PHOSPHORUS MANAGEMENT IN A RICE BASED CROPPING SYSTEM

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Phosphorus management in a rice based cropping system" 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 'Phosphorus balance in a rice based cropping system' is a record of research work done independently by Smt. Annamma George 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

Phosphorus is an essential nutrient element directly affecting crop yield. It is also one of the nutrients found to be deficient over large areas in the country. Addition of phosphorus by way of fertilizer has thus become a necessity under most conditions for augmenting crop yield. However, fertilizer phosphorus is a costly input. This and its relatively poor utilization by individual crop and fixation - immobility phenomena in the soil are some of the principal factors which has promoted attention of the planners, scientists and farmers alike towards most efficient management of fertilizer phosphorus.

In large parts of the country where irrigation facilities exist two or even three or more crops are raised in a year. It has been recognised for sometime that for efficient use of fertilizers, fertilizer recommendations should take into account the cropping system as a whole rather than individual crops. This aspect is particularly important in the case of phosphorus where the percentage utilization of phosphorus by the crop to which it is applied is rather low and there

there is considerable residual effect. In a cropping system removal of phosphorus by the first crop normally does not exceed 10 - 20% of the added phosphorus and the rest stays on the soil (Tandon, 1976).

The FAI - FAO Seminar on 'Optimising agricultural production under limited availability of fertilizers' inter alia recommended that 'Soil test should be linked with soil topography, soil texture and cropping system rather than individual crops'. It further recommended that 'Fertilizer recommendation should be made taking into cognizance the cropping system as a whole rather than individual crops'.

There seems to be five major lines of investigations with regard to determining the need for fertilizer phosphorus by individual crops in a cropping sequence or the latter as a whole. They are (i) experiments designed to study the direct, residual and cumulative effects of fertilizer nutrient in a single year fixed two crop sequence (ii) experiments designed to study the residual effect alone of the nutrient applied to a crop on the succeeding one. (iii) Experiments designed to study the impact of cuts in recommended fertilizer doses through adhoc apportioning of the total available fertilizer to various crops in the sequence (iv) investigation to elucidate the role of specific nutrient fractions for individual crop or crops (v) investigations relating to availability and transformation of phosphorus in soil and linking this with the specific need of fertilizer phosphorus by the crop. The first three are agronomic in approach and the latter two are of importance to soil chemistry and soil fertility. (Goswami and Singh, 1976).

The fertilizer need of a crop in cropping system mainly depends upon the characteristics of the preceding crop and the kind and quantities of fertilizers applied to them. The management of fertilizer phosphorus could be viewed from still another angle namely, from the point of view of root activity and soil versus fertilizer phosphorus feeding capacities of different crops. These two phenomena viz., the residual effect of phosphorus and the differential capacities of plants to utilize soil and fertilizer phosphorus have been taken advantage of in formulating fertilizer phosphorus recommendations for cropping systems. (Roy *et al.* 1978). From the bulk of the long term field experimental data emanating from the All Indian Coordinated Agronomic Research Project of the Indian Council of Agricultural Research (ICAR), it might be inferred that phosphate application may be favoured in Rabi (dry) season crop (wheat) in a maize - wheat, sorghum - wheat, pearlmillet - wheat (Goswami and Singh, 1976) and rice (flooded) - wheat (Singhania and Goswami, 1974 and Joshy, 1974) rotations. This is because wheat cannot utilize the residual phosphorus in the form of Fe - P which is the major transformation product of phosphorus after rice but rice can utilize Fe - P besides Al - P.

Inclusion of deep rooted crops and legumes in particular in rotation may be most effective in making phosphorus available to succeeding crops in the rotation. (Raheja, 1966). Srivastava and Pathak (1976) reported that total response to phosphorus in a paddy-gram cropping sequence was higher when phosphorus fertilizer was applied to gram crop and the residual amount of phosphorus was utilized by the succeeding paddy crop as compared to its application to paddy crop and obtaining residual effect on gram crop. Thus inclusion of legumes in a crop rotation helps in improving the soil fertility resulting in higher yield of the succeeding crops as compared to preceeding exhaustive cereal crops. The common rotation followed in the rice fields under Kerala condition includes a legume crop like cowpea or a non legume crop like sesamum during the third crop season. Therefore the present study was taken up with rice-rice-cowpea/sesamum cropping system with the following objectives:

(1) To find out the possibilities of skipping phosphorus application in any of the rice season in a rice-rice-legume/non legume cropping system.

(2) To assess the residual effect of phosphorus application in a rice based cropping system with legume/non legume during the third crop season.

(3) To find out the suitable phosphorus management in a rice based cropping system.

(4) To assess the economics of the different treatments.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

It has been recognised that for efficient use of fertilizer nutrients, fertilizer recommendation should take into account the cropping system as a whole rather than individual crop. This aspect is particularly important in the case of phosphorus where the percentage of utilization of phosphorus by the crop to which it is applied is rather low and where there is considerable residual effect. Considerable amount of research work has been carried out in India to increase the efficiency of applied phosphorus by crops. Broadly speaking research efforts have been directed towards (a) management of fertilizer phosphorus in a cropping system and (b) phosphorus fertilization in low land paddy.

Some of the salient works in this field are reviewed here under.

2.1. Physico-chemical properties of rice soils

Because rice is grown primarily in a lowland (paddy) soil, the physical properties of the soil are relatively unimportant as long as sufficient water is available (Kawaguchi and Kyuma, 1977).

In submerged and completely saturated paddy profiles all pores are filled with water so that aeration is drastically or totally curtailed. The water in the soil also referred to as soil moisture constitutes the soil solution. Considerable characterization of low land rice soils is done by determining the kinetics of nutrient elements in the soil solution (Ponnamperuma, 1978).

The productivity of low land rice soils is heavily dependent on soil fertility or the chemical nature of the soil. Soil tilth which is considered highly important for an upland crop is generally considered unimportant for low land rice. However, there are a number of physical properties of soil that are of importance for growing rice or for rice based cropping system (De Datta, 1981).

2.2. Phosphours transformation in rice soils

Many workers have reported that the behaviour of phosphate in water logged soils is remarkably different from that in upland soils. The unique soil conditions created by water logging influence the transformation and availability of both native and applied fertilizer phosphate.

The suggestion that submergence of a soil causes an increase in the solubility of phosphate was first made by Bartholomew (1931) who observed that Arakansas rice showed no response to phosphate fertilizers even in soils low in phosphate.

The mechanism of phosphate release in a flooded soil may be explained by (1) reduction of insoluble ferric phosphate to more soluble ferrous phosphate (Islam and Elahi, 1954). (2) release of occluded phosphate by reduction of hydrated ferric oxide coating (Chang and Jackson, 1958). (3) displacement of phosphate from ferric and aluminium phosphate by organic anions (4) hydrolysis of ferric phosphate and (5) anion exchange between clay and organic anion (Russell, 1962).

Mosi et al. (1973) concluded that lowland rice was not likely to respond to the addition of phosphatic fertilizers as upland crops which may be due not so much to a lower nutritional requirement for phosphours but due to the release of soil phosphorus under submerged conditions. Bedrna (1974) observed that in acid soils 90 per cent of the applied superphosphate was transformed into Al-P and Fe-P, but in neutral and calcareous soils only 50 per cent of the applied phosphours was transformed into these forms.

Korableva (1974) observed that Fe-P and Al-P are the predominant fractions in acid flood-plain soils. Between 60 and 65 per cent of the phosphorus applied as dicalcium phosphate is fixed in the form of sparingly soluble iron phosphates.

Gupta and Singh (1977) observed that the poor response of rice to applied phosphorus was attributed to the increase in labile phosphorus during flooding.

2.3. Uptake of phosphorus by rice plant.

Mehrotra et al. (1968) found that the rate of phosphorus absorption continued to increase throughout the growth period. Naphade (1969) reported that the rate of phosphorus absorption was much higher at 40 to 90 days after transplanting than at other period.

Ali and Korachon (1973) reported that in field experiments the uptake of phosphorus by rice plants was higher at the early stages of growth. Throughout the crop growth total uptake of phosphorus was greater under submerged conditions. Muthuswamy et al. (1973) found that 50 per cent of the total requirement of phosphorus was absorbed between panicle initiation and flowering. Alexander et al. (1974) observed that there was a gradual increase in the phosphorus uptake from maximum tillering to flo erin_ sto_ and then a ... d increase fro.. flo ... , to harv. t.

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2.... Role o phosphorus on rice

2. .1. Effect of pho.phorus on growth characters.

2.4.1.1. Plant height

...nivasalu and ...ar (1965) reported that phosphorus has no effect on the plant height at any of the growth stages.

Nair *et al.* (1972) observed that plant height was unaffected by phosphorus application. Alexander *et al.* (1973) reported that phosphorus had no influence on plant height. Kalyanikutty and Morachan (1974) reported that phosphorus did not have any marked effect on the height.

2.4.1.2. Tiller number

Mohankumar (1967) reported that phosphorus application increased tiller production. Nair (1968) also reported similar results. Nair and Pisharody (1970) reported that tillering was markedly influenced by phosphorus application.

Alexander *et al.* (1973) reported that phosphorus had no effect on the number of tillers per hill. Kalyanikutty and Morachan (1974) reported that phosphoric acid did not seem to have any marked effect on the number of tillers. Shiga (1976) reported that in rice tiller number increased until the P content reached about 0.8 per cent P_2O_5. Suseelan *et al.* (1977) reported that phosphorus had no effect on tiller production.

2.4.2. Effect of phosphorus on yield attributes.

2.4.2.1. Productive tillers and panicle

Place *et al.* (1970) reported that the number of panicles were increased with increase in levels of phosphorus. Nair *et al.* (1972) reported that the number of productive tillers per hill was highly influenced by the phosphorus application. Bhattacharya and Chatterjee (1978) reported that application of P aided early tillering which resulted in more panicle bearing tillers.

Alexander *et al.* (1973) found that application of different levels of phosphorus did not have any positive effect on the percentage of productive tillers. Sadanandan and Sasidhar (1976) also observed that increasing rates of applied P had no significant effect on the number of productive tillers per hill.

2.4.2.2. Number of grains per panicle

Aaron *et al.* (1971) reported that increased dressing of phosphorus increased the number of grains per panicle. Singh and Varma (1971) reported an increase in the number of grains per panicle with higher bates of phosphorus application. Sasaki and Wada (1975) reported that low levels of phosphorus increased the percentage of sterile grains and can be altered by the level of applied phosphorus.

Alexander *et al*. (1973) reported that the grain number/panicle was unaffected by phosphorus application. Kalyanikutty and Morachan (1974) showed that phosphoric acid did not have any marked effect on the number of grains. Sadanandan and Sasidhar (1976) found no significant effect on the number of filled grains per panicle with increased rates of applied phosphorus. Suseelan *et al*. (1977) reported that phosphorus application did not significantly influence the percentage of filled grain.

2.4.2.3. Thousand grain weight

Majumdar (1971) observed that thousand grain weight was increased with increase in phosphorus application. Thandapani and Rao (1976) reported that phosphorus levels increased the thousand grain weight. Chowdhury *et al*. (1978) reported that thousand grain weight increased with increasing P application.

Place *et al*. (1970) recorded a decrease in thousand grain weight with increase in levels of phosphorus. Alexander *et al*. (1973) observed that different levels of phosphorus did not have any positive effect on the thousand grain weight. Rao *et al*. (1974) reported that the thousand grain weight was not significantly influenced by the levels of phosphorus. Kalyanikutty and Morachan

(1974) observed that phosphoric acid did not have any marked effect on the thousand grain weight.

2.4.3. Effect of phosphorus on yield

2.4.3.1. Grain yield

Khatua and Sahu (1970) reported that application of 40 kg phosphorus per hectare resulted in increased paddy yields compared to no phosphorus application. Majumdar (1971) also observed increase in paddy yields with incremental doses of phosphorus application. Increase in grain yields with phosphorus application was also reported by Kalyanikutty and Morachan (1974). According to Gopalakrishnan et al. (1975) grain yield was influenced by phosphorus application. Choudhury et al. (1978) reported that phosphorus application influenced paddy yield significantly. Ittiyavarah et al. (1979) reported that yields were adversely affected by omitting the application of phosphorus in alternate years. Shiota et al. (1980) observed that without phosphorus yields were reduced by 40 - 50 per cent.

Sood et al. (1969) reported that grain yields were not significantly affected by phosphorus application. Sundaram et al. (1969) reported that there is little or no response to P_2O_5 in the presence of higher doses of nitrogen. Loganathan and Raj (1971) reported that yields of paddy were not affected by the application of phosphorus. Studies conducted by Rajendran *et al.* (1971) showed that there was lack of significant response to phosphorus at all centres with medium to medium high available phosphorus status. No significant effect on grain yield was observed by the application of different levels of phosphorus by Alexander *et al.* (1973).

Sadanandan and Sasidhar (1976) observed that there was no significant difference in the yield of grain due to various levels of phosphatic fertilizers. Suseelan *et al.* (1977) revealed that the grain yield was not influenced by phosphorus application. Krishnamoorthy et al. (1979) reported that in rice cultivar IR-20, out of 12 crops tried, applied phosphorus increased the yield of only six crops.

Dargan *et al.* (1980) reported that applied phosphorus had no effect on the grain yield. The results of 20 field trials by Rojas and Alvardo (1982) revealed that phosphorus had no effect on the yield.

2.4.3.2. Straw yield

Place *et al.* (1970) observed that increasing phosphorus application increased straw yield but decreased the plant height. Gupta *et al.* (1975) obtained higher straw yield with 60 ppm phosphorus. Singh and Prakash (1979) reported that the crop showed significant response to phosphorus application. Sinha et al. (1980) also reported increase in straw yield with phosphorus application.

However, Loganathan and Raj (1971) reported that straw yields were not affected by the application rates of phosphorus. Alexander et al. (1973) observed no significant effect on straw yield by the application of different levels of phosphorus. Sadanandan and Sasidhar (1976) found that increasing the rate of applied phosphorus had no significant effect on the yield of straw. Grain and straw yield were not influenced by phosphorus application as observed by Suseelan et al. (1977)

2.4.4. Effect of phosphorus on the uptake of major nutrients

Mohankumar (1967) observed a decrease in nitrogen content with increase in phosphate application in rice. Varma (1971) reported that N uptake in grain and straw increased with increasing rates of both N and P. Singh and Prakash (1979) found that the application of P increased the uptake of N significantly over control. Agarwal (1980) recorded an increase in the uptake of nitrogen from 34.2 to 51.8 kg from 0 to 180 kg doses of phosphorus application up to tillering stage.

Kalyanikutty and Morachan (1974) concluded that increased application of P_2O_5 did not have any influence on the nitrogen content in the plants.

Mohankumar (1967) observed an increase in the phosphorus content with increase in the rates of phosphorus application.

Terman and Allen (1970) reported that the percentage of plant phosphorus from labelled fertilizer and the uptake of fertilizer phosphorus increased in all situations with the amount of applied phosphorus and decreased with increase in soil phosphorus level.

Alexander et al. (1974) reported that the effect of different levels of phosphorus was not significant in increasing the phosphorus uptake by the plant at any of the growth stages. Suseelan et al. (1978) reported that there was significant increase in the uptake of phosphorus by the plant with increasing levels of phosphorus.

Singh and Prakash (1979) reported that P application brought about increased uptake of P. Rastogi et al. (1981) showed that increasing levels of applied phosphorus increased the total phosphorus uptake and fertilizer phosphorus uptake, but decreased available phosphorus uptake and utilization percentage of the applied phosphorus at tillering, flowering and maturation.

Loganathan and Raj (1972) reported that levels of phosphorus did not influence potassium uptake by grain. Thandapani and Rao (1974) found that applied phosphorus had no effect on the potassium content of plants and grain. Agarwal (1978) found that increase in the uptake of N, P and K was highest with applied N followed by P and K. Singh and Prakash (1979) reported that addition of P was beneficial for K uptake and a consistent increase in K uptake was observed upto 80 kg P_2O_5/ha. Agarwal (1980) reported that increase in the potassium uptake was from 35.5 to 129.9 kg/ha due to phosphorus application.

2.5. Role of phosphorus in cowpea

2.5.1. Effect of phosphorus on growth

Steward and Reed (1969) pointed out that in cowpea, plant growth was significantly increased by increased application of P_2O_5. The response of cowpea to different P levels was studied by Malik et al. (1972) and he observed that forage production increased with increasing levels of P upto 90 kg P_2O_5/ha. No effect on greenmatter and drymatter yield of cowpea by increased application of P was noticed by Sundaram et al. (1974)

Vegetative growth of cowpea was studied at three phosphorus levels and it was noted that increasing level of applied P enhanced growth and increased flower, leaf number and leaf area (Tarila et al. 1977).

2.5.2. Effect of phosphorus on yield

Singh and Lamba (1971) studied the effect of three levels of P_2O_5 on cowpea and found that highest yield of cowpea was obtained with 45 kg P_2O_5/ha. Johnson and Evans (1975) observed that cowpea yield was not affected by P application in soils where the P content was higher. Subramanian et al. (1977) found increased number of pods per plant and number of grain 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/plant pod length and 100 grain weight) and grain yield in cowpea.

2.5.3. Effect of phosphorus on nutrient uptake

Iswaran et al. (1969) reported that plant uptake of total P, fertilizer P and soil P were significantly higher in inoculated plants of *Vigna sinensis*, *Phaseolus aureus* and *Phaseolus mungo* by the application of 80 kg P_2O_5/ha.

Sahu and Behera (1972) reported that in cowpea, nitrogen content in shoot and grain increased significantly by P manuring at the rate of 22.4 kg/ha. In cowpea, application of 50 kg P_2O_5/ha increased the uptake of phosphorus. (Sharma et al. 1974). Rollin Bhaskar (1979) observed that the uptake of N, P and K in greengram was higher with increased levels of phosphorus.

2.5.4. Effect of phosphorus on soil fertility status

Khare and Rai (1968) showed that in a few leguminous crops like soyabean, cowpea, dhaincha, mung and urid, application of P increased nitrogen content of soil significantly. Garg et al. (1970) from trials conducted with cowpea indicated that P application at the rate of 37, 74 or 111 kg P_2O_5/ha caused increases in residual nitrogen and phosphorus contents in soil. Sahu and Behra (1972) observed that application of phosphorus (22.4 kg/ha) increased the soil nitrogen content by 58, 29 and 20 per cent over control in crops of cowpea, groundnut, greengram respectively. Application of P_2O_5 to legumes at the rate of 35 and 70 kg P_2O_5/ha increased the nitrogen content of the soil significantly. The nitrogen content of the soil with 70 kg P_2O_5 was significantly higher than that with 35 kg P_2O_5/ha (Chundawat, 1972). Sharma and Yadav (1976) reported that in field experiments conducted with gram, the available P_2O_5 content of soil increased with the addition of P_2O_5 upto 34.8 kg/ha in 1972-73 and 52.2 kg in 1973-74.

2.6. Role of phosphorus on sesamum

2.6.1. Effect of phosphorus on plant growth

Ramirez et al. (1975) found that placement of phosphorus increased plant height in sesamum. Rahman et al. (1978) also indicated that the number of branches per plant in safflower increased with increased levels of P. According to Bariy et al. (1978) increase in the rate of P application, increased height of plant in sesamum. Ramirez et al. (1975) reported that application of 30 kg P_2O_5/ha placed along with seed ., 4 and 6 cm below it increased the drymatter of sesame. Wiedenhoren and Caracaro (1975) reported that P applied in band 2-4 cm below seed increased height and dry matter of sesame. Daulay and Singh (1980) noticed a linear increase in dry matter production with an increase in P level. Jalaludeenkutty (1985) reported that P and K along with N had a positive effect on dry weight of plants. Raveendran Nair (1987) reported that applied phosphorus could extent significant influence on the number of leaves per plant in all stages of growth of sesamum. Phosphorus had significant influence on leaf area index at 40 and 60 days after sowing and on total dry matter production at all stages of growth.

