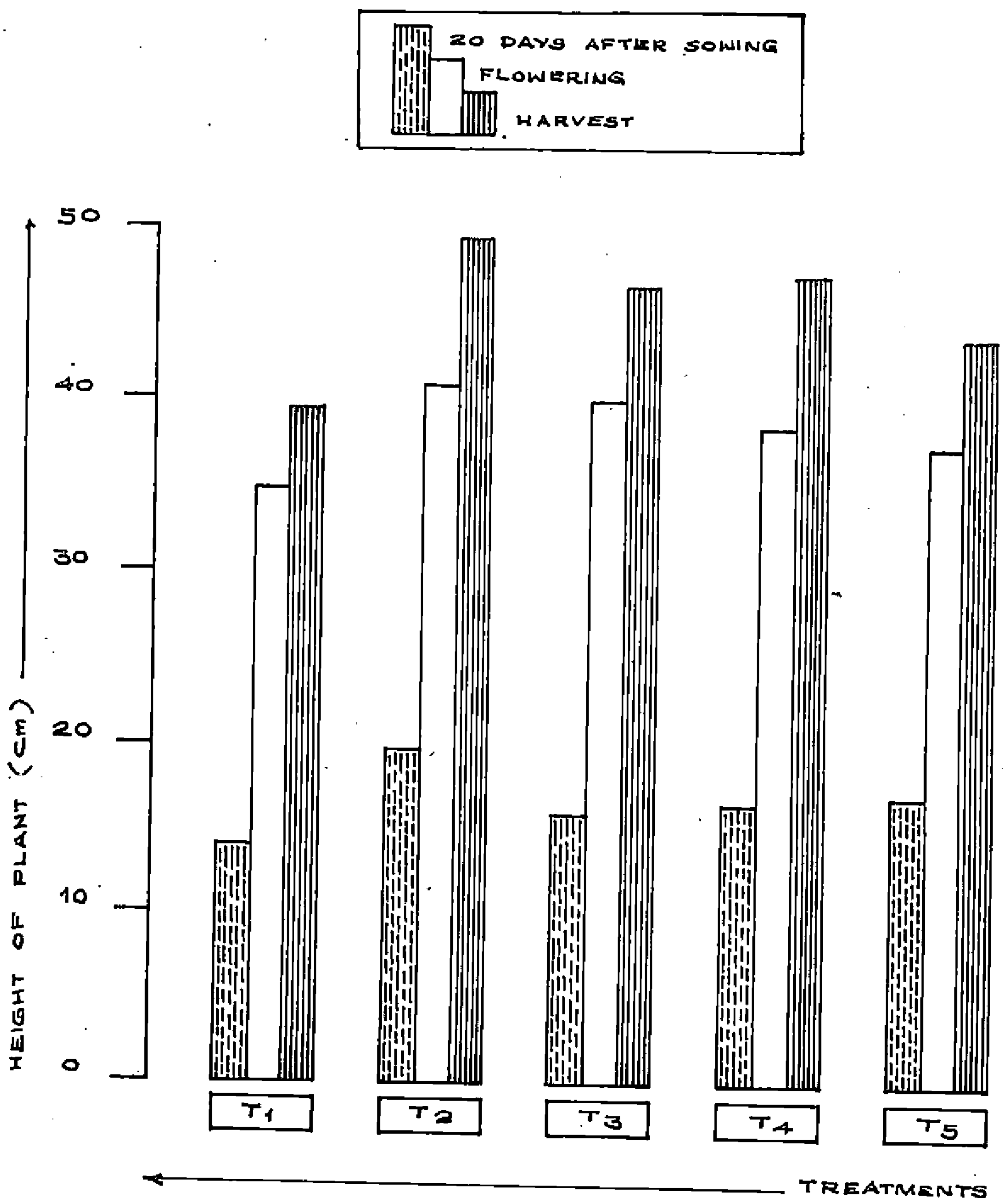


FIG.5. EFFECT OF DIFFERENT SOURCES OF APPLIED PHOSPHORUS ON NUMBER OF LEAVES PER PLANT AT THREE GROWTH STAGES OF COWPEA Viz. 20 DAYS AFTER SOWING, AT FLOWERING AND AT HARVEST