2.6.2. Effect of phosphorus on yield and yield attributes

Rahman *et al.* (1978) found that the number of head of safflower increased with increased level of application of P and obtained maximum heads with the application of 30 kg P_2O_5/ha. Girija Devi (1985) reported that there was significant influence for P on weight of pod/plant, number of seed/plant, 1000 seed weight and finally the seed yield of sesamum. Jalaludeenkutty (1985) also reported significant influence with P on 100 seed weight of sesamum.

Rai and Srivastva (1968) conducted trials in sesamum on red loam soil and found that there was not much response to P application with respect to seed yield. Geur and Trehan (1973) found that seed yield was higher with 50 kg P_2O_5/ha in Kherif season in sesamum. Gouda (1974) pointed out that seed yield was highest with 20 kg P_2O_5/ha (1.44 t/ha). Singh and Kaushal (1975) studied the response of rainfed sesamum to fertilizer levels and found that application of 50 kg P_2O_5/ha along with N increased yield from 431 kg/ha to 617 kg/ha.

Sennaiyan and Arunachalam (1978) pointed out that application of 25 kg P_2O_5/ha to gingelly variety TMV-3 gave highest yield.

Kachapur *et al.* (1979) reported that average seed yield of 405 kg/ha was obtained with 60 kg phosphorus in sugar compared to 22.5 kg without fertilizer. Sandanandan and Sasidhar (1979) reported that seed yield of sesamum variety Kayamkulam-1 grown in red loam soil was significantly influenced by P application at the rate of 0-55 kg/ha. Maiti *et al.* (1981) pointed out that seed yield of six sesamum cultivars was increased by the application of P at the rate of 40 kg/ha. Girija Devi (1985) pointed out that application of P significantly increased the seed yield.

2.C.3. Effect of phosphorus on the uptake of nutrients

Ramirez *et al.* (1975) reported that P uptake was highest where the P was placed 2 or 4 cm below seed. Regression coefficient calculated for P uptake and dry weight was significant indicating the effect of P on the growth component. Vir and Verma (1979) conducted trials on phosphorus content and their uptake in rainfed mustard and found that application of P_2O_5 @ 30 kg/ha increased seed P content and uptake of N and P. Girija Devi (1985) reported that P uptake was increased significantly with applied P and highest uptake was recorded with highest level of P.

2.7. Phosphorus availability in rice based cropping system

Rotation of rice and upland crops is one of the important cropping systems in rice producing countries of the tropics. In the rotation of rice and upland crops the soil undergoes alternate submergence and drying and as such the soil P status is also changed considerably during these processes. Several studies have been conducted on the change of soil P during the conversion from dryness to submergence of soil (Mahapatra and Patrick, 1969; Islam, 1970; Mandal and Khan, 1972; Gupta and Kamal Nayan, 1975; and Singh and Ram, 1976). Excellent review articles were also brought out on this aspect by reputed scientists. (Patrick and Mahapatra, 1968; Ponnamperuma, 1972 and Mandal, 1979). The transformation resulting from alternation of dryness and submergence induces an increased availability of soil P. Goswami and Banerji (1978) considered the cause of this increase to be due to (i) release of P from organic P (ii) increase in solubility of P resulting from decreased soil pH due to the accumulation of CO_2 in calcareous soil (iii) reduction of $Fe PO_4 . 2H_2O$ to $Fe_3(PO_4)_2 8 H_2O$ with higher solubility (iv) higher solubilities of $Fe PO_4 . 2 H_2O$ and $Al PO_4 . 2 H_2O$ resulting from hydrolysis due to the increase of soil pH in acid and strongly acid soils (v) release of phosphate ions from the exchange between organic anion and phosphate ions in Fe, Al phosphates and (vi) increased diffusion of P under submerged conditions.

It is generally known that factors that may increase the availability of P disappear with the change in soil condition from reduction to oxidation. However, some investigators have also found that this process can increase the availability of soil P (Savant et al. 1970). In this case the increase in available P may result from the mineralization of organic P in soil while the availability of iron and aluminium phosphate may be decreased.

It is clear that in a rice based cropping system including upland crops, the soil P availability pattern changes. Increase in P availability occurs with submergence and when soil changes to the dry upland condition P availability may be decreased.

2.8. Direct effect of phosphorus on growth and yield of system components.

On high P fixing soils a lower dose might not give a response and the soil hunger remains. In acute P deficient areas response to P alone has been comparable or even better than that to N at equal rates of application. Supply of P to crops is usually made through the medium of soils and it is met from the P present in the soil and that supplied by the applied phosphate fertilizer the adequacy or deficiency of the former for crop production determines the need of the latter (Goswami, 1975).

De Datta and Gomez (1975) reported that when one rice crop per year was grown with adequate N, response to P might be marginal, but response might become marked under intensive rice cultivation. Patel (1975) observed that low land rice soils (Sandy loam to sandy clay loam) have low P fixation capacity and on submergence the availability of native P increased and showed significant correlation with P uptake by rice though there was no response for fertilizer P on grain yield and P concentration in grain. Pathak et al. (1975) observed a low response of applied P by rice crop. This is primarily because of the submerged condition obtained in rice which makes the Fe-P and occluded P available to rice crop. Application of P aided in early tillering capacity and early tiller gave more panicle and percent of filled spikelets in rice (Bhattacharya and Chatterjee, 1978). Response of crops to P application in India has been reviewed by Kanzaria (1979) Meelu et al. (1979) and Venkata Rao and Subba Rao (1979). Kanwar et al. (1982) observed that to produce 6 t/ha of grain yield, a rice crop removed about 60 kg P_2O_5.

Matzel (1982) proved that P deficiency during the period of tillering of cereals resulted in a reduction of the number of ear bearing culms and grain yield. From tillering to shooting cereal plants set high demands to the relative P uptake under field conditions.

Joshi (1974) reported that the utilization of applied P in a wheat-rice cropping system is more when phosphate is applied to wheat than to rice. Prasad and De (1975) at IARI reported the results of a three year experiment involving a multicrop system of 3 crops in a year namely wheat-moong-bajra and concluded that if 60 kg P_2O_5/ha were the annual budget the entire quantity would go to wheat and if 90 kg P_2O_5/ha, it would be equally divided between moong and bajra crops in the sequence.

In the agronomic studies on fertilizer phosphorus requirements of fixed crop rotation, Goswami and Singh (1976) found that in kharif rice-rabi rice cropping system data over three to four years available from seven centres of which at four centres, application of fertilizer P to any or both the two crops seemed to be of doubtful utility. At the rest three centres, application of P at 60 kg P_2O_5/ha to only one crop (either kharif or rabi) appeared to be adequate. In rice-wheat system, results from seven centres showed that fertilizer P used to be applied to only one crop in the sequence.

Tandon (1976) observed that the removal of P by the first crop necessarily does not exceed 10-20 per cent of the added P and the rest stays on the soil. In a rice based multiple cropping experiment conducted at Coimbatore (Purushothaman, 1979) the yield data revealed that reducing the fertilizer application to each crop to 50 per cent of the recommended level caused a considerable reduction in the yield of all the crops, cereals being the most affected. However, application of N to each crop and P and K only to summer upland crops gave similar yields as application of recommended level of NPK to each crop. Thus P can be restricted to only the summer crops saving about 100 kg P_2O_5/ha/year. Venkateswarlu and Bhaskara Rao (1979) pointed out that slow growing deep root crop (castor) respond less to P while shallow rooted quick growing cereals (Sorghum, pearlmielet) require higher doses of P. Similarly if a legume (Cowpea) is taken up as the first crop in sequence all PO_4 for the system to be applied to cowpea while the N would be supplied to the planting cereal with reduced phosphate dose.

Fertilizer use in rice-rice cropping system was recorded by Mahapatra et al.(1981) from the results of field studies conducted in different centres in India under the All India Co-ordinated Agronomic Experiments Project (AICAEP). In a double crop system with modern to the preceeding wheat crop. Thus application of P fertilizer (26 kg P/ha) to wheat only was sufficient to meet the requirement of both crops. Datta and Gupta (1984) reported that in acid soils of Nagaland, both wheat and rice responded to P application. Dhingra et al. (1984) from their four year study on maize-wheat, bajra-wheat, groundnut-wheat and greengram-wheat cropping systems under Punjab conditions observed that wheat responded significantly to direct P application. In wheat-rice, wheat-maize-rice and berseem-rice cropping systems, Rekhi and Meelu (1984) found that rice didinot respond significantly to direct P application in all the three rotations. Singh et al.(1985) got a direct differential response of 3.9 and 7.3 q/ha due to 30 kg and 60 kg P_2O_5/ha in rice. The response per kg of P showed declining trend as its level increased in the direct series.

It is generally accepted that response to applied P is lesser than the applied crops. This is primarily because of the submerged conditions obtained in rice which make the Fe-P and occluded P available to rice crop. On the contrary under upland condition there is likely to be more response to P application if the soil is low or medium with regard to available P content. Hence in a multiple cropping system, it is only rational to apply the nutrient to the most responding crop (Palaniappan, 1985) to the preceeding wheat crop. Thus application of P fertilizer (26 kg P/ha) to wheat only was sufficient to meet the requirement of both crops. Datta and Gupta (1984) reported that in acid soils of Nagaland, both wheat and rice responded to P application. Dhingra et al. (1984) from their four year study on maize-wheat, bajra-wheat, groundnut-wheat and greengram-wheat cropping systems under Punjab conditions observed that wheat responded significantly to direct P application. In wheat-rice, wheat-maize-rice and berseem-rice cropping systems, Kokhi and Meelu (1984) found that rice didnot respond significantly to direct P application in all the three rotations. Singh et al. (1985) got a direct differential response of 3.9 and 7.3 q/ha due to 30 kg and 60 kg P_2O_5/ha in rice. The response per kg of P showed declining trend as its level increased in the direct series.

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2.9. Residual effect of phosphorus on growth and yield of system components.

Mikhailina (1972) observed marked residual effect of P carried from preceeding crops on wheat, barley, pear and soyabean.

Sekhon (1974) in view of the large residual response to fertilizer P and the observation that alternate application of phosphorus to kharif and rabi crops was nearly as good as its application to both advocated the use of fertilizer P to be limited to only one crop in the rotation.

Singhania and Goswami (1974) reported that there was little residual effect on wheat of the P applied to the preceeding rice crop and suggested that in rice-wheat sequence, the fertilizer P be applied to wheat only taking advantage of the residual effect on rice. This might have been suggested for 3 reasons (a) wheat removes higher amount of fertilizer P than rice (b) wheat could not utilize the residual P in the form of Fe-P which was the major transformation product of P after rice and (c) rice could utilize Fe-P besides Al-P.

In field trials with double cropping of rice and barley, application of P to rice gave no response in the succeeding barley (Chang et al. 1976). Srivastava and

Pathak (1976) reported that total response to P in a paddy-gram cropping sequence was higher when P fertilizer was applied to gram crop and the residual amount of P was utilized by the succeeding paddy crop as compared to its application to paddy crop and obtaining residual effect on gram crop.

Ramamoorthy and Bisen (1977) also observed that rice had a greater capacity than wheat to extract P from Fe-P. In this context the results obtained by Gupta and Virmani (1974) are interesting. They determined the surface activity (isotopically exchangeable) of inoriganic P fractions viz., Al, Fe and Ca-P in about 45 paddy soils of Haryana growing mainly rice-wheat in sequence and obsefved on an average 58% of the Al-P was isotopically exchangeable with added ^{32}P while that of Fe-P was 64% and Ca-P 11% only.

Rao and Bharadwaj (1980) investigated the response of greengram to residual fertility of nutrients applied to maize and wheat in the previous seasons. Haulm and grain production of green-gram was improved on account of the residual effect of fertilizers supplied at higher levels to wheat grown in the preceeding rabi season. Fertilization of maize in the kharif season with similar higher levels also carried sufficient residual fertility showing that in a cereal-cereal-legume-sequence, the legume is benefitted from the P applied to the preceeding crops. Chahal (1983) stated that while crops in the colder rabi season (wheat-rabi rice) benefitted more from a direct application of P, crops in the warmer kharif season (rice, sorghum, pearl millet, maize) could use the residual P more efficiently. Similar findings were obtained by Gill and Meelu (1983 a and 1983 b). Datta and Gupta (1984) however, obtained significant residual effect of P on wheat in a wheat-rice sequence.

In rice-wheat system in the alluvial soils of Ludhiana, in rice-rice-system in medium black soils of A.P. and in red and yellow soils of Orissa, studies have shown that P applied to the rabi crop had great residual effect and that fertilizer P need not be applied to the kharif crop (Meelu and Moris 1984). Such observation were reported by Rekhi and Meelu (1984) in wheat-rice, wheat-fodde maize-rice and berseem-rice system. Biswas et al. (1985) also observed that in potato-jute-rice sequence P application to potato alone was sufficient. Singh et al. (1985) obtained a residual response of 1.3 and 4.0 q/ha to P in rice. The response per kg of P showed increasing trend as its level incresed. Dahama and Sinha (1985) obtained marked residual effect of P applied to preceeding legumes on wheat grain yields. In pot trials with a wheat/greengram/

rice sequence 30, 60 or 90 kg P as diammonium phosphate/ha was applied to wheat and its residual effect on the two subsequent crops was studied. Dry matter yield, P uptake and the residual P uptake in both crops increased with increasing P rates. The average utilization of the applied P by the cropping sequence was 21.42% of which 11.85%, 4.83% and 4.73% were utilized by the Ist, 2nd and 3rd crops respectively. (Kundu et al. 1986).

2.10. Cumulative effect of phosphorus

Gill and Meelu (1983 b) observed that rice and wheat constitute a common cropping sequence. Rice did not respond to direct application of 60 kg P_2O_5/ha, but wheat did. Application of P to both rice and wheat gave no extra yield indicating absence of a beneficial cumulative effect. In a four year study on Maize-wheat, bajra-wheat, groundnut-wheat and mung bean-wheat cropping system under Punjab conditions, Dhingra et al. (1984) reported that cumulative effect of residual and direct phosphorus doses of 30- 60 kg P_2O_5/ha to kharif and wheat crops respectively was equal to 60+60 and 60+30 combinations. Chaudhary and Bathla (1985) reported a cumulative yield response of 11.86 q/ha of wheat grain in Pearmillet-what sequence which was much higher than that obtained with direct or residual effects. Singh et al. (1985) observed cumulative

Prasad and De (1975) at IARI reported results of a two year experiment involving a multicrop system of three crops in a year namely wheat-moong-bajra and concluded that if 60 kg P_2O_5/ha were the annual budget, the entire quantity should go to wheat and if 90 kg P_2O_5/ha were available, the extra 30 kg P_2O_5/ha could be equally divided between moong and bajra crops in the sequence.

The fertilizer need of a crop in a cropping system mainly depends upon the characteristics of the preceeding crop and kind and qualities of fertilisers applied to them. Inclusion of a legume in a crop rotation helps in improving the soil fertility resulting in higher yield of the suceeding crop as compared to preceeding exhaustive cereal crops (Tiwari et al. 1980). Plant species have different capacities to use native and applied P and the residual effect of applied P will also differ. Therefore attempts are being made to recommend a dose of fertilizer for a cropping system rather than one crop. It is also an advantage with the phosphate that applied amount of P is not lost out but remains in the soil. Efficient fertilizer management is possible with greater understanding of direct, residual and cumulative effects on different crops grown in sequence.

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MATERIALS AND METHODS

3. MATERIAL AND METHODS

Field experiments were conducted to develop an appropriate phosphorus management practice in a rice based cropping system involving rice-rice-legume/non legume from June 1984 to September 1986. The various materials used and the methods followed are given below.

3.1. Materials

3.1.1. Field location

The experiments were laid out in the rice fields of the Instructional Farm, College of Agriculture, Vellayani. The Instructional Farm is located at a latitude of 8° N and at an altitude of 29 metres above mean sea level.

3.1.2. Soil

The soil of the experimental area belongs to the textural class of sandy clay loam, medium in available nitrogen, medium in available phosphorus and medium in available potassium. The details of the soil characteristics are given in Table 1.

3.1.3. Season

The experiment was conducted for seven seasons starting from the first crop season of the year 1984-85

Table 1. Soil characteristics of the experimental field

I. Mechanical Analysis

Coarse sand	(%)	- 49.2
Fine sand	(%)	- 24.9
Silt	(%)	- 7.3
Clay	(%)	- 25.7

II. Chemical Analysis

Available N (kg/ha)	- 488
Available P_2O_5 (kg/ha)	- 45
Total P_2O_5 (kg/ha)	- 725
Available K_2O (kg/ha)	- 230
pH (1:2 soil water suspension)	- 5.2

to the first crop season of the year 1986-87. The details of the seasons are as follows:

Year	I crop season (rice)	II crop season (rice)	III crop season (cowpea/sesamum
1984-85	June to September	October to January	February to May
1985-86	June to September	October to December	January to Apr
1986-87	June to September		

3.1.4. Climate

The tract enjoys a warm humid tropical climate and receives a good amount of rainfall through South-West and North-East monsoons. During the cropping period a total rainfall of 453 mm was received (in 40 days) for the first crop of rice, 389 mm (in 25 days) during the second crop of rice, 80.6 mm (in 17 days) during the third crop period of cowpea/sesamum, 414.8 mm (in 30 days) during the fourth crop of rice, 960.4 mm (in 37 days) during the fifth crop of rice, 352.2 mm (in 19 days) during the sixth crop of cowpea/sesamum and 270.4 mm (in 52 days) during the seventh crop of rice. The mean maximum and minimum temperatures were 29.8 and 23.5, 30.2 and 22.8, 32.8 and 23.7, 28.9 and 23.1, 30.8 and 22.6, 32.8 and 21.8 and 30.5 and 22.8°C respectively for the first, second, third, fourth, fifth, sixth and seventh crops. The meteorological data for the cropping period are presented in Figure 1 and in Appendix 1.

3.1.5. Cropping history of the experimental site

The experimental area was under a bulk crop of rice during all the previous seasons.