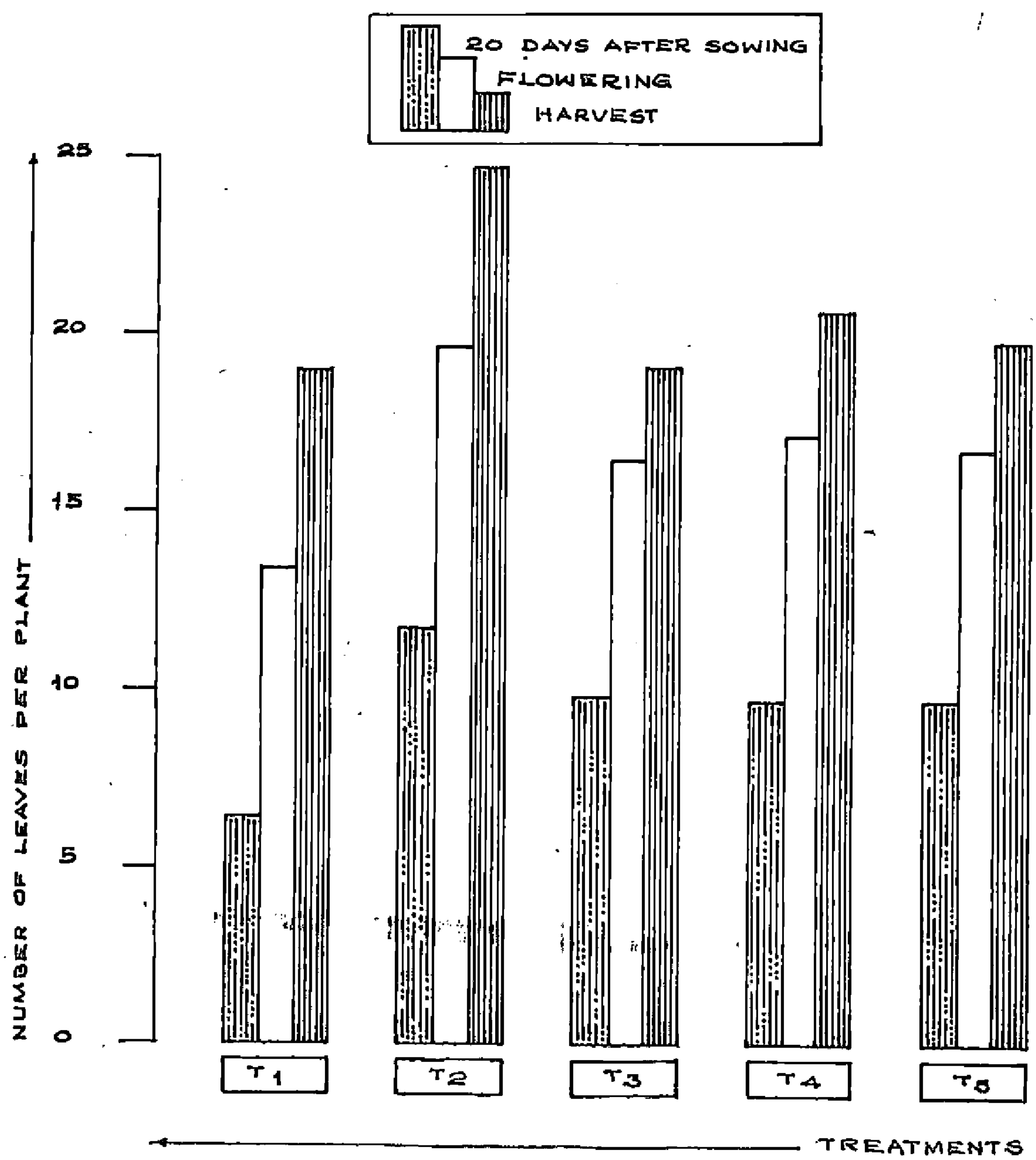
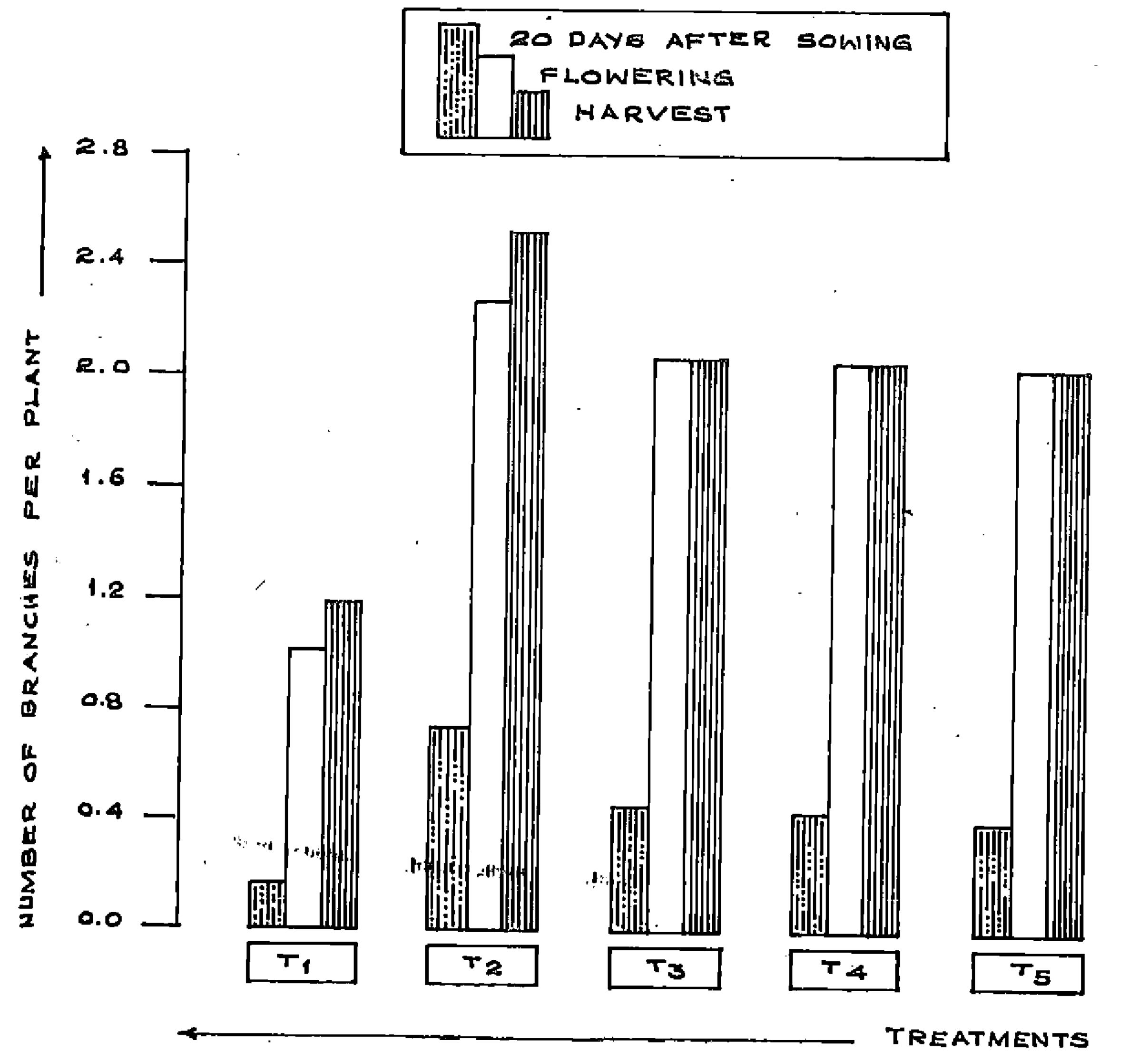


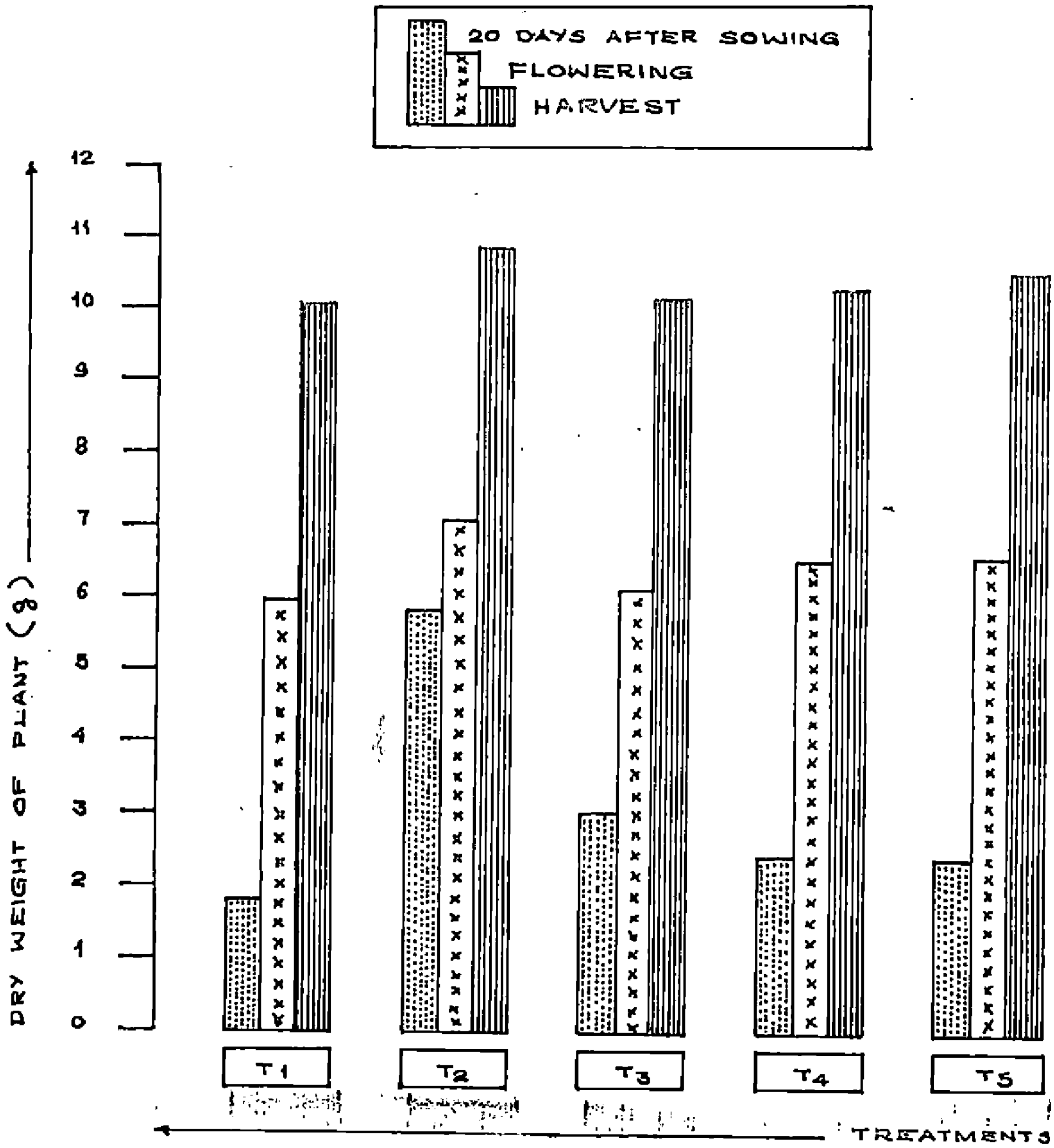
FIG. 6. EFFECT OF DIFFERENT SOURCES OF APPLIED PHOSPHORUS ON NUMBER OF BRANCHES PER PLANT AT THREE STAGES OF COWPEA Viz. 20 DAYS AFTER SOWING, AT FLOWERING AND AT HARVEST