3.1.6. Crops and varieties

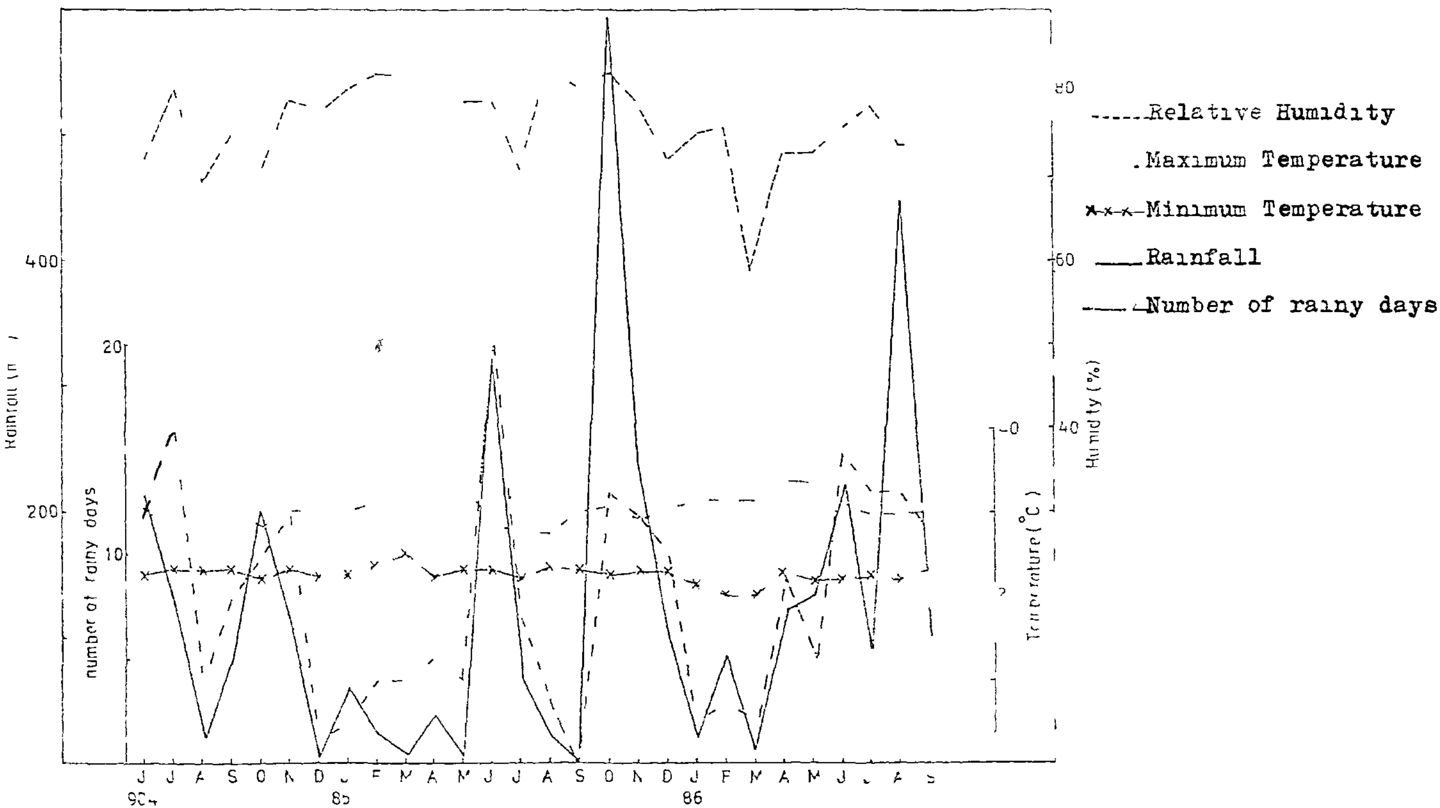
The rice variety used for the experiment (first, second, fourth, fifth and seventh seasons) was Triveni, a high yielding, photo-insensitive, short duration (90-100 days) variety. Triveni has been evolved at Rice Research Station, Pattambi by crossing the dwarf <u>indica</u> strain <u>Annapurna</u> to tall <u>indica</u> PTB-15. The cowpea and sesamum were raised during the third and sixth seasons. Cowpea variety used was <u>Kanakamony</u> (PTB-1). The sesamum variety used was Surya (KMV-2) which is a pure line selection from a West-Bengal type.

3.1.7. Fertilizers

Fertilizers with the following analysis were used for the experiment.

Urea	-	46% N
Super phosphate	-	16% P_2O_5
Muriate of potash	-	60% K_2O

FIG. 1 WEATHER PARAMETERS DURING THE CROPPING PERIOD



3.2.2. Experimental design and Layout

The experiment was laid out in a Randomised Block Design with three replications.

Gross plot size	-	5 x 4 m
Net plot size for rice	-	4.35 x 3.40 m
Net plot size for cowpea	-	4.0 x 3.0 m
Net plot size for sesamum	-	4.2 x 3.8 m
Spacing for rice	-	15 x 10 cm
Spacing for cowpea	-	25 x 15 cm
Spacing for sesamum	-	20 x 20 cm

During the first crop season of rice itself two identical plots of gross plot size 5 x 4 m each having the same treatment was formed in order to avoid disturbance while forming sub plots during the third crop season for raising both cowpea and sesamum under each treatment. For the rice crops and the third crops of legume (cowpea) and non legume (sesamum) the recommended doses of nitrogen and potassium for the respective crops for the respective seasons were applied uniformly, phosphorus was applied according to the treatments based on the package of practices recommendations of KAU. The rice-rice-cowpea/sesamum sequence was conducted for two years and a seventh crop of rice was taken to study the residual and cumulative effects.

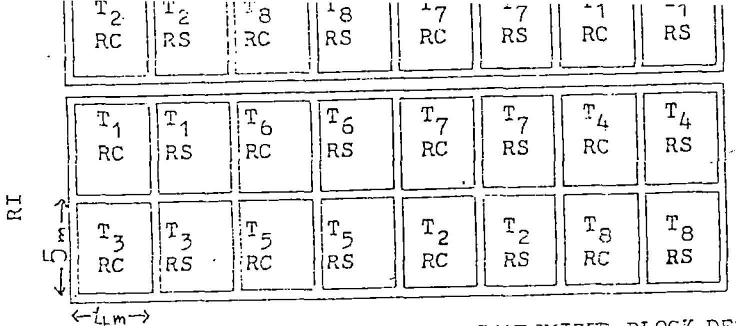
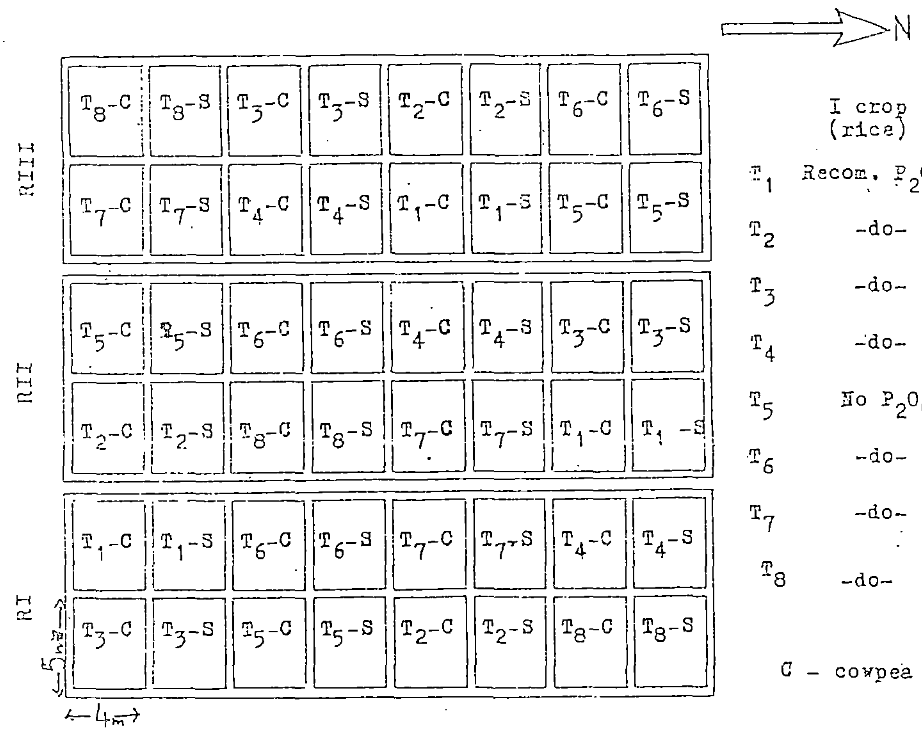


FIG. 4 FIELD LAY OUT PLAN - RANDOMIZED BLOCK DESIGN FIRST CROP OF RICE AFTER COWPEA AND SESAMUM

T_5	No P_2O_5	Recom. P_2O_5	Recom. P_2O_5
T_6	-do-	-do-	No P_2O_5
T_7	-do-	No P_2O_5	Recom. P_2O_5
T_8	-do-	-do-	No P_2O_5

RC - Rice after cowpea

RS - Rice after sesamum

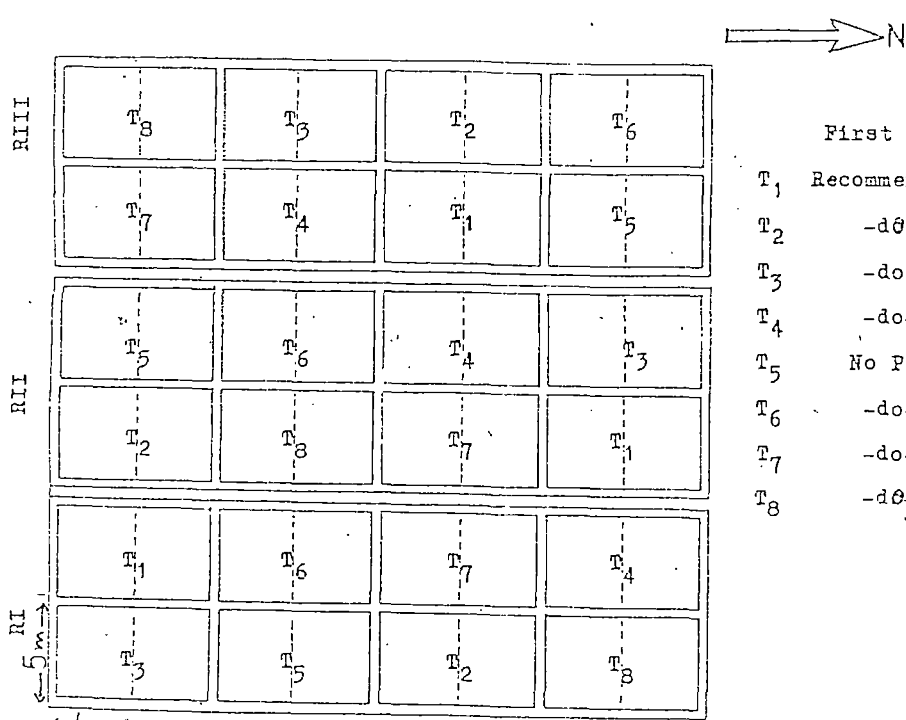


Treatments

	I crop (rice)	II crop (rice)	III crop (cowpea/sesamum)
T_1	Recom. P_2O_5	Recom. P_2O_5	Recom. P_2O_5
T_2	-do-	-do-	No P_2O_5
T_3	-do-	No P_2O_5	Recom. P_2O_5
T_4	-do-	-do-	No P_2O_5
T_5	No P_2O_5	Recom. P_2O_5	Recom. P_2O_5
T_6	-do-	-do-	No P_2O_5
T_7	-do-	No P_2O_5	Recom. P_2O_5
T_8	-do-	-do-	No P_2O_5

C - cowpea S - sesamum

FIG. 3 FIELD LAY OUT PLAN-RANDOMIZED BLOCK DESIGN-THIRD CROP OF COWPEA AND SESAMUM



Treatments

	First crop	Second crop
T_1	Recommended P_2O_5	Recommended P_2O_5
T_2	-do-	-do-
T_3	-do-	No P_2O_5
T_4	-do-	-do-
T_5	No P_2O_5	Recommended P_2O_5
T_6	-do-	-do-
T_7	-do-	No P_2O_5
T_8	-do-	-do-

FIG. 2 FIELD LAY OUT PLAN - RANDOMIZED BLOCK DESIGN

FIRST AND SECOND CROPS (RICE)

T_5	No P_2O_5	Recom P_2O_5	Recom P_2O_5
T_6	-do	-do-	No P_2O_5
T_7	-do	No P_2O_5	Recom P_2O_5
T_8	-do-	do-	No P_2O_5

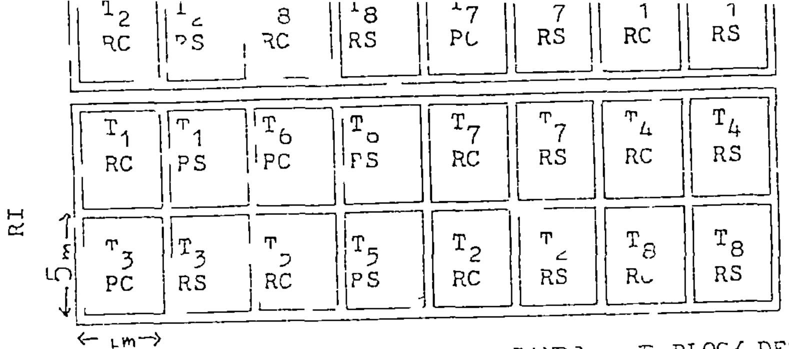
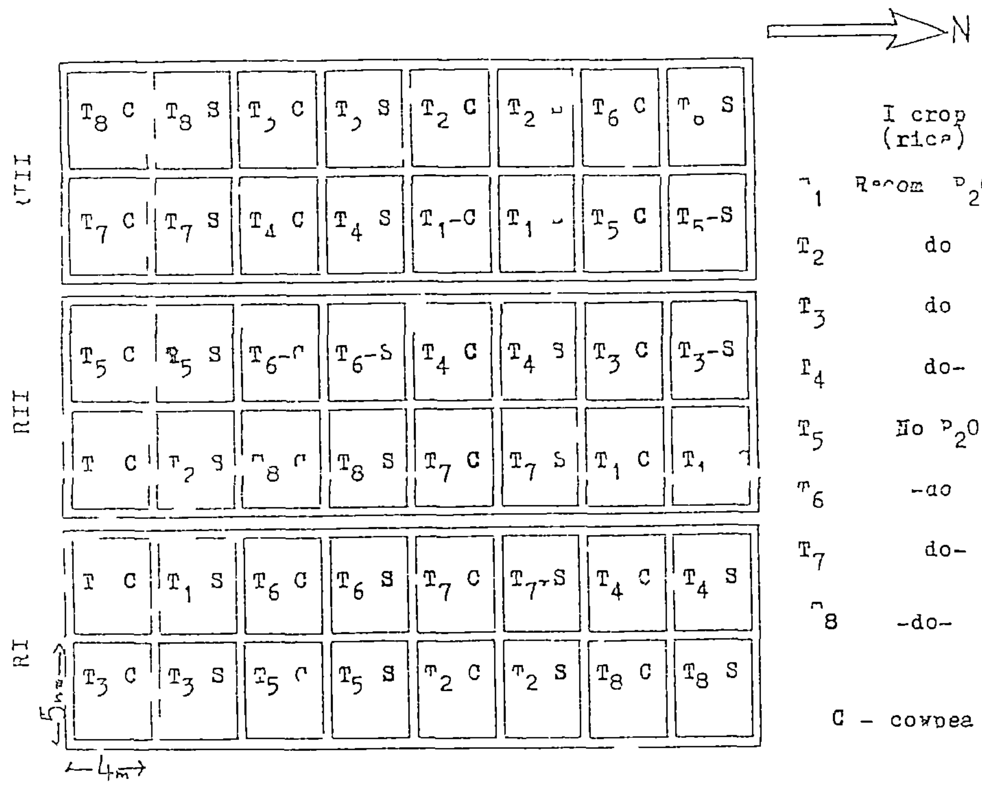


FIG 4 FIELD LAY OUT PLAN - RANDOMIZED BLOCK DESIGN
FIRST CROP OF RICE AFTER COWPEA AND SESAMUM

RC - Rice after cowpea
PS - Rice after sesamum

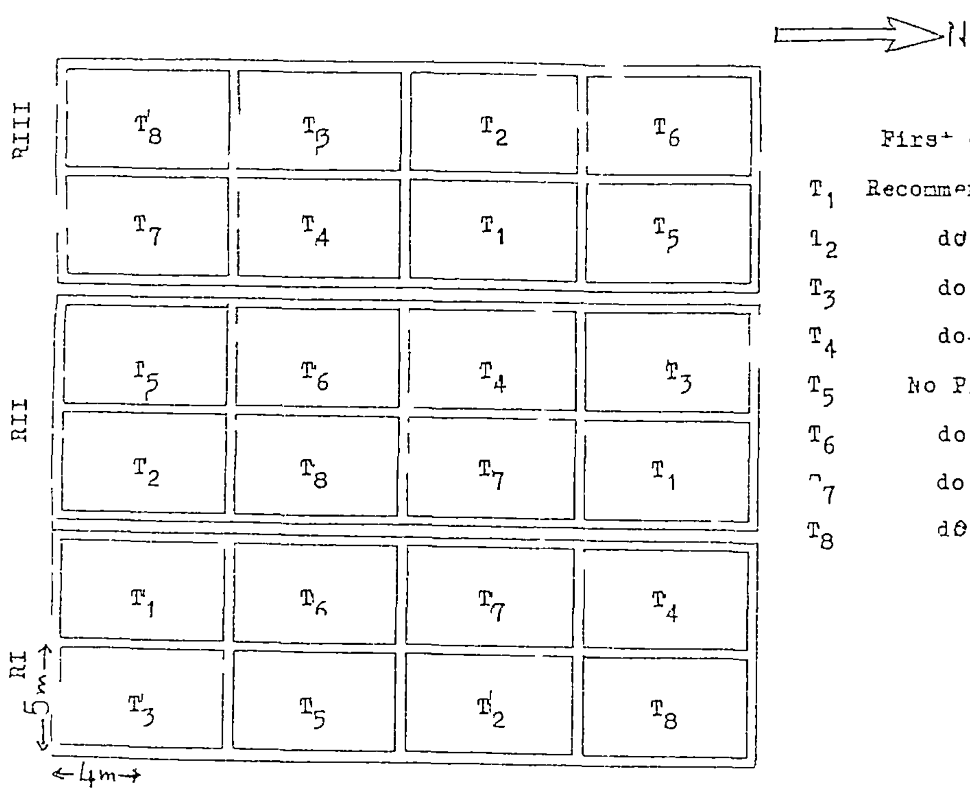


Treatments

	I crop (rice)	II crop (rice)	III crop (cowpea/sesamum)
T_1	Recom P_2O_5	Recom P_2O_5	Recom P_2O_5
T_2	do	do	No P_2O_5
T_3	do	No P_2O_5	Recom. P_2O_5
T_4	do-	do	No P_2O_5
T_5	No P_2O_5	Recom P_2O_5	Recom P_2O_5
T_6	-do	do,	No P_2O_5
T_7	do-	No P_2O_5	Recom P_2O_5
T_8	-do-	-do-	No P_2O_5

C - cowpea S sesamum

FIG 5 FIELD LAY OUT PLAN RANDOMIZED BLOCK DESIGN THIRD CROP OF COWPEA AND SESAMUM



Treatments

	First crop	Second crop
T_1	Recommended P_2O_5	Recommended P_2O_5
T_2	do	-do
T_3	do	No P_2O_5
T_4	do-	-do-
T_5	No P_2O_5	Recommended P_2O_5
T_6	do	do-
T_7	do	No P_2O_5
T_8	do	do-

FIG 2 FIELD LAY OUT PLAN RANDOMIZED BLOCK DESIGN
FIRST AND SECOND CROPS (RICE)

For the cowpea crop, the recommended dose of 20 kg N/ha and 10 kg K_2O/ha as urea and muriate of potash respectively were applied uniformly to all plots. 50% N and full dose of K_2O was applied as basal dressing and the rest 50% N at 20 days after sowing. Phosphorus was applied according to the treatments at the rate of 30 kg P_2O_5/ha as basal dressing.

For the sesamum crop the recommended dose of 30 kg N/ha and 30 kg K_2O/ha as urea and muriate of potash respectively were applied uniformly to all plots. 75% N and full dose of K_2O was applied as basal and 25% N at 30 days after sowing. Phosphorus was applied according to the treatments at the rate of 15 kg P_2O_5/ha as basal dressing.

3.2.5. Seeds and Sowing

For the first and second crop of rice, Triveni seeds obtained from the Instructional Farm, College of Agriculture, Vellayani were raised in wet nurseries and healthy seedlings of 20 days old were transplanted in the main field at 15 x 10 cm spacing. During the third crop season, cowpea seeds of variety Kanakamoni obtained from the State Seed Farm, Ulloor were treated with the appropriate rhizobium culture and dibbled in the field

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Adequate plant protection measures were taken as and when the occurrence of pests and disease was noticed according to the recommendations of the Kerala Agricultural University.

3.2.9. Harvest and threshing

For all the 3 crops, two border rows all around the plots, one line for destructive sampling and its adjacent line were discarded. The crop in the net plot area was harvested. The grain and straw yields were recorded separately from each net plot after threshing, drying and cleaning. The grain yields were recorded after reducing the moisture content to 14 per cent by sun drying. The straw was sundried and yield recorded.

In the case of cowpea harvesting was done twice by picking matured pods from the net plots. The picked pods from each net plot were dried, threshed and grains cleared and final plot wise yields were recorded.

The husk obtained from the net plots were weighed and recorded. The haulm from the net plot was also pulled out, sun dried for three days and weight recorded.

For the sesamum crop, the plants in the net plots were harvested separately, by cutting the root portion and stacked the plants in bundles for four days till the leaves fell off. They were then spread in the sun and beaten with sticks to break open the capsules. Repeated this for three days. The seeds obtained were cleaned and yield recordd. The bhusa weight was also recorded.

3.3. Biometric observations

Five plants from each net plot were chosen by random sampling and tagged. These plants were used for recording all biometric observations at different stages of crop growth as given below:

3.3.1. Growth components

The observation on growth characters for rice were taken at 30 day after transplanting, at flowering and at harvest. For cowpea at 20 DAS, flowering and at harvest, and for sesamum at 30 DAS, 50 DAS and at harvest.

3.3.1.1. Plant height

Plant height was measured in (cm) from the base to the growing tip of the plants.

3.3.1.2. Tiller number

The number of tillers (total and productive tillers) per hill was counted for rice crops.

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3.3.1.3. Number of leaves per plant for cowpea and sesamum

The total number of green leaves present were counte

3.3.1.4. Leaf Area Index (LAI)

Leaf area index was computed by measuring the total area using leaf area meter. For rice, the second top most tiller was selected and the area of leaves of the tiller was measured in a leaf area meter. This area is multiplied by the number of tillers in the hill which give the total leaf area per hill. From this leaf area index was calculated by the formula $\frac{\text{Leaf area}}{\text{Land area}}$ as suggested by Watson (1947).

For cowpea and sesamum, the total area of all the leaves in a plant were measured using the leaf area meter and LAI calculated as suggested by Watson (1947) by the formula $\frac{\text{Leaf area}}{\text{Land area}}$

3.3.1.5. Number of branches per plant

The number of primary branches were counted and recorded in the case of cowpea and sesamum.

3.3.1.6. Dry matter production

From the destructive row, plants were removed at various stages specified for each crop. These samples were first air dried and then over dried at 60°C to a contitant weight. Dry matter content was computed for each treatment and dry matter production worked out and expressed in kg per hectare.

3.3.2. Yield components of rice crops

3.3.2.1. Number of panicle per square metre

The total number of panicles from all the sample hills were counted and divided by the area occupied by the sample hills and recorded as number of panicles per square metre.

3.3.2.2. Number of filled grains/panicle

From each sample hill the centre or middle panicle was separated from the rest of the panicle. The grains from the central panicles from all sample hills were threshed and bulked. The filled grains were separated from the unfilled grains. The number of filled grains (A) were counted and weight of the filled grains was recorded (B) The grains from the rest of the panicles of all sample hills were threshed and filled grains were separated from the unfilled grains and weight of the filled grains (C) was recorded. Ther number of filled grains/panicle was calculated using the formula $\frac{A}{B} \times \frac{(B+C)}{D}$ where D is the total number of panicles. (Gomez, 1972).

3.3.2.3. Weight of 1000 grains

The 1000 grain weight was calculated using the formula $\frac{B}{A}$ x 1000 (Gomez, 1972).

3.3.3. Yield components of Cowpea/Sesamum

3.3.3.1. Number of pods/capsules per plant

The total number of pods/capsules produced by the sample plants were counted and the average recorded.

3.3.3.2. Length of pod

Ten pods were selected randomly from the sample plants, their length measured and average worked out and expressed in 'cm'.

3.3.3.3. Number of grains per pod

The total number of grains obtained from ten pods were counted and average worked out.

3.3.3.4. Thousand grain weight

100 grains obtained from the sample plants were counted and weight recorded in gram.

3.3.4. Yield

3.3.4.1. Grain yield

The grain yields of rice, cowpea and sesamum were

3.4.1.3. Available potassium

This was estimated by Ammonium acetate method (jackson, 1967) and expressed in kg K_2O/ha.

3.4.1.4. Total phosphorus

The total phosphorus was estimated by the perchloric acid digestion method (Jackson, 1967) and expressed in kg P_2O_5/ha.

3.4.2. Plant analysis

The plant samples removed for dry matter estimation were chopped and ground into fine powder in a willey mill. The powdered material was used for chemical analysis and to find out the uptake of major nutrients.

3.4.2.1. Nitrogen

The N content of plant samples was estimated by modified microKjeldahl method (Jackson, 1967) and uptake was estimated by multiplying the content with yield of dry matter and expressed in kg/ha.

3.4.2.2. Phosphorus

The P content of plant samples was estimated colorimetrically by Vanado-molybdo phosphoric yellow colour method (Jackson, 1967) and uptake was estimated as in the case of nitrogen and expressed in kg/ha.

3.4.2.2. Potassium

The K content was determined using Flame Photometer (Jackson, 1967) and uptake calculated as in the case of nitrogen and phosphorus and expressed in kg/ha.

3.5. Total grain yield for the rice-rice-cowpea/sesamum system

Total grain yield of first and second crop of rice after cowpea and sesamum (t/ha) and total grain yield for the rice-rice-cowpea/sesamum system in terms of kilocalories (grain equivalent) were computed and statistically analysed.

3.6. Economics

The gross and net return per hectare for each treatment based on the present market price of the produce and inputs were worked out. The benefit-cost ratio was calculated for different treatments by dividing the gross return by cost of cultivation. Economics was also worked out for the systems of rice-rice-cowpea and rice-rice-sesamum separately.

3.7. Statistical analysis

The data for the characters studied under different treatments were analysed statistically as per RBD and significance was tested by using 'F' Test. (Cochran and Cox, 1965). Important correlations were also worked out.

The analysis of net return, benefit-cost ration, total grain yield and grain equivalent were worked out for both the systems viz., rice-rice-cowpea and rice-rice-sesamum system separately as well as together (2 x 8 = 16 treatments) splitting the treatments into three components with respect to system, treatments and their interaction.

RESULTS

(iv) First crop of second year 1985-86
and first crop of third year
1986-87: First crop of rice after cowpea and sesamum.

4.1. Effect of phosphorus on the first crop of rice (Direct effect of phosphorus)

4.1.1. Growth attributes

4.1.1.1. Plant height

The observations on height of plants were recorded at 30 days after transplanting (30 DAT), at flowering and at harvest. The data on mean height are presented in Table 2.

The data revealed that phosphorus treatment did not have any significant influence on height at any of the growth stages.

4.1.1.2. Number of tillers per hill

The observations on tiller number were recorded at 30 DAT, at flowering and at harvest. The data on mean tiller number are presented in Table 3.

From the data it could be seen that there was no significant difference between the treatments at 30 DAT, flowering and at harvest.

Table 2. Height of plants of first crop of rice (cm)

Treatments	30 DAT	Flowering	Harvest
T_1	40.3	63.2	73.2
T_2	44.5	66.6	73.8
T_3	45.4	68.1	75.5
T_4	44.7	67.1	74.4
Mean (with P)	43.7	66.2	74.2
T_5	45.2	69.1	76.2
T_6	44.2	66.6	73.4
T_7	43.1	66.2	72.9
T_8	45.1	65.4	78.5
Mean (No P)	44.4	66.8	75.2
F_{test}	NS	NS	NS
SE	1.38	1.17	1.04

NS - Not significant.

Table 2. Height of plants of first crop of rice (cm)

Treatments	30 DAT	Flowering	Harvest
T_1	40.3	63.2	73.2
T_2	44.5	66.6	73.8
T_3	45.4	68.1	75.5
T_4	44.7	67.1	74.4
Mean (with P)	43.7	66.2	74.2
T_5	45.2	69.1	76.2
T_6	44.2	66.6	73.4
T_7	43.1	66.2	72.9
T_8	45.1	65.4	78.5
Mean (No P)	44.4	66.8	75.2
F_{test}	NS	NS	NS
S_	1.38	1.17	1.04

NS - Not significant.

Table 3. Number of tillers per hill of first crop of rice.

Treatments	30 DAT	Flowering	Harvest Total tillers	Harvest Productive tillers
T_1	6.2	6.5	6.9	6.8
T_2	6.1	6.7	7.2	7.0
T_3	5.6	5.5	6.1	5.7
T_4	5.4	5.9	8.1	7.8
Mean (with P)	5.8	6.2	7.1	6.8
T_5	6.1	6.3	6.8	6.6
T_6	5.6	6.5	6.7	6.5
T_7	6.4	6.5	6.7	6.6
T_8	5.3	6.5	7.0	6.8
Mean (No P)	5.9	6.4	6.8	6.6
F_{test}	NS	NS	NS	NS
SE	0.22	0.19	0.21	0.21

NS - Not significant.

4.1.1.3. Leaf area index (LAI)

The observations on leaf area index (LAI) were recorded at 30 DAT and at flowering. The data of mean leaf area index are presented in Table 4.

The data revealed that there was significant difference between treatments both at 30 DAT and at flowering. At 30 DAT no phosphorus ~~applied~~ treatment gave the maximum leaf area index of 2.04 which was significantly superior to ~~no~~ phosphorus treatment. At flowering, phosphorus applied treatment gave the maximum leaf area index of 1.44 which was significantly superior to no phosphorus treatment.

4.1.1.4. Dry matter production

The observations on dry matter production were recorded at 30 DAT, at flowering and at harvest. The data on mean dry matter production are presented in Table 5.

It is seen that the treatments had no significant effect on dry matter production at any of the growth stages.

Table 4. Leaf area index of first crop of rice

Treatments	30 DAS	Flowering
T_1	2.11	1.44
T_2	1.59	1.41
T_3	1.62	1.40
T_4	1.61	1.51
Mean (with [illegible])	1.75	1.40
T_5	1.92	1.54
T_6	2.12	1.40
T_7	2.02	1.26
T_8	2.10	1.41
Mean (No [illegible])	2.04	1.36
t test	S	S
CD (0.05)	0.055	0.035
SE	0.025	0.015

S - Significant.

Table 5. D[illegible] production o[illegible] (/ha)

Treatments	60 DAT	Flowering	Harvest
[illegible]	17[illegible]	[illegible]	8[illegible]
[illegible]	[illegible]	[illegible]7 2.[illegible]	[illegible]
[illegible]	1[illegible].7	[illegible]00.0	[illegible]
[illegible]	3500.0	544.3	[illegible]
Mean ([illegible])	1944.5	5[illegible].5	[illegible]614.
[illegible]	2000.0	[illegible]555.7	5[illegible]
[illegible]	1833.3	[illegible]	[illegible]
[illegible]	[illegible]55.7	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]3	[illegible]
Total ([illegible])	1[illegible]6.[illegible]	559[illegible]	[illegible]
F test	[illegible]	[illegible]	[illegible]
F	[illegible]	728.3[illegible]	[illegible]

[illegible]

Table 6. Yield attributes of first crop of rice

Treatments	No. of panicle/m^2	No. of grains/ panicle	1000 grain weight (g)
T_1	455.5	69.0	25.1
T_2	468.9	64.6	24.7
T_3	382.2	69.3	25.8
T_4	522.2	68.3	24.8
Mean (with P)	457.2	67.8	25.1
T_5	442.2	59.6	25.3
T_6	433.3	61.3	24.0
T_7	442.2	60.6	25.1
T_8	451.1	54.6	24.2
Mean (No P)	442.2	59.0	24.6
F_{test}	NS	S	S
$CD_{(0.05)}$	-	3.84	0.49
SE	14.41	1.79	0.23

NS - Not significant.

S - Significant.

Table 6. Yield attributes of first crop of rice

Treatments	No. of panicle/m^2	No. of grains/ panicle	1000 grain weight (g)
T_1	455.5	69.0	25.1
T_2	468.9	64.6	24.7
T_3	382.2	69.3	25.8
T_4	522.2	68.3	24.8
Mean (with P)	457.2	67.8	25.1
T_5	442.2	59.6	25.3
T_6	433.3	61.3	24.0
T_7	442.2	60.6	25.1
T_8	451.1	54.6	24.2
Mean (No P)	442.2	59.0	24.6
F_{test}	NS	S	S
$CD_{(0.05)}$	-	3.84	0.49
SE	14.41	1.79	0.23

NS - Not significant.

S - Significant.

Table 7. Grain and straw yield of first crop of rice (Kg/ha)

Treatments	Grain yield	Straw yield
T_1	3082.7	3782.9
T_2	3189.9	3598.2
T_3	3144.8	3688.0
T_4	3088.3	3965.8
Mean (with P)	3126.4	3758.7
T_5	3161.7	3693.1
T_6	2774.8	3325.6
T_7	2975.4	3894.6
T_8	3144.7	3889.6
Mean (No P)	3014.2	3700.7
F_{test}	NS	NS
SE	115.91	136.61

NS - Not significant.

Table 7. Grain and straw yield of first crop of rice (Kg/ha)

Treatments	Grain yield	Straw yield
T_1	3082.7	3782.9
T_2	3189.9	3598.2
T_3	3144.8	3688.0
T_4	3088.3	3965.8
Mean (with P)	3126.4	3758.7
T_5	3161.7	3693.1
T_6	2774.8	3525.6
T_7	2975.4	3894.6
T_8	3144.7	3889.6
Mean (No P)	3014.2	3700.7
F_{test}	NS	NS
SE	115.91	136.61

NS - Not significant.

Table 8. Nitrogen and potassium uptake by main crop of rice at harvest (kg/ha)

Treatments	Nitrogen uptake	Potassium uptake
T_1	142.2	152.0
T_2	140.1	150.3
T_3	142.[illegible]	150.9
T_4	138.8	149.8
Mean (with P)	140.9	150.7
T_5	116.2	154.8
T_6	117.0	153.1
T_7	115.8	154.6
T_8	116.2	153.[illegible]
Mean (No P)	116.5	153.9
F_{test}	S	S
$CD_{(0.05)}$	0.41	1.07
SE	0.19	0.49

S - Significant.

Table 9. Phosphorus uptake by first crop of rice (kg/ha)

Treatments	30 DAT	Flowering	Harvest
T_1	9.1	18.7	32.8
T_2	10.1	26.3	33.7
T_3	6.8	17.9	32.3
T_4	9.9	22.7	31.8
Mean (with P)	9.0	21.4	32.7
T_5	7.7	15.9	35.9
T_6	5.1	19.2	36.8
T_7	12.4	29.7	37.8
T_8	6.9	17.2	35.3
Mean (No P)	8.0	20.5	36.5
F_{test}	S	NS	S
CD (0.05)	0.78	-	0.28
SE	0.37	0.99	0.13

NS - Not significant.

S - Significant.

Table 9. Phosphorus uptake by first crop of rice (kg/ha)

Treatments	30 DAT	Flowering	Harvest
T_1	9.1	18.7	32.8
T_2	10.1	26.3	33.7
T_3	6.8	17.9	32.3
T_4	9.9	22.7	31.8
Mean (with P)	9.0	21.4	32.7
T_5	7.7	15.9	35.9
T_6	5.1	19.2	36.8
T_7	12.4	29.7	37.8
T_8	6.9	17.2	35.3
Mean (No P)	8.0	20.5	36.5
F_{test}	S	NS	S
CD (0.05)	0.78	-	0.28
SE	0.37	0.99	0.13

NS - Not significant.

S - Significant.

Table 10. Available nitrogen, available phosphorus, total phosphorus, available potassium and phosphorus fixing capacity of the soil after the first crop of rice (kg/ha).

Treatments	Available nitrogen	Available phosphorus	Total phosphorus	Available potassium	P fixing capacity
T_1	530.3	77.2	786.7	236.0	159.8
T_2	533.7	72.7	823.3	242.7	159.9
T_3	534.3	76.9	758.3	237.7	160.5
T_4	532.3	59.4	723.3	240.0	159.3
Mean (with P)	532.6	71.6	772.9	239.1	159.9
T_5	490.3	58.5	791.7	202.3	166.1
T_6	487.0	62.1	756.7	204.7	166.2
T_7	488.0	50.5	718.3	199.3	165.2
T_8	490.7	50.6	616.7	200.7	166.0
Mean (No P)	489.0	55.4	720.8	201.7	165.9
F_{test}	S	S	S	S	S
CD (0.05)	0.76	7.87	5.78	2.14	1.14
SE	0.36	3.67	2.69	0.99	0.53

S - Significant.

There was significant difference in the available potassium content of the soil with treatments. Phosphorus applied plots recorded significantly higher value of available potassium content than no phosphorus plots.

4.1.6. Correlation studies.

Simple correlations were worked out involving the variables phosphorus uptake, dry matter yield, grain yield, available phosphorus content of the soil, nitrogen uptake and potassium uptake.

From the Table 11, it could be seen that phosphorus uptake at harvest was significantly and negatively correlated with grain yield, available phosphorus content of the soil and nitrogen uptake at harvest but significantly and positively correlated with potassium uptake. Dry matter yield at harvest was significantly and positively correlated with nitrogen uptake and significantly and negatively correlated with potassium uptake. Grain yield was significantly and positively correlated with nitrogen uptake. Available phosphorus content of the soil was significantly and positively correlated with nitrogen uptake at harvest and negatively correlated with potassium uptake. Nitrogen uptake was significantly and negatively correlated with potassium uptake.

Table 11. Intercorrelation matrix involving the variables P-uptake, (X_1), dry matter yield (X_2) grain yield (X_3) available phosphorus contents of the soil (X_4), N-uptake (X_5) and K-uptake (X_6) - first crop of rice.

Variables	X_1	X_2	X_3	X_4	X_5	X_6
X_1	1.0000	-0.3013	-0.5356**	-0.7420**	-0.9087**	0.8671**
X_2		1.0000	-0.2778	0.3371	0.4077*	-0.5442**
X_3			1.0000	0.3153	0.4241*	-0.3091
X_4				1.0000	0.8951**	-0.6508**
X_5					1.0000	-0.8694**
X_6						1.0000

* Significant at 5% probability level.

** Significant at 1% probability level.

Table 11. Intercorrelation matrix involving the variables P-uptake, (X_1), dry matter yield (X_2) grain yield (X_3) available phosphorus contents of the soil (X_4), N-uptake (X_5) and K-uptake (X_6) - first crop of rice.

Variables	X_1	X_2	X_3	X_4	X_5	X_6
X_1	1.0000	-0.3013	-0.5356**	-0.7420**	-0.9087**	0.8671**
X_2		1.0000	-0.2778	0.3371	0.4077*	-0.5442**
X_3			1.0000	0.3153	0.4241*	-0.3091
X_4				1.0000	0.8951**	-0.6508**
X_5					1.0000	-0.8694**
X_6						1.0000

* Significant at 5% probability level.

** Significant at 1% probability level.

Table 12. Height of plants of second crop of rice (cm.)