nutrients leading to increased height, number of leaves and number of branches per plant. Such a positive effect of the influence of soluble phosphates at the early growth stages of cowpea might have favourably affected the growth and nodulation of cowpea as proposed by Tisdale and Nelson (1966). Vyas and Desai (1953) have shown that in different legumes, phosphate application improved nitrogen assimilation, which promotes vegetative growth. Similar increase in leaf number due to phosphorus application has been reported in cowpea by Tarila et al. (1977) and Savithri (1980) in green gram. Sanchez and Mata (1972) reported that highest utilization of applied phosphorus by groundnut was obtained from superphosphate. Atanasiu et al. (1978) reported that water soluble phosphate resulted in better maize development and highest phosphate uptake at the beginning of growing period. The early accessibility combined with immediate availability might have promoted rapid growth in superphosphate applied plant. Effect of different sources of rock phosphate on plant height, number of leaves per plant and number of branches per plant were almost similar. In superphosphate the phosphorus is in the water soluble form and hence is more readily available to the plant than the water insoluble tricalcium phosphate present in rock phosphate. However, due to the acidic nature of the soil the rock phosphate might have gradually undergone chemical reaction leading to the greater availability at the later stages of growth. Similar findings were earlier reported by Minhas and Kick (1974). This may be due to the fact that the P_2O_5 in rock phosphate becomes gradually more available at later stages. It was indicated that citrate soluble sources were not in any way inferior to water soluble forms in promoting growth and development (Anonymous, 1971).

From the results presented in Table 1 and the diagram presented in Fig.4 it may be noted that the phosphorus treatment has increased the plant dry weight compared to the untreated control which recorded the lowest values. During the early stages of plant growth, superphosphate application resulted in a higher dry weight of plant than the rock phosphates. The immediate availability of phosphorus from superphosphate might have been a contributing factor in promoting rapid growth at the early stages. However, at flowering and at harvest stages the effect due to rock phosphate and superphosphate were found to be on par. The increased availability

FIG. 4. EFFECT OF DIFFERENT SOURCES OF APPLIED PHOSPHORUS ON DRY WEIGHT OF PLANT AT THREE STAGES OF COWPEA Viz. 20 DAYS AFTER SOWING, AT FLOWERING AND AT HARVEST



of phosphorus from rock phosphates under the acid condition of the soil might have contributed to the higher dry weight. Motsara and Datta (1971) obtained similar values for rock phosphate treatment than for superphosphate applied to pea plants.

II. Yield and yield contributing factors

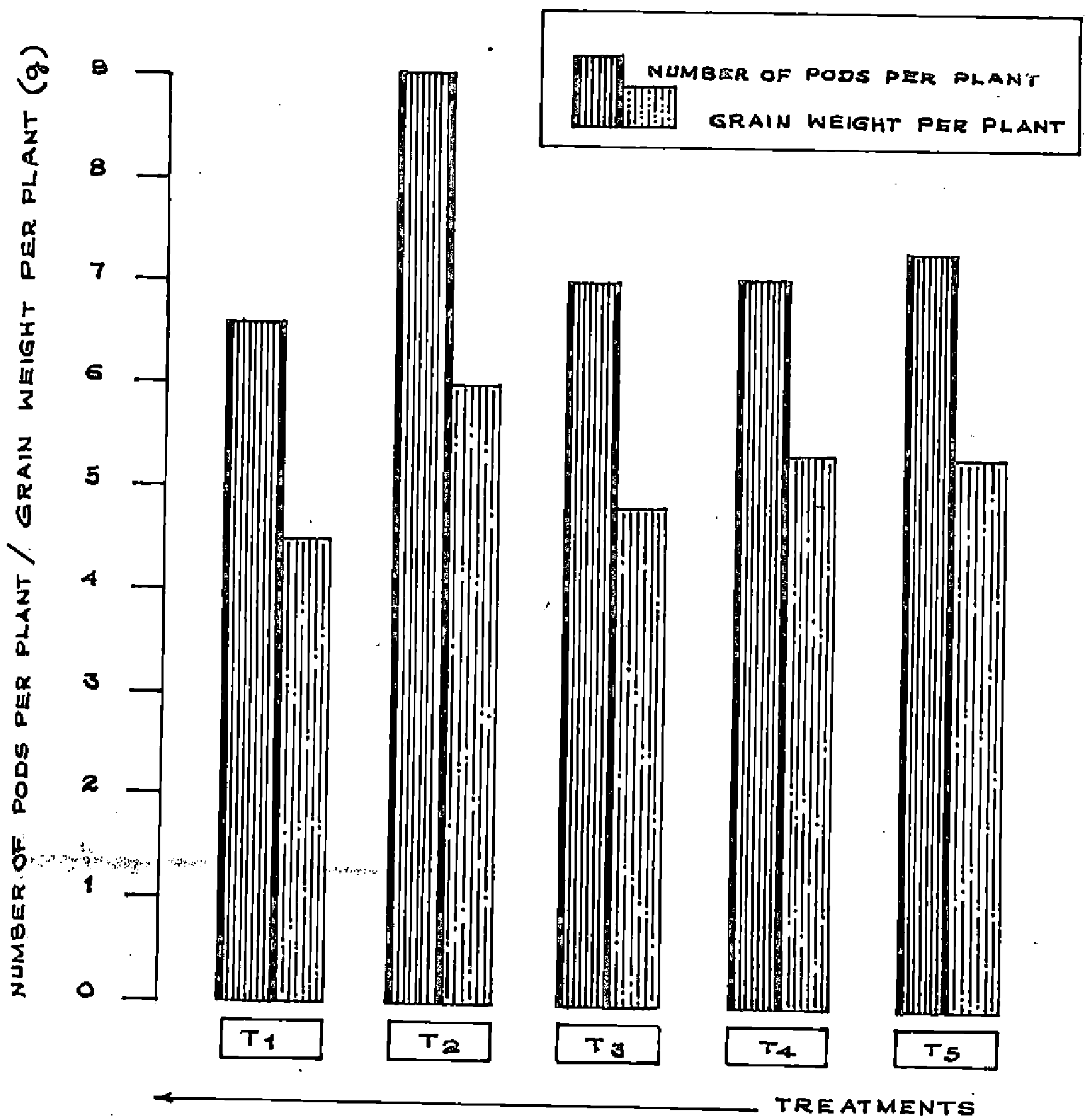
The number of grains per pod was remarkably increased by phosphorus application. The effect due to different sources of phosphorus application was statistically similar, though an increase in number of grains per pod could be obtained from superphosphate treatment. An adequate supply of phosphorus is important in laying down the primordia for reproductive parts of plants (Tisdale and Nelson 1966).

An increase in the number of grains per pod by phosphorus application in peas has been reported by Ahmed and Shafi (1975). Singh et al. (1975) and Subramonian et al. (1977). However Duraisamy and Palaniappan (1979) have reported that the number of seeds per pod was not influenced by phosphorus application.

The data on the length of pod in the different treatments are also in agreement with the findings of Duraisamy and Palaniappan (1979) in that the length of pod was not significantly influenced by phosphorus application. The results also revealed non-significant difference among the sources of phosphorus tried.