Treatments.	30 DAT I year 1984-85	30 DAT II year 1985-86	Flowering I year 1984-85	Flowering II year 1985-86	Harvest I year 1984-85	Harvest II year 1985-86
T_1	42.1	50.5	66.8	66.5	64.1	70.3
T_2	42.8	49.8	64.5	66.4	62.8	71.3
Mean (cumulative P)	42.5		65.6		63.4	
T_3	43.9	54.8	70.7	70.3	68.8	74.0
T_4	42.5	52.9	66.8	65.1	65.3	74.3
Mean (Residual P)	43.2		68.7		67.1	
T_5	41.1	51.2	64.1	64.7	64.5	71.4
T_6	41.7	50.5	64.5	65.9	63.3	70.8
Mean (Direct P)	41.4		64.3		63.9	
T_7	41.3	51.4	66.2	65.1	66.0	71.4
T_8	42.8	48.3	64.7	68.8	63.0	69.1
Mean (Control)	42.1		65.4		64.5	
F_{test}	NS	S	NS	NS	NS	NS
$CD_{(0.05)}$	-	2.50	-	-	-	-
SE	1.82	1.17	2.06	2.78	1.89	1.75

NS - Not significant. S - Significant.

Cumulative P - P applied to both first and second crop.

Residual P - P applied to only first crop.

Direct P - P applied to only second crop.

Table 12. Height of plants of second crop of rice (cm.)

Treatments	30 DAT I year 1984-85	30 DAT II year 1985-86	Flowering I year 1984-85	Flowering II year 1985-86	Harvest I year 1984-85	Harvest II year 1985-86
T_1	42.1	50.5	66.8	66.5	64.1	70.3
T_2	42.8	49.8	64.5	66.4	62.8	71.3
Mean (cumulative P)	42.5		65.6		63.4	
T_3	43.9	54.8	70.7	70.3	68.8	74.0
T_4	42.5	52.9	66.8	65.1	65.3	74.3
Mean (Residual P)	43.2		68.7		67.1	
T_5	41.1	51.2	64.1	64.7	64.5	71.4
T_6	41.7	50.5	64.5	65.9	63.3	70.8
Mean (Direct P)	41.4		64.3		63.9	
T_7	41.3	51.4	66.2	65.1	66.0	71.4
T_8	42.8	48.3	64.7	68.8	63.0	69.1
Mean (Control)	42.1		65.4		64.5	
F_{test}	NS	S	NS	NS	NS	NS
$CD_{(0.05)}$	-	2.50	-	-	-	-
SE	1.82	1.17	2.06	2.78	1.89	1.75

NS - Not significant. S - Significant.

Cumulative P - P applied to both first and second crop.

Residual P - P applied to only first crop.

Direct P - P applied to only second crop.

Table 13. Number of tillers/hill of second crop of rice

Treatments	30 DAT		Flowering		Harvest			
					Total tillers		Productive tillers	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	5.7	4.9	6.5	4.6	5.4	5.5	5.3	4.8
T_2	6.1	5.5	5.6	4.5	5.5	5.1	5.3	4.7
Mean (Cumulative P)	5.4		6.1		5.4		5.3	
T_3	5.9	4.9	6.0	4.1	5.3	3.9	5.3	3.1
T_4	5.7	4.8	6.4	4.8	5.9	5.7	5.8	5.3
Mean (Residual P)	5.8		6.2		5.6		5.6	
T_5	6.5	4.6	6.1	4.5	5.9	5.3	5.8	5.0
T_6	5.9	5.2	6.1	4.9	5.9	5.5	5.8	4.9
Mean (Direct P)	6.1		6.1		5.9		5.8	
T_7	5.8	5.4	6.4	4.9	5.7	5.1	5.5	4.7
T_8	5.7	4.8	6.2	4.4	5.6	4.4	5.5	3.9
Mean (Control)	5.8		6.3		5.6		5.5	
F_{test}	NS	S	NS	NS	NS	NS	NS	NS
$CD_{(0.05)}$	-	0.45	-	-	-	-	-	-
SE	0.25	0.21	0.32	0.38	0.38	0.85	0.40	0.72

NS - Not significant. S- Significant.

The data revealed that the direct, residual and cumulative effects of P had no significant effect on tiller count at any of the growth stages of the rice crop in the first year.

In the second year there was significant difference in tiller number at 30 DAT. The highest number of 5.5 was recorded by the treatment T_2 which was on par with T_6 & T_7 and significantly superior to all the other treatments. At flowering and harvest stages there was no significant difference between treatments.

4.2.1.3. Leaf area index (LAI)

The observations on leaf area index was recorded at 30 DAT and at flowering. The data on mean leaf area index are presented in Table 14.

It was seen that there was no significant variation in LAI at 30 DAT and at flowering due to the direct, residual and cumulative effects of phosphorus during both the years.

4.2.1.4. Dry matter production.

The observations on dry matter production were recorded at 30 DAT, at flowering and at harvest. The data on mean dry matter production are presented in Table 15.

The data on dry matter production revealed that the direct, residual and cumulative effects of phosphorus

Table 14. Leaf area index of second crop of rice

Treatments	30 DAT I year 1984-85	30 DAT II year 1985-86	Flowering I year 1984-85	Flowering II year 1985-86
T_1	1.17	1.11	1.24	1.73
T_2	0.67	1.15	1.15	2.75
Mean (Cumulative P)	0.92		1.19	
T_3	1.09	0.99	1.17	2.51
T_4	0.59	1.05	0.77	2.04
Mean (Residual P)	0.84		0.97	
T_5	1.19	0.83	0.92	2.52
T_6	1.12	1.68	0.79	2.84
Mean (Direct P)	1.15		0.86	
T_7	1.19	1.48	1.22	1.88
T_8	1.02	1.30	1.23	2.81
Mean (Control)	1.10		1.22	
F_{test}	NS	NS	NS	NS
SE	0.16	0.26	0.16	0.60

NS - Not significant.

Table 15. Dry matter production of second crop of rice (kg/ha)

Treatments	30 DAT I year 1984-85	30 DAT II year 1985-86	Flowering I year 1984-85	Flowering II year 1985-86	Harvest I year 1984-85	Harvest II year 1985-86
T_1	1611.0	1833.7	2500.0	3000.3	4961.0	4736.3
T_2	1444.3	1444.3	2444.3	3778.3	4837.0	4541.7
Mean (Cumulative P)	1527.6		2472.1		4899.0	
T_3	1555.8	1277.7	2166.7	3055.7	5695.0	4695.0
T_4	1500.0	1805.7	2166.3	2694.7	5066.3	6139.3
Mean (Residual P)	1527.9		2166.5		5380.6	
T_5	1278.0	1361.7	2333.3	2916.7	4515.3	4750.3
T_6	1388.6	2139.3	1666.6	3750.0	4490.0	4931.0
Mean (Direct P)	1333.4		1999.9		4502.6	
T_7	1889.0	2333.7	2777.7	2880.0	4408.0	4431.0
T_8	1277.8	1444.7	2333.3	3055.7	4259.3	4722.3
Mean (Control)	1583.4		2555.5		4333.6	
F test	NS	[illegible]	[illegible]	[illegible]	NS	NS
SE	282.16	394.97	293.58	571.59	[illegible]61.14	720.08

NS - not significant.

Table 16. Yield attributes of second crop of rice

Treatments	No. of panicle/m^2		No. of grains/ panicle		1000 grain weight (g)	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	355.8	316.6	82.6	36.1	23.5	22.1
T_2	353.1	311.1	64.9	33.6	23.6	19.6
Mean (Cumulative P)	354.5		73.7		23.5	
T_3	354.6	205.5	80.4	36.5	24.2	20.8
T_4	386.2	355.5	73.2	40.8	23.5	20.0
Mean (Residual P)	370.4		76.8		23.8	
T_5	389.1	333.3	56.8	32.1	24.2	21.7
T_6	389.1	327.8	59.2	31.8	23.6	20.4
Mean (Direct P)	389.1		58.0		23.9	
T_7	369.6	311.1	76.8	46.6	24.5	18.8
T_8	369.6	261.1	66.1	45.8	23.9	23.3
Mean (Control)	369.6		71.4		24.2	
F_{test}	NS	NS	NS	NS	NS	NS
SE	25.99	48.19	7.52	5.58	0.41	2.10

NS - Not significant.

Table 16. Yield attributes of second crop of rice

Treatments	No. of panicle/m^2		No. of grains/ panicle		1000 grain weight (g)	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	355.8	316.6	82.6	36.1	23.5	22.1
T_2	353.1	311.1	64.9	33.6	23.6	19.6
Mean (Cumulative P)	354.5		73.7		23.5	
T_3	354.6	205.5	80.4	36.5	24.2	20.8
T_4	386.2	355.5	73.2	40.8	23.5	20.0
Mean (Residual P)	370.4		76.8		23.8	
T_5	389.1	333.3	56.8	32.1	24.2	21.7
T_6	389.1	327.8	59.2	31.8	23.6	20.4
Mean (Direct P)	389.1		58.0		23.9	
T_7	369.6	311.1	76.8	46.6	24.5	18.8
T_8	369.6	261.1	66.1	45.8	23.9	23.3
Mean (Control)	369.6		71.4		24.2	
F_{test}	NS	NS	NS	NS	NS	NS
SE	25.99	48.19	7.52	5.56	0.41	2.10

NS - Not significant.

Table 17. Grain yield and straw yield of second crop of rice (kg/ha)

Treatments	Grain yield I year 1984-85	Grain yield II year 1985-86	Straw yield I year 1984-85	Straw yield II year 1985-86
T_1	1232.0	1438.6	1307.8	4286.3
T_2	1345.4	1328.5	1991.9	4293.1
Mean (Cumulative P)	1288.7		1649.8	
T_3	1425.1	1288.4	2221.9	3845.9
T_4	1317.8	1417.7	1608.0	4060.5
Mean (Residual P)	1371.4		1914.9	
T_5	1346.6	1349.9	1645.4	4096.7
T_6	1321.1	1465.7	1697.2	4139.6
Mean (Direct P)	1333.8		1671.3	
T_7	1461.2	1385.5	1669.2	4916.5
T_8	1296.9	1274.8	1361.2	3665.3
Mean (Control)	1379.0		1515.2	
F_{test}	NS	NS	S	NS
$CD_{(0.05)}$	-	-	336.42	-
SE	78.68	128.12	156.84	693.46

NS - Not significant.

S - Significant.

Table 17. Grain yield and straw yield of second crop of rice (kg/ha)

Treatments	Grain yield I year 1984-85	Grain yield II year 1985-86	Straw yield I year 1984-85	Straw yield II year 1985-86
T_1	1232.0	1438.6	1307.8	4286.3
T_2	1345.4	1328.5	1991.9	4293.1
Mean (Cumulative P)	1288.7		1649.8	
T_3	1425.1	1288.4	2 21.9	3845.9
T_4	1317.8	1417.7	1608.0	4060.5
Mean (Residual P)	1371.4		1914.9	
T_5	1346.6	1349.9	1645.4	4096.7
T_6	1321.1	1465.7	1697.2	4139.6
Mean (Direct P)	1333.8		1671.3	
T_7	1461.2	1385.5	1669.2	4916.5
T_8	1296.9	1274.8	1361.2	3665.3
Mean (Control)	1379.0		1515.2	
F_{test}	NS	NS	S	NS
$CD_{(0.05)}$	-	-	336.42	-
SD	78.68	128.12	156.84	693.46

NS - Not significant.

S - Significant.

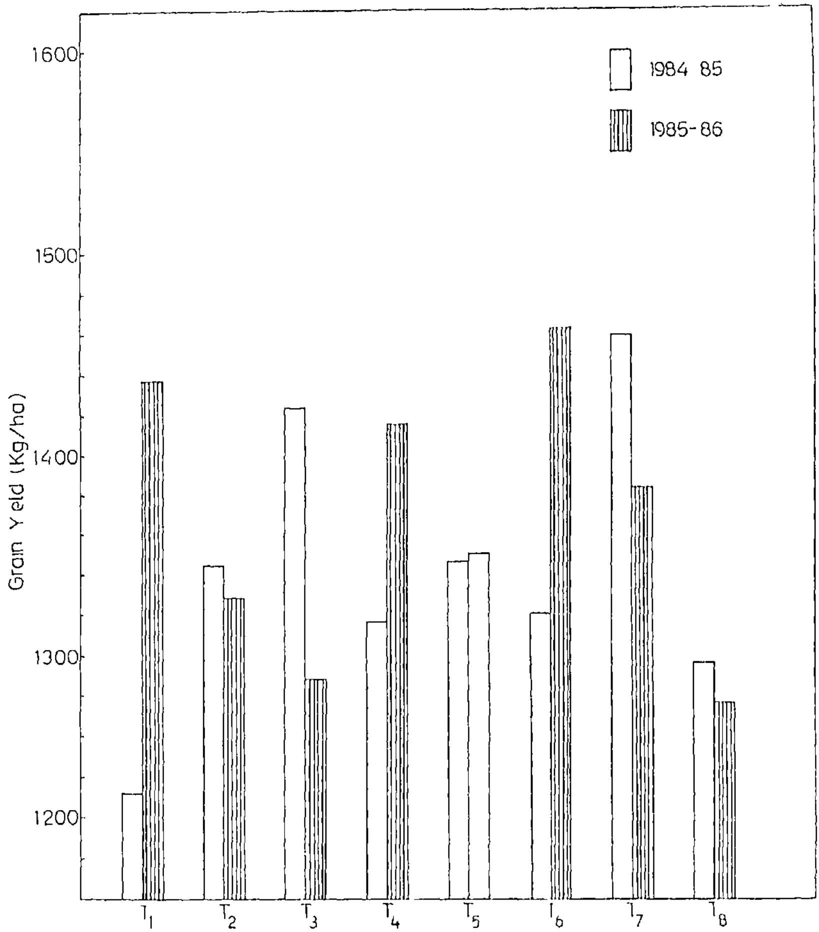


FIG. 6 GRAIN YIELD OF SECOND CROP OF RICE

Table 10. Nitrogen and phosphorus uptake at harvest by second crop of rice (kg/ha)

Treatments	Nitrogen uptake I year 1984-85	Nitrogen uptake II year 1985-86	Phosphorus uptake I year 1984-85	Phosphorus uptake II year 1985-86
T_1	9 .6	77.[illegible]	62.3	5 .5
T_2	55.[illegible]	57.2	57.9	57.1
Mean (Cumulative P)	75.[illegible]		60.1	
T_3	89.5	71.5	71.7	5[illegible].6
T_4	76.4	75.2	54.3	51.5
Mean (Residual P)	82.8		63.0	
T_5	51.5	52.9	55.[illegible]	53.2
T_6	64.5	59.2	66.	40.6
Mean (Direct P)	56.0		61.0	
T_7	81.[illegible]	63.[illegible]	50.	58.4
T_8	68.6	52.3	19.2	53.3
Mean (Control)	74.9		50.0	
F test	[illegible]	[illegible]	[illegible]	NS
CD (0.05)	9.74	12. 5	9.51	-
SE	4.54	5.82	4.43	-.91

NS - Not significant. S - Significant.

Table 19. Phosphorus uptake by the second crop of rice (kg/ha)

Treatments	30 DAT		Flowering		Harvest	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	9.0	5.0	11.3	12.2	24.5	20.7
T_2	7.4	5.2	10.7	15.4	21.1	16.9
Mean (Cumulative P)	8.2		11.0		22.8	
T_3	8.8	4.3	10.8	12.5	30.0	15.1
T_4	8.7	6.7	11.8	11.1	26.8	22.9
Mean (Residual P)	8.8		11.3		28.4	
T_5	6.5	5.1	11.9	12.5	23.3	18.7
T_6	7.9	7.3	7.4	14.5	22.4	17.9
Mean (Direct P)	7.2		9.7		22.8	
T_7	8.9	8.3	11.6	11.8	21.7	20.5
T_8	6.9	5.6	9.3	12.4	23.7	18.7
Mean (Control)	7.9		10.4		22.7	
F_{test}	NS	NS	NS	NS	NS	NS
SE	1.65	1.28	1.26	2.39	2.28	2.85

NS - Not significant.

Table 19. Phosphorus uptake by the second crop of rice (kg/ha)

Treatments	30 DAT		Flowering		Harvest	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	9.0	5.0	11.[illegible]	12.2	2[illegible].5	[illegible]0.7
T_2	7.4	5.2	10.7	15.4	21.1	16.9
Mean (Cumulative P)	8.2		11.0		22.8	
T_3	8.8	4.3	10.8	12.5	30.0	15.1
T_4	8.7	6.7	11.8	11.1	26.3	2[illegible].9
Mean (Residual P)	8.8		11.3		25.4	
T_5	6.5	5.1	11.9	12.5	23.3	1[illegible].7
T_6	7.9	7.3	7.4	14.5	22.[illegible]	17.[illegible]
Mean (Direct P)	7.2		9.7		2[illegible].8	
T_7	8.9	6.3	11.6	11.[illegible]	2[illegible]	[illegible]0.5
T_8	6.9	5.6	9.[illegible]	12.[illegible]	[illegible]	10.[illegible]
Mean (Control)	7.9		10.4		22.7	
F test	NS	NS	[illegible]		[illegible]	[illegible]
CD	1.65	[illegible].28	1.[illegible]6	2.39	2.[illegible]8	[illegible].85

NS - Not significant.

Table 20. Available nitrogen and potassium content of the soil after the second crop of rice (kg/ha)

Treatments	Available nitrogen I year 1984-85	Available nitrogen II year 1985-86	Available potassium I year 1984-85	Available potassium II year 1985-86
T_1	439.3	437.3	202.0	199.7
T_2	442.3	440.0	199.0	197.3
Mean (Cumulative P)	440.8		200.5	
T_3	474.3	472.3	259.0	254.3
T_4	465.7	464.0	258.0	256.6
Mean (Residual P)	470.0		258.5	
T_5	419.0	417.0	300.0	303.6
T_6	419.7	417.7	297.0	299.6
Mean (Direct P)	419.3		298.5	
T_7	415.0	413.0	319.0	315.6
T_8	417.0	415.0	317.0	312.3
Mean (Control)	416.0		318.0	
F_{test}	S	S	S	S
$CD_{(0.05)}$	3.29	5.06	3.56	2.42
SE	1.53	2.36	1.66	1.13

S - Significant.

Table 20. Available nitrogen and potassium content of the soil after the second crop of rice (kg/ha)

Treatments	Available nitrogen I year 1984-85	Available nitrogen II year 1985-86	Available potassium I year 1984-85	Available potassium II year 1985-86
T_1	439.3	437.3	202.0	199.7
T_2	442.3	440.0	199.0	197.3
Mean (Cumulative P)	440.8		200.5	
T_3	474.3	472.3	259.0	257.3
T_4	465.7	464.0	258.0	256.6
Mean (Residual P)	470.0		258.5	
T_5	419.0	417.0	300.0	30[illegible].6
T_6	419.7	417.7	297.0	293.6
Mean (Direct P)	419.3		298.5	
T_7	415.0	413.0	319.0	315.6
T_8	417.0	415.0	317.0	312.3
Mean (Control)	416.0		318.0	
F_{test}	S	S	S	[illegible]
$CD_{(0.05)}$	3.29	5.06	3.56	2.42
SE	1.53	2.[illegible]6	1.66	1.13

S - Significant.

phosphorus which was significantly superior to all the other treatments.

4.2.5.4. Phosphorus fixing capacity of the soil

The data on mean phosphorus fixing capacity of the soil are given in Table 21.

There was significant difference between treatments during both the years.

The control plots, recorded the highest values which were significantly superior to all the other treatments.

4.2.5.5. Available potassium

The data on available potassium content of the soil are given in Table 20.