From the result in Table 3 and bar diagram (Fig.7) it could be seen that maximum number of 9.13 pods per plant could be obtained from plants treated with superphosphate, which was significant, where as the number of pods from plants treated with rock phosphate (Madhya Pradesh), Mussoorie phosphate and Udaipur phosphate was found to be 7.63, 7.88 and 8.00 respectively. Control plot registered the lowest number of pods per plant (6.5). The increased number of pods per plant in the superphosphate treatment can be attributed to the ready availability of phosphorus throughout the plant growth period. Phosphorus is considered essential for seed setting and for the formation of fruits. The presence of readily available phosphorus appears to have a stimulating effect on the production of more pods. Similar increase in pod number by phosphorus application was reported by Deshpande and Bathkal (1965) and Venugopalan and Morachan

FIG. 7. EFFECT OF DIFFERENT SOURCES OF APPLIED PHOSPHORUS ON NUMBER OF PODS PER PLANT AND GRAIN WEIGHT PER PLANT (COWPEA)



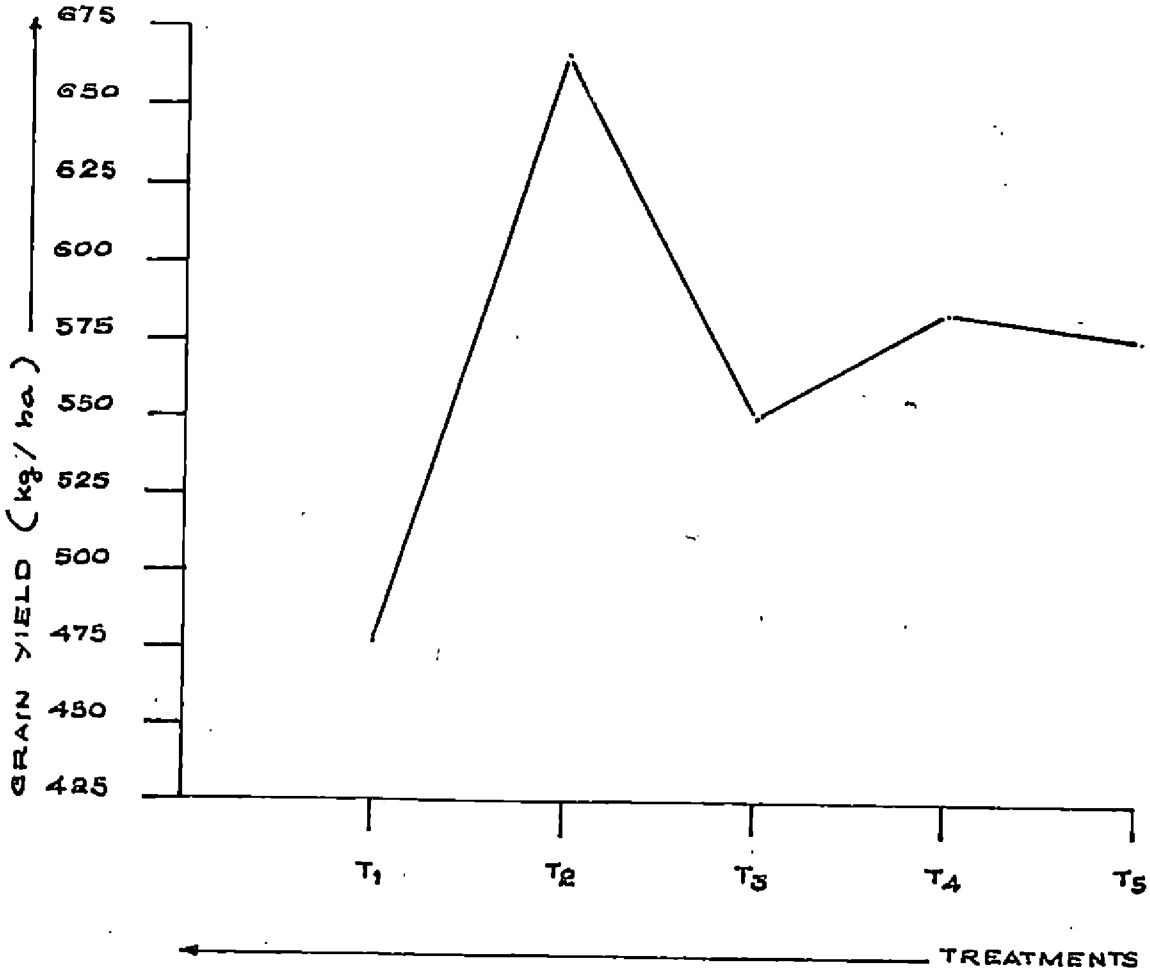
(1974) in green gram, Ahmad and Shafi (1975) in peas and Subramonian et al. (1977) in cowpea.

The grain yield per plant as affected by the different sources of phosphorus was found to be significant in the superphosphate treatment which gavê the maximum grain yield of 6.25 g/plot. The yield of grain per plant from the three rock phosphates was on par. Evidently, the available phosphorus from superphosphate might have stimulated grain formation.

Hundred grain weight was not seen influenced by phosphorus application. This result is in agreement with the findings of Duraisamy Reddy and Palaniappan (1979).

Data on the grain yield per plant given in Table 3 and Fig.7 and yield in kg/ha given in Table 4 and Fig.8 indicate that the different sources of phosphorus application have significant influence. Ahlawat et al. (1979) reported that application of phosphorus and marked effect in increasing the grain yield in cowpea. Increased grain yield by phosphorus application was also evident from the results of experiments conducted in pulse crops by several workers like Ezedinma (1965), Gill et al. (1971), Worley (1971), Kurdikeri et al. (1973) and Martin et al. (1974). The maximum yield was obtai-

FIG. 8. EFFECT OF DIFFERENT SOURCES OF APPLIED PHOSPHORUS ON YIELD OF GRAIN (COWPEA)



ned by superphosphate application followed by Mussoorie phosphate, Udaipur phosphate and rock phosphate (Madhya Pradesh). The yields from different rock phosphates were on par. The increase in grain yield is evidently due to enhanced initial vegetative growth brought about by the application of easily available fertilizer like superphosphate.

The additive effects of bhusa yield and grain yield are reflected in the total dry matter production. Maximum dry matter yield of 2.31 t/ha was obtained from superphosphate treated plants and this was followed by Mussoorie phosphate, Udaipur phosphate and Madhya Pradesh phosphate. However, the results were not significant.

III. Soil analysis

From the data shown in Table 5(a), it is clear that the pH of soil at all growth stages in superphosphate treated plot was significantly lower than those treated with the different rock phosphates. Increased level of pH in the rock phosphate treated soils may probably be due to the presence of free calcium carbonate in the different rock phosphates.

From the data furnished in Table 5(a), it is clear that the application of phosphorus has increased the nitrogen content of the soil significantly. Sen and Rao (1953) reported that nodule bacteria require an adequate supply of phosphorus for their normal development and nitrogen fixation in symbiosis with the legume. The increase in the amount of nitrogen fixed in the presence of higher levels of phosphorus has resulted in higher soil nitrogen content. Similar increase in nitrogen content of soil by phosphorus application to cowpea by Khare and Rai 1968) Garg et al. (1970) and Sahu and Behera (1972).