Significant difference between treatments are observed during both the years. In the first year control plot and in the second year treatment T_7 recorded the highest value of available potassium which was significantly superior to all the other treatments.

4.2.6. Correlation studies

It could be seen from the table 22, that phosphorus uptake was significantly and positively correlated with dry matter yield and nitrogen uptake during both the years and

Table 22. Intercorrelation matrix involving the variables P-uptake (X_1). dry matter yield (X_2) grain yield (X_3), available phosphorus content of the soil (X_4), N-uptake (X_5) and K-uptake (X_6) - second crop of rice

Variables	X_1	X_2	X_3	X_4	X_5	X_6
X_1		0.8190**	0.0963	-0.0088	0.5618**	0.5086
X_2	0.5947		0.1419	0.2442	0.5210*	0.7034**
X_3	0.6358**	0.3993		-0.4081*	0.0138	0.0282
X_4	0.5156*	0.4579*	0.5913**		0.6089**	0.2438
X_5	0.7631	0.3419	0.3626	0.1124		0.3156
X_6	-0.0838	-0.5173**	-0.5554**	-0.4391*	0.2359	

Figures in the upper and lower diagonals are respectively the correlations for the First (1984-85) and Second (1985-86) years.

* Significant at 5% probability level.

** Significant at 1% probability level.

Table 22. Intercorrelation matrix involving the variables P-uptake (X_1). dry matter yield (X_2) grain yield (X_3), available phosphorus content of the soil (X_4), N-uptake (X_5) and K-uptake (X_6) - second crop of rice

Variables	X_1	X_2	X_3	X_4	X_5	X_6
X_1		0.8190**	0.0963	-0.0088	0.5618**	0.5086
X_2	0.5947		0.1419	0.2442	0.5210*	0.7034**
X_3	0.6358**	0.3993		-0.4081*	0.0138	0.0232
X_4	0.5156*	0.4579*	0.5913**		0.6089**	0.2438
X_5	0.7631	0.3419	0.3626	0.1124		0.3156
X_6	-0.0838	-0.5173**	-0.5554*	-0.4391*	0.2359	

Figures in the upper and lower diagonals are respectively the correlations for the First (1984-85) and Second (1985-86) years.

* Significant at 5% probability level.

** Significant at 1% probability level.

with potassium uptake in the first year (1984-85) and with grain yield and available phosphorus content of the soil in the second year (1985-86).

Dry matter yield was positively and significantly correlated with nitrogen uptake and potassium uptake in the first year (1984-85) and positively and significantly correlated with available phosphorus content of the soil and significantly and negatively correlated with potassium uptake in the second year (1985-86).

Grain yield was significantly and negatively correlated with available phosphorus content of the soil in the first year (1984-85) but positively correlated with available phosphorus and negatively correlated with potassium uptake in the second year (1985-86).

Available phosphorus content of the soil was significantly and positively correlated with nitrogen uptake in the first year (1984-85) but negatively correlated with potassium uptake in the second year (1985-86).

4.3. Effect of phosphorus on the third crops of cowpea/sesamum.

(Direct, residual and cumulative effects of phosphorus)

4.3.1. Growth attributes of Cowpea

4.3.1.1. Plant height

The observations on plants height were recorded at 20 days after sowing (20 DAS), at flowering and at harvest. The data on mean height of plants are presented in Table 23.

There was no significant difference between treatments at 20 DAS during the first year, but significance observed during the second year. The treatment T_1 recorded the maximum height which was significantly superior to T_4 T_6 and T_8.

At flowering stage there was significant difference between treatments in the first year, but the differences were not significant during the second year. During the first year the treatment T_4 was significantly inferior to all the other treatments. All the treatments except T_4 were on par. Eventhen the maximum plant height was recorded by the treatment T_7 closely followed by T_1.

At the harvest stage there occured significant difference between treatments during both the years. In the first year T_5 gave the maximum height which was on par with T_7 and both T_5 and T_7 were significantly superior to all the other treatments. In the second year also T_7

Table 23. Height of plants of third crop of cowpea (cm.)

Treatments	20 DAS		Flowering		Harvest	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	36.9	36.6	97.3	79.9	132.5	161.8
T_2	33.5	33.8	94.1	76.6	111.0	116.3
T_3	36.1	35.3	95.8	79.7	134.8	133.8
T_4	35.4	31.4	76.2	62.2	142.6	117.8
T_5	37.4	34.9	93.0	77.0	171.0	177.3
T_6	34.7	31.6	90.5	75.0	142.8	162.9
T_7	36.2	35.7	98.8	79.7	170.8	233.2
T_8	34.3	31.5	93.5	78.5	162.0	155.8
F test	NS	S	S	NS	S	S
CD(0.05)	-	3.53	12.28	-	3.96	35.72
SE	1.18	1.64	5.73	8.31	1.84	16.65

NS - Not significant.

S - Significant.

recorded maximum height which was significantly superior to all the other treatments.

4.3.1.2. Number of leaves/plant

The observations on leaf number were recorded at 20 DAS and at flowering. The data on mean leaf number are presented in Table 24.

The data revealed no significant difference between treatments in the number of leaves per plant at 20 DAS during both the years. However the highest number of 4.9 leaves in the first year recorded by T_5 followed by T_7 and T_1. In the second year T_1 ranked first followed by T_7.

At flowering stage there was significant difference between treatments during both the years. In the first year T_7 recorded the highest number which was significantly superior to the other treatments except T_3. In the second year also T_7 recorded the highest number which was significantly superior to T_4, T_6 & T_8.

4.3.1.3. Leaf area index (LAI)

The observations on LAI was recorded at 20 DAS and at flowering. The data on mean LAI are presented in Table 25.

Table 24. Number of leaves per plant of third crop of cowpea

Treatments	20 DAS		Flowering	
	I year (1984-85)	II year (1985-86)	I year (1984-85)	II year (1985-86)
T_1	4.7	4.5	15.9	11.2
T_2	4.2	4.2	14.6	10.7
T_3	4.1	4.1	16.8	11.2
T_4	4.1	3.8	14.5	8.7
T_5	4.9	4.2	15.8	10.6
T_6	4.5	3.9	14.5	9.9
T_7	4.7	4.4	18.6	12.0
T_8	4.0	4.3	13.8	7.7
F_{test}	NS	NS	S	S
CD(0.05)	-	-	1.87	2.07
SE	0.39	0.22	0.87	0.96

NS - Not significant.

S - Significant.

The data revealed significant difference between treatments at 20 DAS during both the years. The treatment T_5 recorded the highest LAI which was on par with T_1 but significantly superior to all the other treatments. The next highest value was recorded by the treatment T_7.

At flowering stage there was no significance between treatments during both the years. However T_7 recorded the highest LAI of 4.67 during the first year and 2.67 in the second year.

4.3.1.4 Number of branches/plant

The data on the number of branches per plant are presented in Table 25.

It was seen that there was no significant difference between treatments during both the years. However in the first year T_5 recorded the highest number of branches closely followed by T_7. In the second year T_7 recorded the highest number.

4.3.1.5. Dry matter production

The observations on dry matter production were recorded at 20 DAS, at flowering and at harvest. The data on mean dry matter production are presented in Table 26.

The data on dry matter production revealed that

Table 25. Leaf area index and number of branches per plant of third crop of cowpea

Treatments	Leaf area index				Number of branches	
	20 DAS		Flowering			
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	0.57	0.53	2.81	1.97	4.8	4.6
T_2	0.46	0.45	2.98	2.12	4.8	4.8
T_3	0.34	0.34	[illegible].59	1.35	3.6	3.6
T_4	0.46	0.42	2.56	1.54	4.5	4.1
T_5	0.64	0.61	2.78	1.75	5.4	4.6
T_6	0.40	0.39	2.56	1.88	3.3	2.9
T_7	0.51	0.48	4.67	2.67	5.3	5.0
T_8	0.35	0.34	2.43	1.97	4.3	[illegible].6
F_{test}	S	S	NS	NS	NS	NS
$CD_{(0.05)}$	0.08	0.07	-	-	-	-
SE	0.04	0.03	0.65	0.43	0.68	0.65

NS - Not significant.

S - Significant.

Table 26. Dry matter production of third crop of cowpea (kg/ha)

Treatments	20 DAS		Flowering		Harvest	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	149.4	276.3	2066.7	1823.3	6720.0	3755.2
T_2	133.4	221.0	1733.3	1547.0	6458.9	3672.3
T_3	110.7	262.4	2466.7	1187.9	6462.2	2523.1
T_4	124.0	221.0	1866.7	1132.6	6396.5	3644.7
T_5	133.4	234.8	1533.3	1215.5	4595.6	3922.7
T_6	146.6	234.8	2000.0	1989.0	5155.3	4269.0
T_7	170.7	276.3	2933.3	2265.3	6524.5	4497.4
T_8	140.0	221.0	2533.3	1768.0	5902.1	3392.3
F test	NS	NS	NS	S	NS	S
CD(0.05)	-	-	-	458.81	-	1008.90
SE	18.42	38.33	465.99	213.90	788.55	470.35

NS - Not significant.

S - Significant.

there was no significant difference between the treatments at 20 DAS during both the years. However in the first year T_7 recorded the highest dry matter production followed by T_1. In the second year T_1 and T_7 recorded the highest values followed by T_3.

At flowering stage also, there was no significant difference between the treatments in the first year, but the effect was significant during the second year. In the second year T_7 gave the highest dry matter which was significantly superior to T_2, T_3, T_4, T_5 and T_8.

At harvest stage also there was no significant difference between the treatments in the first year, but the effects were significant during the second year. Though there was no significant difference in the first year T_1 recorded the highest dry matter closely followed by T_7. In the second year, T_7 recorded the highest dry matter which was significantly superior to T_3 and T_8.

4.3.2. Yield attributes of cowpea

4.3.2.1. Number of pods/plant

The data on the number of pods/plant are presented in Table 27.

The data revealed no significant difference between treatments during both the years. However, T_7 and T_3 gave

Table 27. Yield atrributes of third crop of cowpea

Treatments	Number of cowpea pod/plant		Number of grains/pod		Length of pod (cm)		1000 grain weight (g)	
	I YEAR 1984-85	II YEAR 1985-86	I YEAR 1984-85	II YEAR 1985-86	I YEAR 1984-85	II YEAR 1985-86	I YEAR 1984-85	II YEAR 1985-86
T_1	12.1	8.4	13.1	12.5	15.5	14.3	121.2	121.7
T_2	13.3	9.6	13.7	13.1	16.3	15.2	116.1	116.7
T_3	14.8	7.8	13.9	13.4	16.6	15.5	121.5	121.7
T_4	13.1	9.5	13.8	13.2	14.7	13.5	121.8	121.7
T_5	11.0	8.0	13.2	13.0	15.2	14.1	119.8	119.2
T_6	11.3	7.6	11.9	11.5	14.7	13.6	110.1	110.0
T_7	15.5	11.5	13.3	13.0	15.5	14.8	124.6	125.0
T_8	11.2	7.5	11.7	11.1	15.1	14.0	113.0	113.3
F test	NS	NS	NS	S	S	S	S	NS
CD(0.05)	-	-	-	0.65	1.24	1.18	1.08	-
SE	1.83	1.43	0.96	0.30	0.58	0.55	0.51	4.53

NS - Not significant.

S - Significant.

the highest number of 15.5 and 14.8 respectively in the first year. In the second year T_7 gave the highest number of 11.5 pods.

4.3.2.2. Number of grains/pod

The data on number of grains/pod are presented in Table 27.

The data revealed that there was no significant difference between treatments in the first year. However in the second year there was significance between treatments. Treatments T_2, T_3, T_4, T_5 and T_7 were on par but significantly superior to T_1, T_6 and T_8.

4.3.2.3. Length of pod

The data on mean length of pod are presented in Table 27.

The data revealed significant difference between treatments during both the years. The treatment T_3 recorded the highest length which was significantly superior to T_4, T_5, T_6 and T_8 but on par with T_1, T_2 and T_7.

4.3.2.4. 1000 grain weight

The data on mean weight of 1000 grains are presented in Table 27.

There was significant difference between treatments in the first year. But no significant difference was observed in the second year. In the first year, T_7 recorded the highest weight which was significantly superior to all the other treatments. Though the treatment differences were non-significant in the second year, the same trend as that of the first year was observed, T_7 recording the highest weight.

4.3.3. Yield of cowpea

4.3.3.1. Grain yield of cowpea

The data on mean yield of cowpea grain are presented in Table 28 and Fig. 7.

The data on grain yield revealed significant difference between treatments in the first year, but the difference was not significant in the second year.

In the first year T_7 recorded the highest yield of 895 kg/ha which was significantly superior to all other treatments followed by T_1.

In the second year eventhough the difference was not significant, the treatment T_7 recorded the highest yield of 519.2 kg/ha.

4.3.3.2. Haulum yield

The data on mean yield of haulum are presented in Table 28.

Table 28. Grain yield and haulm yield of third crop of cow pea (kg/ha)

Treatments	Grain yield		Haulm yield	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	664.2	421.7	2756.7	698.7
T_2	648.3	450.0	1920.0	891.2
T_3	620.8	356.7	2200.0	555.3
T_4	565.0	383.3	2156.7	619.2
T_5	639.2	435.0	2138.3	739.2
T_6	559.2	383.2	2202.7	726.2
T_7	895.0	519.2	2571.7	896.3
T_8	413.3	346.7	2540.0	753.0
F test	S	NS	NS	NS
CD(0.05)	218.86	-	-	-
SE	102.63	77.92	308.06	192.96

NS - Not significant.

S - Significant.

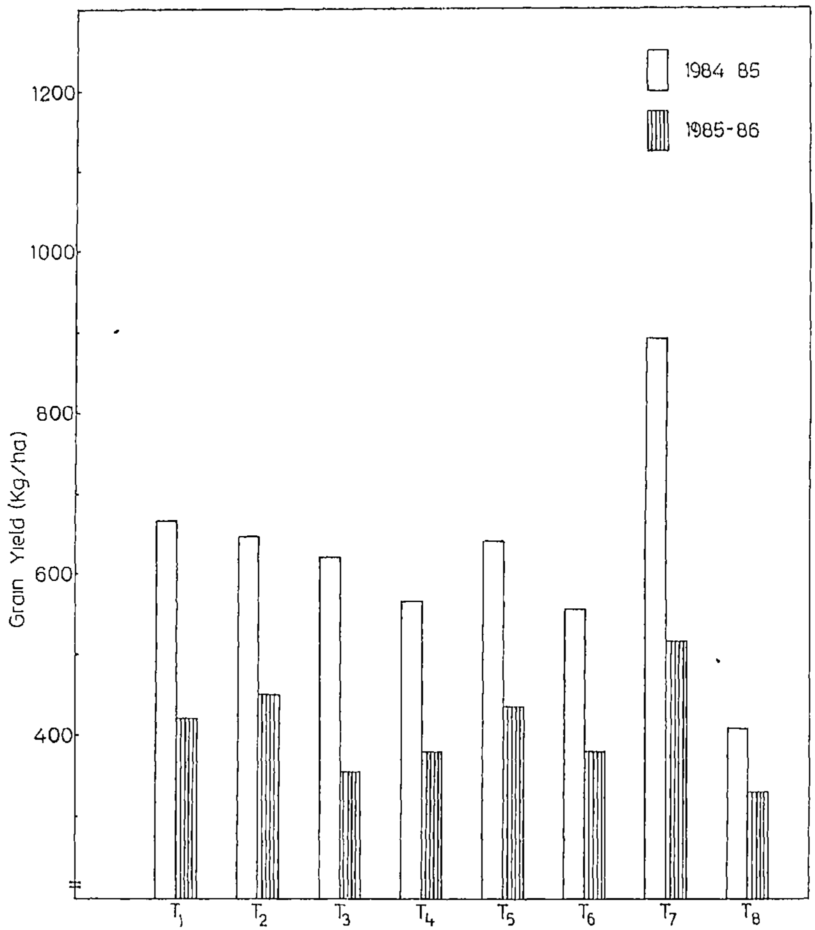


FIG. 7 GRAIN YIELD OF THIRD CROP OF COWPEA

The data revealed that there was no significant difference between treatments during both the years.

4.3.4. Uptake of major nutrients by cowpea

4.3.4.1. Nitrogen uptake

The data on mean uptake of nitrogen at harvest are presented in Table 29.

The data on nitrogen uptake revealed significant difference between treatments in the first year, but the difference was not significant in the second year.

In the first year T_2 recorded the highest value which was significantly superior to T_4, T_6 and T_8.

In the second year, T_7 recorded the highest uptake eventhough the effect was not significant.

4.3.4.2. Phosphorus uptake

The observations on phosphorus uptake were recorded at 20 DAS, at flowering and at harvest. The data on mean phosphorus uptake are presented in Table 30 and Fig. 8.

The data on phosphorus uptake revealed that there was no significant difference between different treatments at 20 DAS during both the years.

At flowering stage, there was no significant difference between treatments in the first year, but

Table 29. Nitrogen and potassium uptake by third crop of cowpea (kg/ha)

Treatments	Nitrogen uptake		Potassium uptake	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	201.3	112.8	105.2	58.8
T_2	216.7	120.4	105.5	58.9
T_3	200.2	78.1	97.5	57.9
T_4	174.7	107.9	95.7	54.5
T_5	189.6	102.4	92.3	86.5
T_6	161.9	133.7	91.7	76.5
T_7	199.5	140.7	102.4	74.6
T_8	113.8	101.3	102.1	58.5
F test	S	NS	NS	NS
CD(0.05)	41.65	-	-	-
SE	19.42	19.53	9.28	14.17

NS - Not significant.

S - Significant.

Table 30. Phosphorus uptake by third crop of cowpea (kg/ha)

Treatments	20 DAS		Flowering		Harvest	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	Ist year 1984-85	II year 1985-86
T_1	1.1	1.4	13.0	10.2	32.3	17.1
T_2	1.0	1.1	11.5	10.9	28.2	16.8
T_3	0.96	1.2	16.5	10.3	29.9	12.0
T_4	0.94	1.1	12.4	5.5	25.6	13.1
T_5	1.0	1.2	10.5	8.5	25.8	19.4
T_6	1.2	1.1	13.2	6.5	27.3	18.7
T_7	1.2	1.4	19.3	11.8	29.4	22.1
T_8	0.88	1.3	16.0	5.6	21.9	15.8
F test	NS	NS	NS	S	NS	S
CD(0.05)	-	-	-	3.43	-	2.76
SE	0.13	0.22	3.66	1.60	4.19	1.29

NS - Not significant.

S - Significant.