Increase in available phosphorus by the application of phosphate fertilizers has been reported by Garg et al.(1970) and Sharma and Yadav (1976). Data shown in Table 5(a) indicates that a similar increase in available phosphorus could be obtained in the present study also. According to Tisdale and Nelson (1966) the calcium in acid humid region soils occurs largely in the exchangeable form. If the activity of calcium in the soil solution is increased, there tends to be a shift of equilibrium in the opposite direction and more and more calcium brought into the available pool with subsequent absorption of some of the calcium by the exchange complex. Legumes in view of the high cation exchange capacity of their roots absorb more calcium. Under such condition the tricalcium forms of phosphate will be slowly converted to divalent and monovalent forms and will contribute to an increase in the available phosphorus status of the soil. In the case of superphosphate in later stages, a slight reduction in available phosphorus content was noticed. Mandal and Khan (1972) demonstrated that more than 86 per cent of phosphorus added as super phosphate is converted into unavailable form within 15 days of incubation. This phenomenon might have resulted in a slight reduction in the content of available phosphorus in the superphosphate treatments. However, the total phosphorus content of the soil increased with application of phosphorus.

Data on the potassium content of the soil, presented in Table 5(a) showed that available potassium content was not significantly influenced by phosphorus application.

IV. Nutrient uptake

A significant increase in nitrogen uptake of plants in superphosphate treatment followed by rock phosphate as compared to control could be observed. This may be due to the influence of nitrogen on root development, nitrogen fixation and meristematic activity of the plant which was resulted in an increase in the total dry matter production. This increase in dry matter production leads to an increase in nitrogen uptake. Similar increase in nitrogen uptake by legumes has been reported by Singh and Jain (1968) and Sahu and Behera (1972) in cowpea and Rollin Bhaskar (1979) in green gram. The maximum uptake of nitrogen was obtained when phosphorus was applied as superphosphate.

The uptake of phosphorus was found maximum in the superphosphate treatment. This can be attributed to the better and earlier availability of phosphorus. Sharma et al. (1976) has reported an increase in the uptake of phosphorus by cowpea due to phosphorus application. Dalal and Quilt (1977) reported that the total phosphorus uptake significantly increased with fertilizer phosphorus applied.

The uptake of potassium, calcium and magnesium were not found to be influenced by any of the forms of phosphorus applied. This may be due to the presence of sufficient amounts of these elements in the soil.

Experiment II (Rice)

Experiment II which dealt with the study of the residual effect of applied phosphorus to cowpea on the succeeding paddy crop which has given rise to the following results.

Growth characters

The treatments which received normal dose of phosphorus prescribed for rice as per the package of practices registered significantly higher values for plant height and tiller count at active tillering and at harvest stages compared to the corresponding treatments where phosphorus was skipped.

Among the phosphorus skipped treatments for rice, the subplot which earlier received rock phosphate for the cowpea crop performed better than the corresponding superphosphate treatment. The same trend in the growth characters was observed in the treatments which received phosphorus for both the cowpea and the rice crops. The increased plant height and tiller count over those of the superphosphate treatment can be attributed to the residual effects of the different rock phosphates earlier applied to the cowpea crop. The effect of residual phosphorus plus the effect of phosphorus applied to the rice crop has resulted in the better growth performance when compared with the corresponding phosphorus skipped treatments. There was conspicuous difference in the growth of paddy plants between skipped and unskipped phosphorus treatments, which was visually evident.

Yield characters

With regard to productive tillers, filled grains per panicle, unfilled grains per panicle and thousand grain weight, the combined effect of residual phosphorus from the rock phosphate plus the phosphorus applied later to the rice crop was significant over the corresponding combined effect of superphosphate alone. With regard to the length of panicle also, a favourable effect could be observed in the rock phosphate though not significant. The better residual effect of phosphorus from the rock phosphate treatment over that from the superphosphate treatment is thus evident. Motsara and Datta (1971) have found that rock phosphate was significantly better than superphosphate with respect to crop yields and residual phosphorus status of the soil. Monkwunye (1975) reported that rock phosphate had a better residual effect on subsequent crops, than superphosphate.

All the treatments give significantly higher yield of grain over control. The treatments where phosphorus was skipped recorded significantly lower yield of grain than the treatments which received phosphorus for the rice crop. Mean yield data indicated that in general plants treated with phosphorus for the rice crop gave about 7 per cent increase in yield of paddy grain over the phosphorus skipped plants which was significant. From the treatment means it was noted that the increase in yield of grain from the plots which had residual phosphorus plus phosphorus applied to rice was 16, 11, 2,4 and 4 per cent respectively for T_1, T_2, T_3, T_4 and T_5 treatments, compared to the corresponding phosphorus skipped plots. The findings reveal that the application of phosphorus separately for the rice crop would benefit the rice crop. However, the extent of benefit varies with the different sources of phosphorus fixation. Among the phosphorus fertilizers studied rock phosphates have given higher yield than superphosphate. Among the rock phosphates Mussoorie phosphate has given the highest yield.

The better performance of the crop with phosphorus skipped treatments was also better on the case of the three rock phosphates and significant when compared to superphosphate. This can be attributed to the residual effects of the rock phosphate fertilizers on rice. The result also reveal that if a subsequent crop of rice has to be raised after the harvest of cowpea without separate phosphorus application for rice, Mussoorie phosphate would give better yield than superphosphate. Thereby suggesting that rock phosphates have better residual effect than the phosphorus from single superphosphate. Same trend could be observed when the residual phosphorus on the soil was supplemented by separate application of phosphorus to rice crop. Motsara and Datta (1971) reported that in the residual effect of rock phosphate was found significantly better than superphosphate with respect to crop yields and residual status of soil. Monkwunye (1975) has also reported the same type of finding.

The yield of straw was significantly higher in the rock phosphate treatments as compared to superphosphate. Highest straw yield of 3935 kg/ha could be obtained from Mussoorie phosphate treatment. As in the case of grain yield, the residual effect of rock phosphates has played a major role in enhancing the straw yield.

The present work gives an indication on the feasibility of reducing the dose of phosphorus for rice crop without appreciable yield decrease of grain and straw, when raised subsequent to a cowpea crop raised with rock phosphate application.

Soil analysis

Among the phosphorus skipped treatments for the rice crop, Mussoorie phosphate treatment to the earlier cowpea crop registered higher pH values than the corresponding Rajasthan phosphate, superphosphate and control treatments. The same trend was observed in the treatments which received rock phosphate for the cowpea crop and normal dose of phosphorus for the rice crop. However, highest pH of 5.3 in the soil was observed in the rock phosphate (Madhya Pradesh) treatment for cowpea with normal phosphorus application to rice and in Mussoorie phosphate treatment, without phosphorus added later to the rice crop. Presence of calcium in these rock phosphate might have contributed to higher pH values.

The treatments which received normal dose of phosphorus needed for the rice crop as per the package of practices recorded a slight reduction in the available nitrogen content of the soil compared to the corresponding treatments in which phosphorus was skipped. Maximum content of available nitrogen was obtained in the treatment which earlier received phosphorus as Mussoorie phosphate.

The treatments which received normal dose of phosphorus needed for the rice crop registered significantly higher values for the available phosphorus content of soil ranging between 56 to 89.6 kg/ha as compared to the phosphorus skipped treatments. Among the phosphorus skipped treatments, the sub plot which received the different rock phosphate for the cowpea crop registered a higher available P status of soil than the corresponding superphosphate treatment, though no significance could be obtained. The same trend was observed in the treatments which received phosphorus for both cowpea and rice crops. Motsara and Datta (1971) reported that rock phosphate showed better residual phosphorus status of soil than superphosphate. The higher available phosphorus content of the rock phosphate treated soils over those of the superphosphate treatment can be attributed to the residual effect of the different rock phosphates earlier supplied to the cowpea crop.

With regard to the exchangeable potassium content of the rock phosphate treated soils, the combined effect of residual phosphorus and supplied phosphorus was not significant over the corresponding combined effect from superphosphate treatments.

Plant analysis

The treatments which received normal dose of phosphorus for the rice crop as per the package of practices showed significantly higher values for nitrogen content of grain and straw, compared to the treatments where phosphorus fertilizer was skipped for rice. The significant increase in the nitrogen uptake with increase in the level of phosphorus application may be due to the significant influence of phosphorus on root development, nitrogen fixation and meristematic activity of the plant which resulted in an increase in nitrogen uptake. Shende and Sen (1958) have reported that application of phosphorus increased the nitrogen content of plant in guar. Increased protein content of seed in cowpea has been reported by Omueti and Oyenuga (1970) by superphosphate application. Sahu and Behera (1972) reported that in cowpea nitrogen content in shoot, root and grain increased significantly by phosphorus manuring.

With regard to phosphorus content of grain and straw the combined effect of residual phosphorus from the rock phosphates earlier applied to the cowpea and the phosphorus applied later to the rice crop was significant over the corresponding effect of superphosphate alone applied to cowpea and rice. Among the treatments where phosphorus was skipped, the subplot which earlier received rock phosphate for the cowpea crop gave higher phosphorus content than the corresponding treatments which earlier received superphosphate. The same trend in the phosphorus content of paddy grain and straw was observed in the treatments which received phosphorus for both cowpea and rice crop. The increased phosphorus content over those of superphosphate treatments can be attributed to the residual effect of the different rock phosphate earlier applied to the cowpea crop.

With regard to the potassium content of grain and straw both the skipped and unskipped treatments were not influenced by different sources of phosphorus application.

The treatments which received normal dose of phosphorus needed for the rice crop recorded nonsignificant difference in values for calcium and magnesium contents of grain and straw. The same trend was followed in those treatments where phosphorus was skipped.

Economics

The economics of phosphorus application in different forms was worked out on the basis of mean yield data of cowpea and paddy. The data are presented in Tables 22 and 23. Grain yield of cowpea was valued @ Rs.6 per kg and cost of P_2O_5 @ Rs.5 per kg for superphosphate and as Rs.3 per kg for rock phosphate.

Among the different forms of phosphorus studied, highest net return of Rs.698/= per hectare was obtained from the application of superphosphate to cowpea and this was followed by Mussoorie phosphate (Rs.314/=) and Udaipur phosphate Rs.302/=.When the net rice yield in addition to the yield of cowpea is considered, Mussoorie phosphate treatment was found

Table No.22 Economics of phosphorus applications to cowpea in rupees per hectare

Treatments	Cost of production (₨/ha)	Yield of grain (kg/ha)	Value of grain @ ₨.6/kg	Net profit(+)/ Net loss(-) (₨)
T_1	3090/-	474	2844/-	-246/-
T_2	3250/-	658	3948/-	+698/-
T_3	3190/-	548	3288/-	+ 98/-
T_4	3190/-	584	3504/-	+314/-
T_5	3190/-	582	3492/-	+302/-

- loss

+ gain

Table No.23 Economics of cultivation
(Cowpea + Paddy)

Treat-ment	Cost of Production (Rs)		Yield (kg/ha)				Value (Rs)						Net profit (Rs)			
	P_0 Treat-ment	P_1 Treat-ment	P_0 Treatment		P_1 Treatment		P_0 Treatment			P_1 Treatment			P_0 Treatment		P_1 Treatment	
			Grain	Straw	Grain	Straw	Grain	Straw	Total	Grain @ 2000/= per ton	Straw @ 700/= per ton	Total	Rice	Rice + Cowpea	Rice	Rice + Cowpea
T_1	7609	7744	2706	3290	3230	3325	5412	2303	7715	6459	2327	8786	106	-140	1042	796
T_2	7609	7744	3002	3390	3381	3410	6003	2303	8306	6761	2387	9148	1697	+2395	1404	2102
T_3	7609	7744	3810	3785	3915	3920	7621	2649	10230	7830	2744	10574	2621	+2719	2030	2928
T_4	7609	7744	3815	3755	3996	3935	7629	2628	10257	7992	2754	10747	2648	+2962	3003	3317
T_5	7609	7744	3810	3737	3995	3920	7620	2590	10210	7990	2744	10734	2601	+2903	2990	3292

more economical and resulted in the highest net return. This was followed by Rajasthan phosphate, rock phosphate (Madhya Pradesh) and superphosphate in order.

In considering the economics of rice production, the existing cost of Rs.2000/ton for paddy and Rs.700/ton for straw were used in the computation. It was seen that there was a net profit of Rs.3003/= when Mussoorie phosphate was applied to the cowpea crop and phosphorus applied to the rice crop as per package of practices.

The results of the present study thus indicate that in a package of crops consisting of summer fallow pulses and virippu rice, application of rock phosphates are economically more beneficial than soluble phosphates. However, these two crops together form only part of a total multiple cropping system in a generally rice based cropping system. The long term effects of rock phosphates verses soluble phosphates in rice based cropping systems, however, needs further study.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

An investigation was undertaken in a farmer's field at Kalliyoor in Trivandrum District to find out the effect of application of different sources of phosphatic fertilizer on growth, yield and composition of cowpea, grown in summer rice fallows. The residual effect of phosphorus applied to cowpea, on the paddy crop raised in the subsequent season was also investigated. In the present study, the effect of Mussoorie phosphate, rock phosphate (Madhya Pradesh) and Udaipur phosphate on cowpea were compared with superphosphate. For studying the residual effect of phosphorus on paddy, each plot after the cowpea crop was subdivided into two, in which one plot received normal phosphorus recommended for paddy while in the other plot phosphorus was skipped. The important findings from the study are:

1. Plant height in cowpea was increased significantly by superphosphate application over the other sources of phosphorus tried.
2. Number of leaves and number of branches per plant were significantly increased by phosphorus application.

3. The influence of different sources of phosphorus on yield contributing characters such as number of pods per plant and pod yield per plant was significant. Maximum values with respect to these characters were obtained by application of phosphorus in the form of superphosphate.

4. Grain yield of cowpea was also significantly increased by application of phosphorus as superphosphate. Maximum yield of 658 kg cowpea grain per hectare was obtained in the superphosphate treatment. This was followed by Mussoorie phosphate, Udaipur phosphate and rock phosphate (Madhya Pradesh) which were on par.

5. Available nitrogen and phosphorus contents in the soil at different stages of growth and after the harvest of cowpea were found to be significantly influenced by different sources of applied phosphorus. The values were maximum in the superphosphate treatment and it was followed by Mussoorie phosphate and Udaipur phosphate. Potassium content of the soil was, however, not influenced by any of the forms of phosphorus applied.

6. The different sources of phosphorus were found to have significant effect on the nitrogen and phosphorus uptake

by cowpea. Superphosphate resulted in the maximum uptake at all the growth stages of cowpea.

7. Grain yield of cowpea was significantly and positively correlated to height of cowpea plant at twenty days after sowing, number of pods per plant and available phosphorus content of soil at different growth stages.

8. In the succeeding crop of paddy, the height of the plant, number of tillers per plant at maximum tillering and grain ripening stages, number of filled grains per panicle, thousand grain weight and mean grain yield were significantly influenced by the residual effect of the different rock phosphates. The highest rice grain yield was recorded in the Mussoorie phosphate treatment. But there was no significant difference in the yield between the different rock phosphate treatments.

9. Phosphorus content of the soil at harvest was also significantly influenced by rock phosphate as was the case with the preceeding cowpea crop.

10. The different rock phosphates were found to have significant influences on the uptake of phosphorus by the rice plant.

11. Grain yield of paddy was significantly and positively correlated to phosphorus content of soil, plant height and number of tillers at different growth stages, length of panicle, number of filled grains per panicle and thousand grain weight.