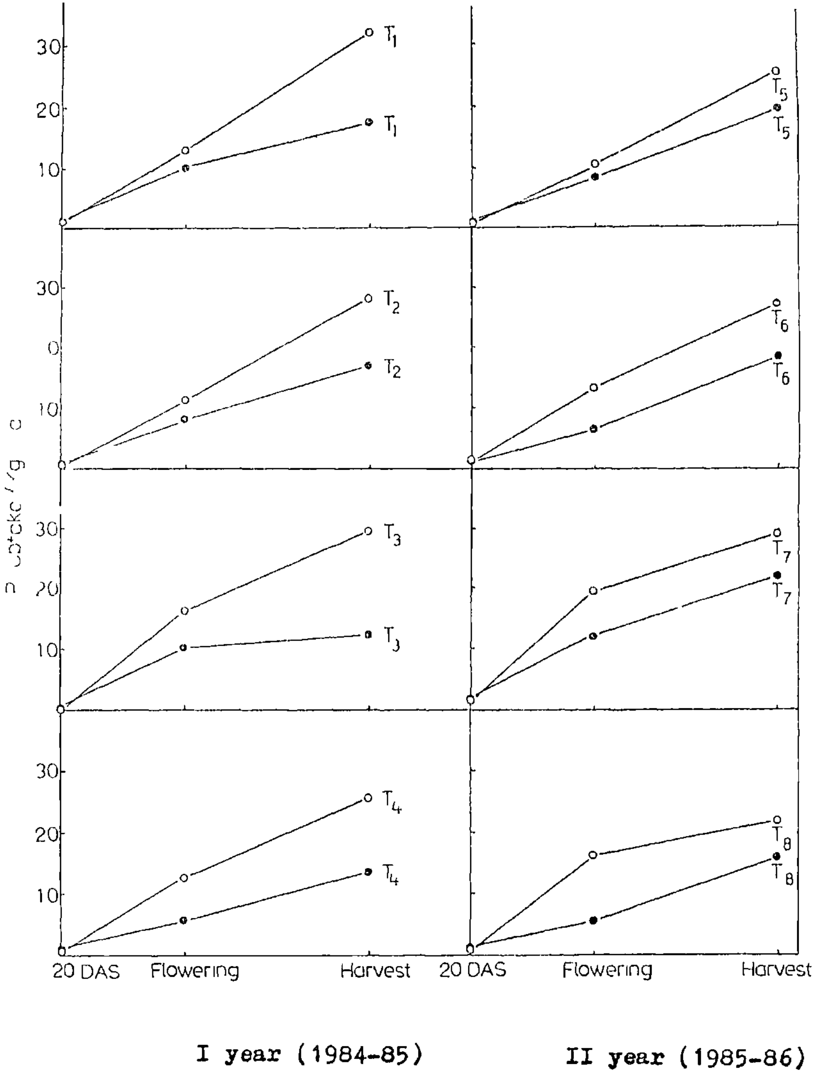


FIG. 8 PHOSPHORUS UPTAKE BY THIRD CROP OF COWPEA

significant difference was observed in the second year. However in the first and second years, T_7 recorded the highest uptake of 19.3 kg and 11.8 kg respectively. Moreover during the second year, T_7 was significantly superior to T_2, T_4, T_6 and T_8.

At harvest stage also no significant difference was observed in the first year, but significance observed in the second year. However, in the first year T_1 recorded the highest uptake closely followed by T_3 and T_7. In the second year T_7 recorded the highest uptake of 22.1 kg which was significantly superior to all other treatments except T_5.

4.3.4.3. Potassium uptake

The data on potassium uptake at harvest are presented in Table 29.

It can be seen from the data that there was no significant difference in Potassium uptake by the different treatments.

4.3.5. Soil nutrient status after the third crop of cowpea.

4.3.5.1. Available nitrogen

The data on mean available nitrogen contents of the soil are presented in Table 31.

The data revealed significant difference between

Table 31. Available nitrogen and potassium of the soil after the third crop of cowpea (kg/ha)

Treatments	Available nitrogen		Available potassium	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	278.0	277.7	141.7	144.1
T_2	419.0	418.0	220.0	204.0
T_3	297.7	299.7	105.0	109.0
T_4	436.3	438.0	135.0	134.0
T_5	364.3	365.7	200.0	200.0
T_6	491.7	500.3	200.0	193.7
T_7	403.7	407.7	205.0	204.3
T_8	553.3	550.0	201.7	191.7
F test	S	S	S	S
CD(0.05)	5.86	7.33	8.19	8.34
SE	2.73	3.42	3.82	3.89

S - Significant.

treatments during both the years. The treatment T_8 recorded the highest nitrogen content of 553.3 kg and 550 kg respectively for the first and second year, which was significantly superior to all the other treatments.

4.3.5.2. Available phosphorus

The data on mean available phosphorus content of the soil are presented in Table 32, Fig. 13.

The data revealed significant difference between treatments during both the years.

In the first year T_4 recorded the highest content of available phosphorus which was significantly superior to all the other treatments. The next higher value was recorded by T_1.

In the second year T_1 recorded the highest value which was significantly superior to all the other treatments, followed by T_3.

4.3.5.3. Total phosphorus

The data on mean total phosphorus content of the soil are presented in Table 32.

It was seen that there was significant difference between treatments during both the years. T_1 recorded the highest value which was significantly superior to all

Table 32. Available phosphorus, total phosphorus and phosphorus fixing capacity of the soil after the third crop of cowpea (kg/ha)

Treatments	Available phosphorus		Total phosphorus		P fixing capacity	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	53.8	57.8	843.3	770.0	155.6	121.0
T_2	50.2	45.9	831.3	740.0	137.8	127.6
T_3	47.1	50.6	748.3	719.0	159.7	161.5
T_4	55.2	41.3	720.0	707.7	155.6	145.4
T_5	44.6	45.8	741.7	702.3	153.7	144.6
T_6	41.7	42.4	705.0	700.0	152.9	166.5
T_7	47.7	45.1	696.7	654.3	155.8	157.1
T_8	36.7	52.4	670.0	649.0	146.8	138.5
F test	S	S	S	S	S	S
CD(0.05)	0.87	4.52	10.73	6.15	0.26	1.39
SE	0.40	2.11	5.00	2.87	0.12	0.65

S - significant.

the other treatments followed by T_2.

4.3.5.4. Phosphorus fixing capacity of the soil.

The data on mean phosphorus fixing capacity of the soil are presented in Table 32.

The data revealed that there was significant difference between treatments. Treatment T_6 recorded the highest value which was significantly superior to all the other treatments followed by T_3.

4.3.5.5. Available potassium

The data on mean available potassium content of soil are presented in Table 31.

It revealed that there was significant difference between treatments during both the years. The treatment T_2 recorded the highest available potassium content of 220 kg/ha in the first year which was significantly superior to all the other treatments.

In the second year T_7 recorded the highest value which was on par with T_2 and T_5 but significantly superior to the others.

4.3.5.6. Correlation studies

It could be seen from Table 33 that phosphorus uptake was significantly and positively correlated with dry matter yield, nitrogen uptake and potassium uptake

Table 33. Intercorrelation matrix involving the variables P-uptake (X_1), dry matter yield (X_2) grain yield (X_3), availabe phosphorus content of the soil (X_4) N-uptake (X_5) K-uptake (X_6) - third crop of cowpea

Variables	X_1	X_2	X_3	X_4	X_5	X_6
X_1		0.9059**	0.2176	-0.1239	0.8650**	0.5415**
X_2	0.8757**		0.1475	0.1572	0.9470**	0.4276*
X_3	0.6959**	0.5625**		-0.0469	0.1294	0.2434
X_4	-0.2140	-0.2068	0.4743		0.0925	-0.2378
X_5	0.7838**	0.9251**	0.5587**	-0.1119		0.4419
X_6	0.8621**	0.8384**	0.5128*	-0.4203	0.6134**	

Figures in the upper and lower diagonals are respectively the correlations for First (1984-85) and Second (1985-86) years.

* Significant at 5% probability level.

** Significant at 1% probability level.

during both the years and also with grain yield in the second year.

Dry matter yield was significantly and positively correlated with nitrogen uptake and potassium uptake during both the years and also with grain yield during the second year.

Grain yield was significantly and negatively correlated with available phosphorus content of the soil and positively correlated with nitrogen uptake and potassium uptake during the second year.

Available phosphorus content of the soil was significantly negatively correlated with potassium uptake during the second year.

Nitrogen uptake was significantly and positively correlated with potassium uptake during both the years.

4.3.6. Growth attributes of sesamum

4.3.6.1. Plant height

The observations on plant height were recorded at 30 DAS, at 50 DAS and at harvest. The data on mean height of plants are presented in Table 34.

There was significant difference between the treatments in plant height at 30 DAS during the first and second years. In the first year T_7 recorded the maximum plant height

Table 34. Height of plants of third crop of sesamum (cm.)

Treatments	30 DAS		50 DAS		Harvest	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	47.9	44.9	119.8	100.3	130.0	101.8
T_2	44.8	35.1	114.9	104.1	117.3	116.1
T_3	49.2	40.7	124.3	116.5	131.9	111.0
T_4	49.7	31.5	122.4	94.1	125.5	100.4
T_5	47.5	46.7	118.2	115.9	131.4	112.1
T_6	45.0	41.4	118.8	101.9	139.1	104.3
T_7	51.7	42.6	133.0	111.1	148.5	111.7
T_8	43.5	32.0	118.2	98.0	120.4	103.5
F test	S	S	NS	S	S	NS
CD(0.05)	4.93	7.16	-	11.88	13.29	-
SE±	2.30	3.34	6.29	5.54	6.19	5.21

NS - Not significant.

S - Significant.

which was significantly superior to T_2, T_6 and T_8 and was on par with the others. In the second year T_5 recorded the maximum plant height, which was significantly superior to T_2, T_4 and T_8 but was on par with T_1, T_3, T_6 and T_7.

At 50 DAS there was no significant difference between treatments in the first year, but the maximum height was recorded by T_7. During the second year there was significant difference between treatments. The treatment T_3 recorded the maximum height which was on par with T_5 and T_7 but significantly superior to the other treatments.

At harvest stage also there was significant difference between treatments in the first year, The treatment T_7 recorded the maximum plant height which was significantly superior to T_2, T_4 and T_8 but was on par with the others. During the second year no significance was observed.

4.3.6.2. Number of leaves/plant

The observation on leaf number were recorded at 30 DAS and 50 DAS. The data on mean number of leaves are presented in Table 35.

The data revealed that there was significant difference in the number of leaves at 30 DAS both in the first and second years. In the first year T_7 recorded

TABLE 35. Number of leaves per plant and leaf area index of third crop of sesamum

Treatments	Number of leaves				Leaf area index			
	30 DAS		50 DAS		30 DAS		50 DAS	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	21.7	8.4	60.1	29.2	0.67	0.26	1.75	0.85
T_2	18.4	9.4	33.8	34.7	0.37	0.19	0.98	0.01
T_3	16.4	8.4	59.6	36.8	0.42	0.22	1.73	1.07
T_4	21.9	8.2	64.2	32.8	0.81	0.30	1.86	0.95
T_5	19.3	10.8	67.4	42.4	0.60	0.34	1.96	1.23
T_6	20.6	9.0	70.0	32.0	0.64	0.27	2.04	0.92
T_7	26.3	10.4	70.3	39.0	1.44	0.60	2.04	1.13
T_8	20.2	9.2	52.0	33.4	0.41	0.19	1.53	0.97
F test	S	S	S	NS	S	NS	S	NS
CD(0.05)	3.87	1.13	5.41	--	0.55	--	0.15	--
SE	1.81	0.53	2.52	4.08	0.25	0.12	0.07	0.12

NS - Not significant. S - Significant.

the highest number which was significantly superior to all the other treatments. In the second year T_5 recorded the highest number which was on par with T_7, but significantly superior to all the other treatments.

At 50 DAS, there was significant difference between treatment during the first year. T_7 recorded the highest number which was on par with T_6 and T_5 but significantly superior to all the others. In the second year the difference was not significant. However T_5 recorded the highest number followed by T_7.

4.3.6.3. Leaf area index (LAI)

The observations on leaf area index were recorded at 30 DAS and at 50 DAS. The data on mean leaf area index are presented in Table 35.

The data revealed significant difference between treatments at 30 DAS during the first year. T_7 recorded the highest LAI which was significantly superior to all the other treatments. In the second year, T_7 recorded the highest LAI eventhough the difference was not significant.

At 50 DAS, there was significant difference between treatments in the first year, T_7 and T_6 recording the highest LAI values which were on par with T_5, but significantly superior to all other treatments. In the second year the treatment difference was not significant. However T_5 recorded the highest number closely followed by T_7.

4.3.6.4. Number of branches/plant

The data on mean number of branches/plant are presented in Table 37.

There was significant difference between treatments during both the years. In both the first and second years, T_7 recorded the highest number of branches of 4.5 and 3.4 respectively, which was significantly superior to the other treatments, except T_1 in the first year and T_2 and T_3 in the second year.

4.3.6.5. Dry matter production

The observations on dry matter production were recorded at 30 DAS, 50 DAS and at harvest. The data on mean dry matter production are presented in Table 36.

The data revealed significant difference between treatments at 30 DAS in the first year. T_7 recorded the highest dry matter which was significantly superior to all treatments except T_1.

At 50 DAS, there was no significant difference between treatments in the first year, but in the second year there was significant difference. The treatment T_7 recorded the highest dry matter which was significantly superior to all the other treatments except T_5.

Table 36. Dry matter production of third crop of sesamum (kg/ha)

Treatments	30 DAS I year 1984-85	30 DAS II year 1985-86	50 DAS I year 1984-85	50 DAS II year 1985-86	Harvest I year 1984-85	Harvest II year 1985-86
T_1	583.--	312.5	3416.7	2475.0	57[illegible].4	2675.0
T_2	500.0	327.9	3166.7	2733.3	4274.9	3237.5
T_3	500.0	312.5	3083.4	1908.3	6083.4	2312.5
T_4	416.7	250.0	4166.7	2008.3	3916.7	2412.5
T_5	250.0	345.8	283[illegible].4	5[illegible]83.3	6833.3	2468.3
T_6	550.0	250.0	4166.7	2008.3	3916.7	2412.5
T_7	666.7	312.5	4250.0	3433.3	7583.4	3908.3
T_8	333.3	233.3	2166.7	1744.6	4783.4	2075.0
F test	S	NS	NS	S	S	S
CD(0.05)	144.62	-	-	669.29	1271.34	937.72
SE	67.42	53.70	812.39	312.02	592.70	437.17

NS - Not significant.

S - Significant.

At harvest stage, there was significant difference between the treatments during both the years. T_7 recorded the highest dry matter production of 7583.4 kg in the first year and 3968.3 kg in the second year and was significantly superior to all the other treatments except T_5 in the first year and T_2 in the second year.

4.3.7. Yield attributes of sesamum

4.3.7.1. Number of pods/plant

The data on mean number of pods/plant are presented in Table 37.

The data on the number of pods revealed that there was no significant difference between treatments in the first year, whereas significant difference occured between treatments in the second year. In the second year T_7 recorded the maximum number of 27.5 pods/plant which was on par with T_5 and was significantly superior to all the other treatments. In the first year eventhough there was no significant difference between treetments, T_5 gave the highest number of 35.3 pods/plant followed by T_7 (33.8).

4.3.8. Yield of sesamum

4.3.8.1. Seed yield

The data on mean seed yield are presented in Table 38 and Fig. 9.

It was seen that there was no significant difference

Table 37. Number of pods and number of branches per plant of third crop of sesamum

Treatments	Number of pods		Number of branches	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	28.2	18.7	4.2	2.5
T_2	25.5	20.6	3.3	3.3
T_3	26.4	18.7	3.1	3.0
T_4	37.4	17.1	8.5	1.3
T_5	35.3	24.0	5.1	2.5
T_6	33.5	18.6	5.5	2.5
T_7	37.8	27.5	4.3	[illegible]
T_8	34.9	16.5	3.3	2.0
F test	NS	S	S	S
CD(0.05)	-	4.05	0.15	0.46
SE	[illegible].08	1.86	0.07	0.22

NS - Not significant.

S - Significant.

Table 38. Seed yield and bhusa yield of third crop of sesamum (kg/ha)

Treatments	Seed yield		Bhusa yield	
	I year 1984–85	II year 1985–86	I year 1984–85	II year 1985–86
T_1	532.5	421.7	1326.3	500.0
T_2	555.8	465.0	1296.7	725.0
T_3	506.7	406.7	1213.3	603.3
T_4	488.3	385.0	1595.0	[illegible]
T_5	560.0	490.0	1105.0	[illegible]
T_6	475.8	391.7	973.3	700.0
T_7	613.3	433.3	1388.3	930.7
T_8	450.0	355.0	[illegible]	620.0
F test	NS	NS	NS	NS
SE	70.88	76.11	285.46	132.15

NS - Not significant.

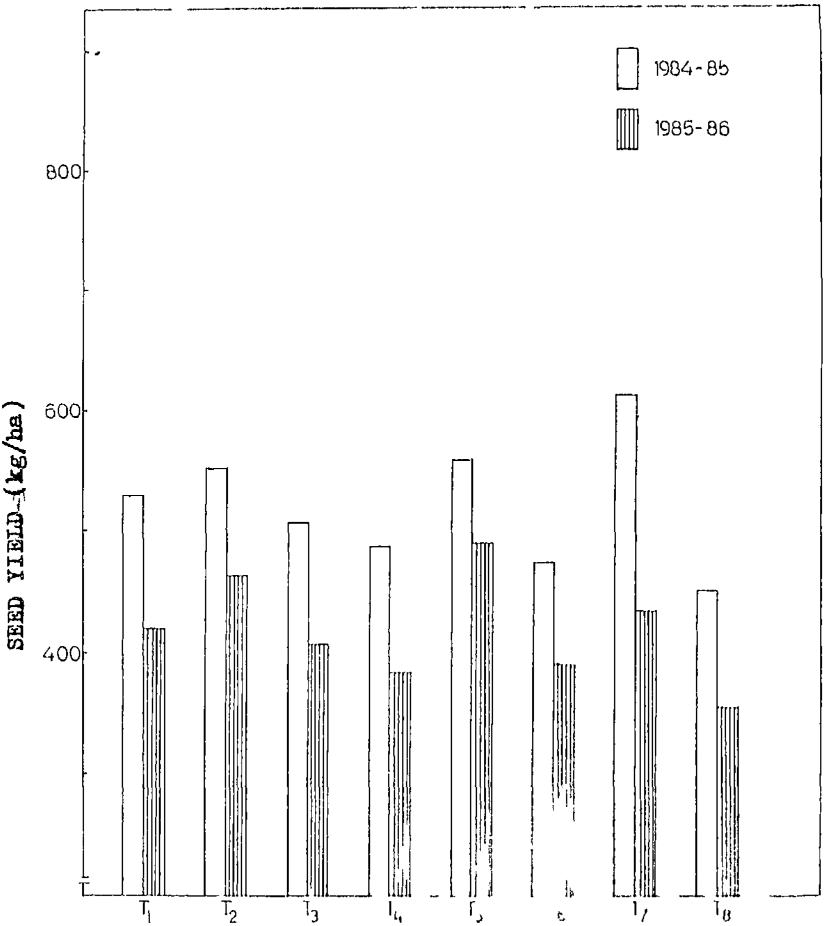


FIG. 9 SEED YIELD OF THIRD CROP OF SESAMUM

between treatments in seed yield of sesamum during both the years. However T_7 recorded the highest yield of 613.3 kg/ha in the first year and T_5 in the second year.

4.3.8.2. Bhusa yield

The data on mean bhusa yield are presented in Table 38.

The data revealed no significant difference between treatments during both the years.

4.3.9. Uptake of major nutrients by sesamum

4.3.9.1. Nitrogen uptake

The data on mean nitrogen uptake by the crop at harvest are presented in Table 39.

The data revealed significant difference in nitrogen uptake between treatments during both the years. The treatment T_5 recorded the highest nitrogen uptake which was on par with T_7 but significantly superior to all the other treatments in the first year. In the second year T_7 recorded the highest uptake which was on par with T_2, T_5 and T_6.

4.3.9.2. Phosphorus uptake

The observations on phosphorus uptake were recorded at 30 DAS, 50 DAS and at harvest. The data on mean phosphorus uptake are presented in Table 40 and Fig. 10.