12. Economics worked out for the different treatments indicated that superphosphate treatment for cowpea was more economical than the other forms of phosphorus studied. The residual effect of rock phosphate particularly that of Mussoorie phosphate was also helpful in increasing the yield of paddy raised during the subsequent season. Economics worked out for the different treatments for cowpea plus rice indicated that Mussoorie phosphate was a better source of fertilizer than the other forms of phosphorus studied.

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APPENDICES

APPENDIX I

Abstract of analysis of variance table for plant height at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	Harvesting stage
Treatment	4	14.785**	37.407**	46.953**
Block	3	4.720	17.959	57.719**
Error	12	1.858	5.371	5.215

** Significant at one per cent level

APPENDIX II

Abstract of analysis of variance table for plant dry weight at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	Harvesting stage
Treatment	4	6.408**	0.979	0.248
Block	3	1.548	1.869	3.656
Error	12	0.914	1.692	5.366

** Significant at one per cent level

APPENDIX III

Abstract of analysis of variance table for number of leaves per plant at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	Harvesting stage
Treatment	4	16.05**	20.45	23.95*
Block	3	1.733	5.78	1.783
Error	12	2.483	4.62	5.45

** Significant at one per cent level

* Significant at five per cent level

APPENDIX IV

Abstract of analysis of variance table for number of branches per plant at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	Harvesting stage
Treatment	4	0.168**	0.856**	0.535
Block	3	0.066	0.016	1.349
Error	12	0.019	0.066	0.589

** Significant at one per cent level

APPENDIX V

Abstract of analysis of variance table for number of pods per plant, length of pod, number of grains per pod, grain weight per plant and hundred grain weight

Source	df	Mean squares				
		No. of pods per plant	Length of pod	No. of grains per pod	Grain weight per plant	Hundred grain weight
Treatment	4	0.519**	0.225	0.358	1.617**	0.026
Block	3	0.146	0.033	0.173	0.123	0.162
Error	12	0.302	0.087	0.353	0.136	0.074

** Significant at one per cent level

APPENDIX VI

Abstract of analysis of variance table for grain yield, Bhusa yield, shelling percentage and dry matter production

Source	df	Mean squares			
		Grain yield	Bhusa yield	Shelling percentage	Dry matter production
Treatment	4	0.0180*	0.0087	0.3856	0.0032
Block	3	0.0013	0.0022	0.0937	0.0029
Error	12	0.0016	0.0128	1.0301	0.0136

* Significant at five per cent level

APPENDIX . VII

Abstract of analysis of variance table for pH of soil at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	At harvest
Treatment	4	0.152**	0.392**	0.272**
Block	3	0.001	0.013	0.004
Error	12	0.021	0.037	0.0257

** Significant at one per cent level

APPENDIX VIII

Abstract of analysis of variance table for available nitrogen content of soil at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	At harvest
Treatment	4	17554.3	3148.3	1480.2**
Block	3	2524.6	9272.4	222.6*
Error	12	9579.6	2789.9	61.1

** Significant at one per cent level

* Significant at five per cent level

APPENDIX IX

Abstract of analysis of variance table for available Phosphorus (P_2O_5) content of soil at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	At harvest
Treatment	4	857.37**	269.64**	356.34**
Block	3	12.71	8.73	9.90
Error	12	16.91	1.76	6.75

** Significant at one per cent level

* Significant at five per cent level

APPENDIX X

Abstract of analysis of variance table for exchangeable potassium (K_2O) content of soil at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	At harvest
Treatment	4	750.94**	726.15**	1150.09
Block	3	43.54	47.65	358.47
Error	12	32.69	121.14	783.43

** Significant at one per cent level

APPENDIX XI

Abstract of analysis of variance table for total nitrogen and potassium K_2O) content of soil at harvest and total phosphorus (P_2O_5) content of soil at different growth stages

Source	df	Mean squares				
		Total N at harvest	P_2O_5			Total K_2O at harvest
			Twenty days after sowing	Flowering stage	At harvest	
Treatment	4	0.000006	0.00051**	0.000266**	0.00020667**	0.0000075
Block	3	0.00000023	0.000003	0.00000033	0.00000032*	0.0000933
Error	12	0.00000011	0.00003	0.00000008	0.00000022	0.00033

** Significant at one per cent level

* Significant at five per cent level

APPENDIX XII

Abstract of analysis of variance table for nitrogen content of plant sample at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	At harvest
Treatment	4	0.1480*	0.203**	0.380**
Block	3	0.0113	0.057*	0.029
Error	12	0.0313	0.010	0.012

** Significant at one per cent level

* Significant at five per cent level

APPENDIX XIII

Abstract of analysis of variance table for phosphorus (P_2O_5) content of plant sample at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	At harvest
Treatment	4	0.063**	0.1785**	0.089**
Block	3	0.002	0.0007	0.014
Error	12	0.003	0.0042	0.007

** Significant at one per cent level

APPENDIX XIV

Abstract of analysis of variance table for potassium (K_2O) content of plant sample at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	At harvest
Treatment	4	0.002	0.028**	0.005
Block	3	0.011	0.003	0.011**
Error	12	0.003	0.001	0.001

** Significant at one per cent level

* Significant at five per cent level

APPENDIX XV

Abstract of analysis of variance table for calcium (Ca) content of plant sample at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	At harvest
Treatment	4	0.0042	0.0006	0.00092
Block	3	0.0086	0.0796**	0.00006
Error	12	0.0139	0.0043	0.00375

** Significant at one per cent level

APPENDIX XVI

Abstract of analysis of variance table for magnesium (Mg) content of plant sample at different growth stages

Source	df	Mean squares		
		Twenty days after sowing	Flowering stage	At harvest
Treatment	4	0.024**	0.043**	0.009
Block	3	0.003	0.003	0.005
Error	12	0.003	0.008	0.006

** Significant at one per cent level

APPENDIX XVII

Abstract of analysis of variance table for nitrogen (N) phosphorus (P_2O_5) potassium (K_2O) calcium (Ca) and magnesium (Mg) content of cowpea grain

Source	df	Mean squares				
		N	P_2O_5	K_2O	Ca	Mg
Treatment	4	0.188**	0.085**	0.0010	0.00011	0.00027
Block	3	0.201	0.033	0.0013	0.00011	0.00007
Error	12	0.011	0.012	0.0004	0.00026	0.00037

** Significant at one per cent level

APPENDIX XVIII

Abstract of analysis of variance table for plant height and number of tillers at maximum tillering stage and height of plant and number of productive tillers at harvest stage

Source	df	Mean squares			
		Height of plant at maximum tillering stage	Number of tillers at maximum tillering stage	Height of plant at harvest stage	Number of productive tillers at harvest stage
Block	3	0.166	0.009	7.200*	0.158
Main plot	4	38.813**	1.557**	69.538**	5.288**
Error(1)	12	1.313	0.021	1.221	0.338
Between plots of main plot 1	1	4.50*	0.151**	12.500*	4.5**
Between plots of main plot 2	1	3.125	0.045*	18.000**	1.125
Between plots of main plot 3	1	4.50*	0.011	40.500**	6.125*
Between plots of main plot 4	1	4.50*	0.045*	15.125**	3.125
Between plots of main plot 5	1	3.125	0.061*	10.125*	8.000**
Error(2)	15	0.95	0.008	1.717	

** Significant at one per cent level

* Significant at five per cent level

APPENDIX XIX

Abstract of analysis of variance table for length of panicle, number of filled grains per panicle and number of unfilled grains per panicle

Source	df	Mean squares		
		Length of panicle	Number of filled grains per panicle	Number of unfilled grains per panicle
Block	3	0.048	46.867	1.367
Main plot	4	1.662**	436.75**	30.963**
Error(1)	12	0.175	12.783	1.096
Between plots of Main plot 1	1	0.080	0.500	6.125
Between plots of Main plot 2	1	1.531**	0.500	8.000
Between plots of Main plot 3	1	1.201*	512.000**	10.125*
Between plots of Main plot 4	1	1.201*	200.000**	8.000
Between plots of Main plot 5	1	1.62**	180.500*	8.000
Eroor(2)	15	0.165	21.567	1.833

** Significant at one per cent level
 * Significant at five per cent level

APPENDIX XX

Abstract of analysis of variance table for thousand grain weight, grain yield and straw yield

Source	df	Mean squares		
		Thousand grain weight	Grain yield	Straw yield
Block	3	0.038	2960.030	34648.970
Main plot	4	4.104**	1629318.530**	625666.960**
Error(1)	1	0.079	4256.138	16136.779
Between plots of Main plot 1	1	0.781	547581.250**	2415.00
Between plots of Main plot 2	1	1.301**	287281.500**	804-00
Between plots of Main plot 3	1	2.541**	21841.140*	36312.00
Between plots of Main plot 4	1	1.561**	66067.240**	65161.00*
Between plots of Main plot 5	1	0.785**	68451.000**	59856.00*
Error(2)	15	0.059	3890.283	12425.867

** Significant at one per cent level

* Significant at five per cent level

APPENDIX - XXI

Abstract of analysis of variance table for pH in soil after harvest of paddy

Source	df	Mean squares
		pH
Block	3	0.010
Main plot	4	0.096**
Error(1)	12	0.014
Between plots of main plot 1	1	0.02
Between plots of main plot 2	1	0.02
Between plots of main plot 3	1	0.02
Between plots of main plot 4	1	0.02
Between plots of main plot 5	1	0.02
Error (2)	15	0.012

** Significant at one per cent level

APPENDIX XXII

Abstract of analysis of variance table for available nitrogen, phosphorus (P_2O_5) and exchangeable potassium (K_2O) content in soil after harvest of paddy

Source	df	Mean squares		
		Available	Available	Exchangeable K_2O
Block	3	6236.93**	13.809	37.16
Main plot	4	5997.35**	2575.21**	1511.81
Error(1)	12	880.18	117.02	590.82
Between plots of main plot 1	1	512.00	2719.15**	9391.35**
Between plots of main plot 2	1	512.00	795.01**	520.03*
Between plots of main plot 3	1	4.50	599.27**	361.805
Between plots of main plot 4	1	6612.5*	427.20**	1596.13**
Between plots of main plot 5	1	512.0	390.74**	3.65
Error (2)	15	1051.3	18.55	107.37

** Significant at one per cent level

* Significant at five per cent level

APPENDIX XXIII

Abstract of analysis of variance table for total nitrogen, phosphorus (P_2O_5) and potassium (K_2O) content in soil after harvest of paddy

Source	df	Mean squares		
		Total N	Total P_2O_5	Total K_2O
Block	3	0.00000027	0.00000417**	0.0004558
Main plot	4	0.00002041**	0.00651082**	0.0000463
Error (1)	12	0.00000012	0.00000072	0.0002996
Between plots of main plot 1	1	0.00000242	0.00049928**	0.000313
Between plots of main plot 2	1	0.00000002	0.00049298*	0.000113
Between plots of main plot 3	1	0.00001058	0.00017298**	0.000013
Between plots of main plot 4	1	0.00000242	0.00022472**	0.000000
Between plots of main plot 5	1	0.00005408**	0.00024641**	0.000050
Error (2)	15	0.00000032	0.00000118	0.0002107

** Significant at one per cent level

APPENDIX XXIV

Abstract of analysis of variance table for N, P_2O_5, K_2O, Ca and Mg content of paddy grain

Source	df	Mean squares				
		N	P_2O_5	K_2O	Ca	Mg
Block	3	0.0028	0.0153**	0.0012	0.0000847	0.0002353
Main plot	4	0.6911**	0.0482**	0.0019	0.0000065	0.0001018
Error(1)	12	0.0019	0.0026	0.0011	0.0000204	0.0001173
Between plots of main plot 1	1	0.1013**	0.1102**	0.0002	0.0000101	0.0003246
Between plots of main plot 2	1	2.1013**	0.1532**	0.0002	0.0000080	0.0000101
Between plots of main plots 3	1	2.1736**	0.1434**	0.0008	0.0000031	0.0000005
Between plots of main plot 4	1	2.0000**	0.1426**	0.002	0.0000045	0.0000320
Between plots of main plot 5	1	1.1628**	0.1152**	0.0001	0.0000004	0.0000005
Error(2)	15	0.0026	0.0018	0.0002	0.0000083	0.1278862

** Significant at one per cent level

* Significant at five per cent level

APPENDIX XXV

Abstract of analysis of variance table for N, P_2O_5, K_2O, Ca and Mg content of paddy straw

Source	df	Mean squares				
		N	P_2O_5	K_2O	Ca	Mg
Block	3	0.0342**	0.0042	0.0031	0.000985	0.063833**
Main plot	4	0.0372**	0.0938**	0.0422	0.000422	0.00086
Error(1)	12	0.0042	0.0059	0.0245	0.000282	0.00093
Between plots of main plot 1	1	0.2278	0.0024	0.0200	0.000200	0.00099
Between plots of main plot 2	1	0.6613**	0.0159**	0.0421**	0.000006	0.00023
Between plots of main plot 3	1	0.4050**	0.0230**	0.0025	0.000091	0.00004
Between plots of main plot 4	1	0.2450**	0.0269**	0.0005	0.000231	0.00049
Between plots of main plot 5	1	0.3613**	0.0753**	0.0512**	0.000265	0.00013
Error(2)	15	0.0061	0.0015	0.0057	0.000285	0.00076

** Significant at one per cent level
* Significant at five per cent level

ABSTRACT

USE OF CHEAPER AND EFFICIENT SOURCES OF PHOSPHATIC FERTILIZER FOR COWPEA IN RICE FALLOWS

By

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THESIS

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ABSTRACT

An experiment was conducted in a farmer's field at Kalliyoor in Trivandrum District with a view to study the effect of different cheaper sources of phosphorus application on growth, yield and composition of cowpea. The residual effect of these sources of phosphorus was also studied by raising a paddy crop during the subsequent season. The trial was laid out in a randamised block design with five treatments and four replications. The treatments included Mussoorie phosphate, Udaipur phosphate, rock phosphate (Madhya Pradesh) and single superphosphate. The subsequent trial was laid out in split plot non-factorial structural design with five mainplots, two subplots and four replications. The study revealed that phosphorus application significantly influenced the growth characters of cowpea viz. plant height, number of leaves per plant and number of branches per plant. Yield contributing factors viz. number of pods per plant and grain yield per plant were also significantly increased by different sources of phosphorus. Application of superphosphate resulted in heighest value for all these yield characters of cowpea. Maximum grain yield of 658 kg/ha could be obtained from the superphosphate treatment and this was followed by Mussoorie phosphate.

Studies on the effect of residual phosphorus on the subsequent paddy crop indicated that height of plant and the tiller number per plant at maximum tillering stage and grain ripening stage were significantly influenced by rock phosphate application. The yield contributing factors such as number of filled grains per panicle, thousand grain weight and grain yield of paddy were also significantly influenced by the residual effect of rock phosphates applied to cowpea plus superphosphate applied to paddy than that of superphosphate alone applied to both cowpea and paddy.

Grain yield of cowpea was positively and significantly correlated to height of plant at twenty days after sowing, number of pods per plant and available phosphorus content of soil at different growth stages.

The yield paddy grain was positively and significantly correlated to plant height and number of tillers per plant at maximum tillering and grain ripening stages, length of panicle, number of filled grains per panicle and thousand grain weight.

Mussoorie phosphate treatment for the cowpea crop followed by rice crop which gave the maximum net profit of Rs.3317/= per hectare was more economical.