The data on phosphorus uptake revealed that at 30 DAS

Table 39. Nitrogen and potassium uptake at harvest by third crop of sesamum (kg/ha)

Treatments	Nitrogen uptake		Potassium uptake	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	86.2	34.90	108.5	[illegible]3.7
T_2	91.0	63.50	99.5	74.9
T_3	71.6	39.7	91.6	51.3
T_4	96.7	39.1	91.6	57.[illegible]
T_5	144.9	52.4	140.1	50.6
T_6	100.5	56.2	84.6	54.8
T_7	130.1	68.8	144.3	75.3
T_8	107.5	45.6	1[illegible]9.1	44.0
F test	[illegible]	[illegible]	[illegible]	[illegible]
CD(0.05)	27.77	18.41	19.38	17.97
SD	12.95	8.58	9.03	8.38

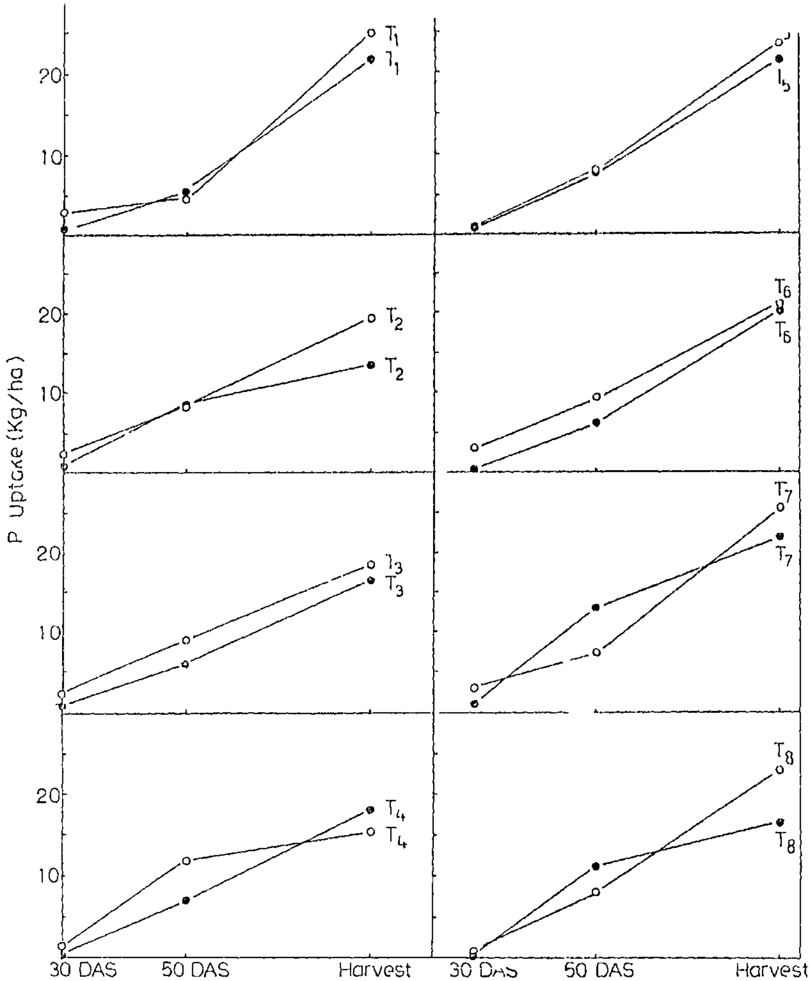
S - Significant.

Table 40. Phosphorus uptako by third crop of sosamum (kg/ha)

Treatments	30 DAS		50 DAS		Harvest	
	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86	I year 1984-85	II year 1985-86
T_1	2.92	0.99	4.59	5.88	24.90	21.90
T_2	2.55	1.11	8.95	9.06	19.50	13.80
T_3	2.77	1.05	9.16	6.20	18.50	16.70
T_4	1.88	0.66	12.16	7.17	15.10	18.14
T_5	1.33	1.18	8.07	8.02	23.50	21.50
T_6	3.18	0.55	9.48	6.70	21.40	20.90
T_7	3.46	1.03	7.42	13.39	25.50	22.20
T_8	1.34	0.92	6.71	11.39	25.50	16.50
F test	S	NS	NS	S	NS	S
CD(0.05)	0.74	-	-	1.81	-	5.50
SE	0.35	0.24	2.29	0.84	4.52	2.57

NS - Not significant.

S - Significant.



I year (1984-85) II year (1985-86)

FIG. 10 PHOSPHORUS UPTAKE BY THIRD CROP OF SESAMUM the uptake was significantly different between different treatments during the first year, but was not significant in the second year. In the first year, T_7 recorded the highest uptake which was significantly superior to T_2, T_4, T_5 and T_8. In the second year though there was no significant difference T_5 recorded the highest value.

At 50 DAS, the data revealed significant difference between treatments in the second year, but not in the first year. In the second year, T_7 recorded the highest uptake which was significantly superior to all the other treatments.

At harvest stage also phosphorus uptake recorded significant difference between the treatments during the second year. In the second year T_7 recorded the highest uptake which was significantly superior to T_2 and T_8 but was on par with the rest. In the first year though not significant T_7 recorded the highest uptake followed by T_4.

4.3.9.3. Potassium uptake

The data on mean potassium uptake are presented in Table 39.

The data revealed significant difference between treatments during both the years. The treatment T_7 recorded the highest uptake which was significantly superior to all the other treatments except T_5 and T_8 in the first year and T_2 in the second year.

4.3.10. Soil nutrient status after the third crop of sesamum

4.3.10.1. Available nitrogen

The data on mean available nitrogen content of the soil are presented in Table 41.

The data revealed significant difference in nitrogen content by the different treatments during both the years. Treatment T_7 recorded the highest nitrogen content which was significantly superior to all the other treatments in the first year but was on par with T_6 in the second year.

4.3.10.2. Available phosphorus

The data of mean available phosphorus content of the soil are presented in Table 41 and Fig. 11.

The data on available phosphorus content of the soil revealed significant difference between treatments during both the years. In the first year the treatment T_4 recorded the highest value of available phosphorus which was significantly superior to all the other treatments.

In the second year T_1 recorded the highest value which was on par with T_2 but was significantly superior to all the other treatments.

4.3.10.3. Total phosphorus

The data on mean total phosphorus content of the soil are recorded in Table 41.

Total phosphorus content of the soil recorded significant difference between treatments during both the

Table 41. Available nitrogen, available potassium, available and total phosphorus and phosphorus fixing capacity of the soil after the third crop of sesamum (kg/ha)

Treatments	Available nitrogen I Year 1984-85	Available nitrogen II Year 1985-86	Available potassium I Year 1984-85	Available potassium II Year 1985-86	Available phosphorus I Year 1984-85	Available phosphorus II Year 1985-86	Total Phosphorus I Year 1984-85	Total Phosphorus II Year 1985-86	P fixing Capacity I Year 1984-85
T_1	315.0	317.7	155.0	158.3	49.7	54.6	738.3	755.7	160.6
T_2	392.3	393.0	255.0	245.3	42.3	53.[illegible]	718.3	740.0	176.0
T_3	289.0	291.7	211.7	215.0	42.7	46.6	696.7	704.0	165.3
T_4	589.0	584.3	355.0	336.5	59.2	40.2	670.0	635.0	151.9
T_5	278.3	281.7	255.0	245.0	43.6	45.5	670.0	752.3	146.7
T_6	544.3	545.3	255.0	230.0	55.4	45.1	655.0	600.0	151.6
T_7	571.9	572.3	351.0	310.0	45.6	44.2	640.0	689.0	162.8
T_8	440.7	442.3	130.7	195.0	35.4	32.1	568.3	524.3	158.9
F test	S	S	S	S	S	S	S	S	S
CD(0.05)	26.84	30.25	71.93	13.85	1.04	3.76	11.25	6.63	0.37
SE	12.51	14.10	33.56	6.45	0.48	1.76	5.24	3.09	0.17

S - significant.

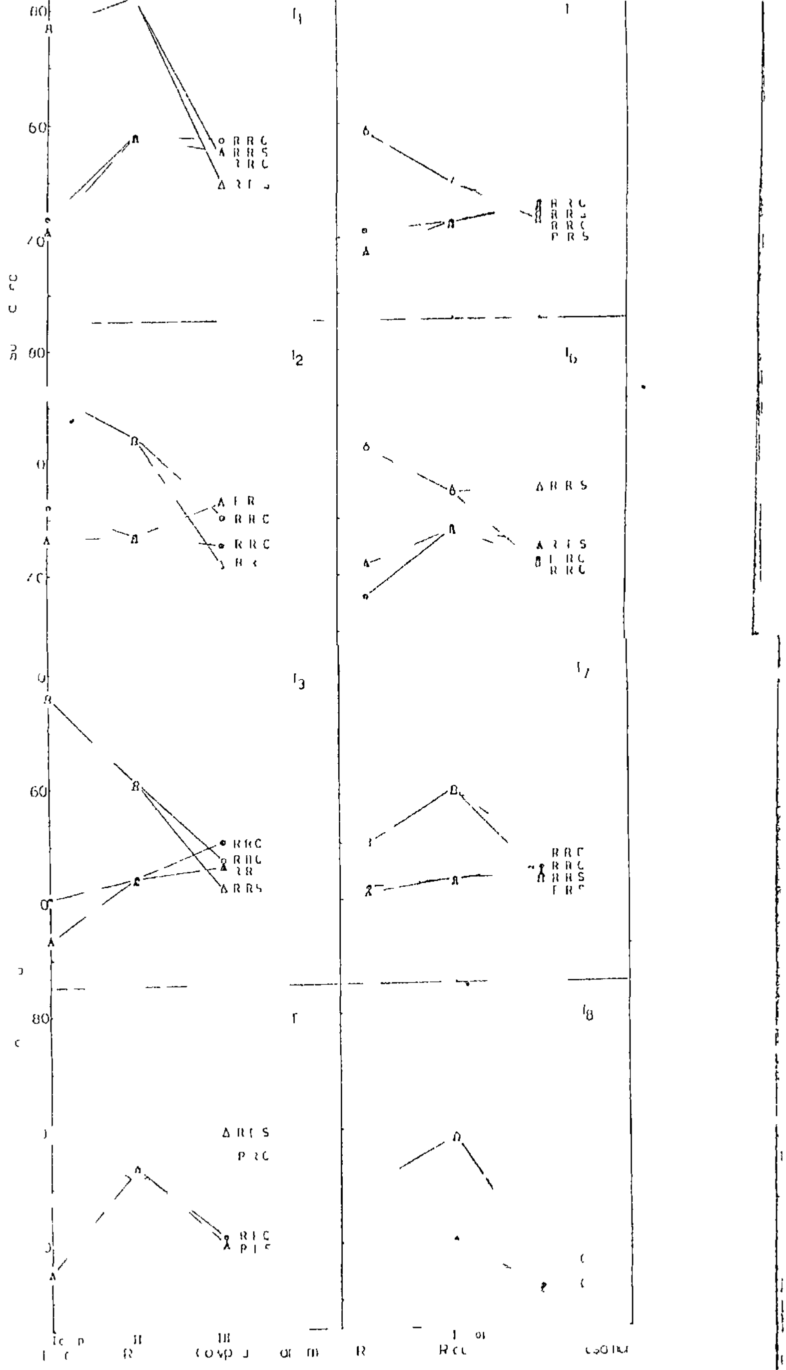


FIG. 11 AVAILABLE PHOSPHORUS STATUS OF THE SOIL AFTER THE

years. T_1 recorded the highest value which was significantly superior to all the other treatments except T_5 in the second year.

4.3.10.4. Phosphorus fixing capacity of the soil.

The data on mean phosphorus fixing capacity of the soil are presented in Table 41.

The data revealed significant difference between treatments. The treatment T_2 recorded the highest value which was significantly superior to all the other treatments.

4.3.10.5. Available potassium

The data on mean available potassium of the soil are presented in Table 41.

There was significant difference between treatments during both the years. Treatment T_4 recorded the highest available potassium which was significantly superior to all the other treatments except T_7 in the first year.

4.3.11. Correlation studies

It can be seen from Table 42 that phosphorus uptake was significantly and positively correlated with dry matter yield, nitrogen uptake and potassium uptake in the first year and negatively correlated with available phosphorus content of the soil during the second year.

Dry matter yield was positively and significantly correlated with grain yield, nitrogen uptake and potassium uptake during both the years.

Table 42. Intercorrelation matrix involving the variables P-uptake (X_1), dry matter yield (X_2) grain yield (X_3), available phosphorus content of the soil (X_4) N-uptake (X_5) and K-uptake (X_6) - third crop of sesamum

Variables	X_1	X_2	X_3	X_4	X_5	X_6
X_1		0.7591**	-0.0526	0.0498	0.4918*	0.6744**
X_2	0.0151		0.4134*	-0.1684	0.5680**	0.9449**
X_3	-0.0014	0.4777*		0.0558	0.1991	0.4269*
X_4	-0.4578*	0.3007	0.4114*		0.2635	-0.2186
X_5	-0.0400	0.7948**	0.4259*	0.0251		0.7215**
X_6	-0.1654	0.9358**	0.5162*	0.3296	0.8913**	

Figures in the upper and lower diagonals are respectively the correlations for First (1984-85) and second (1985-86) years.

* Significant at 5% probability level.

** Significant at 1% probability level.

Grain yield was significantly and positively correlated with potassium uptake during both the years and also positively correlated with available phosphorus content of the soil and nitrogen uptake during the second year.

Nitrogen uptake was significantly positively correlated with potassium uptake during both the years.

4.4. Effect of phosphorus on the first crop of rice after cowpea and sesamum

(Direct, residual and cumulative effects of phosphorus fertilisation)

4.4.1. Growth attributes of rice after cowpea

4.4.1.1. Plant height

The observations on plant height were recorded at 30 DAT, at flowering and at harvest. The data on mean height of plants are presented in Table 43.

The data on plant height revealed no significant difference between treatments at any of the growth stages during both the years.

4.4.1.2. Number of tillers per hill

The observations on tiller number were recorded at 30 DAT, at flowering and at harvest. The data on mean tiller number are presented in Table 44.

The data on tiller number revealed that there was no significant difference between the treatments at 30 DAT

Table 43. Height of plants of Bir ... crop ... [illegible]

co... (.)

Treatments	30 [illegible]		Flowering		Harvest	
	I year 1965-66	II year 1966-67	I year 1965-67	II year 1966-67	I year 1965-66	II year 1966-67
T_1	36.7	32.9	75.5	[illegible]	73.[illegible]	62.C
T_2	39.3	34.5	68.[illegible]	[illegible]	73.[illegible]	65.5
T_3	40.[illegible]	32.2	[illegible]0.1	57.[illegible]	72.[illegible]	5[illegible].3
T_4	[illegible]	33.4	73.4	59.8	71.[illegible]	[illegible]3.5
T_5	[illegible].8	34.[illegible]	65.6	[illegible].3	[illegible]	66.0
T_6	38.1	[illegible]	[illegible]4.1	[illegible]	[illegible]	65.7
T_7	3[illegible]	[illegible]	[illegible].0	[illegible]	[illegible]	55.1
T_8	[illegible]	32.6	[illegible].3	[illegible]	[illegible]	[illegible].0
[illegible]	NS	NS	NS	[illegible]	[illegible]	NS
[illegible]	3.[illegible]	1.18	3.95	2.55	2.93	2.23

NS - Not significant.

Table 44. Number of tillers per hill of first crop of rice after cowpea

Treatments	30 DAT		Flowering		Harvest			
					Total tillers		Productive tillers	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	5.7	5.9	6.0	6.6	4.7	5.3	4.4	4.3
T_2	6.2	5.5	7.6	6.4	4.4	4.5	4.4	3.6
T_3	6.3	5.8	6.3	6.5	4.3	4.8	4.2	4.3
T_4	6.2	6.2	6.0	6.8	5.0	4.8	4.9	4.0
T_5	6.0	7.1	7.5	7.5	4.9	5.4	4.7	5.1
T_6	6.3	6.2	6.5	7.4	4.8	5.2	4.3	4.7
T_7	6.8	5.6	6.5	6.5	5.4	5.0	5.3	3.8
T_8	5.3	5.7	5.4	6.1	5.0	4.2	5.0	4.1
F test	NS	S	S	S	NS	S	NS	S
CD(0.05)	-	0.35	0.95	0.47	-	0.47	-	0.62
SE	0.65	0.16	0.44	0.22	0.48	0.22	0.44	0.29

NS - Not significant.

S - Significant.

during the first year. During the second year the treatment effect was significant, with T_5 recording the highest number which was significantly superior to all the other treatments.

At flowering stage there was significant difference between treatments during both the years. In the first year T_7 recorded the highest number which was on par with T_2 and T_5 but significantly superior to all the other treatments. In the second year T_5 recorded the highest number which was on par with T_6.

At harvest stage, there was no significant difference between treatments with regard total tillers during the first year, but the difference was significant during the second year. The treatment T_5 recorded the highest number which was on par with T_1, T_6 and T_7 but was significantly superior to all the other treatments. The productive tillers at harvest stage also showed no significant difference in the first year, but significant difference was observed during the second year. The treatment T_5 recorded the highest number which was on par with T_6, but was significantly superior to all the other treatments.

4.4.1.3. Leaf area index (LAI)

The observations on LAI were recorded at 30 DAT and at flowering. The data on mean LAI are presented in Table 45.

Table 45. Leaf area index (LAI) of first crop of rice after cowpea

Treatments	30 DAT		Flowering	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	1.7	1.4	2.5	2.5
T_2	1.1	1.0	2.1	2.0
T_3	0.93	1.1	2.6	2.5
T_4	1.3	1.3	2.1	2.1
T_5	1.5	1.4	1.7	1.7
T_6	1.5	1.5	2.3	2.3
T_7	1.6	1.6	2.9	2.8
T_8	1.7	1.6	1.9	1.8
F test	NS	NS	NS	S
CD(0.05)	-	-	-	0.62
SE	0.51	0.22	0.45	0.29

NS - Not significant.

S - Significant.

The data on LAI revealed that there was no significant difference between the treatments at 30 DAT during both the years. At flowering stage while LAI recorded no significant difference during the first year, there was significant difference in the second year. T_7 recorded the highest LAI which was on par with T_1, T_3, and T_6. In the first year, though not significant T_7 recorded the highest LAI.

4.4.1.4. Dry matter production

The observations on dry matter production were recorded at 30 DAT, at flowering and at harvest. The data on mean dry matter production are presented in Table 46.

The data revealed no significant difference between the treatments in any of the growth stages during both the years except at 30 DAT during the second year. At 30 DAT during the second year, T_1 recorded the highest dry matter which was significantly superior to T_5, T_6 and T_8 but was on par with the others.

4.4.2. Yield attributes of rice after cowpea

4.4.2.1. Number of panicle/sq.m.

The data on mean panicle number/sq.m. are presented in Table 47.

There was no significant difference between treatments in the first year, but the difference was signifi-

Table 46. Dry matter production of first crop of rice after cowpea (kg/ha)

Treatments	30 DAT I year 1985-86	30 DAT II year 1986-87	Flowering I year 1985-86	Flowering II year 1986-87	Harvest I year 1985-86	Harvest II year 1986-87
T_1	1555.7	1275.7	5333.3	4373.4	9667.7	7460.0
T_2	1611.0	1092.4	5667.0	3842.4	10338.7	6946.1
T_3	1055.3	1106.4	6222.3	3993.2	6850.0	4538.9
T_4	1444.0	1016.5	6222.0	4379.8	9003.3	5830.2
T_5	1055.7	903.7	4944.7	3920.8	9000.0	5976.9
T_6	999.7	846.6	6000.3	4261.6	8020.0	5604.4
T_7	1444.7	1015.6	6222.3	4374.0	10270.9	6556.3
T_8	1666.7	810.6	4888.7	3245.3	8007.7	5109.0
F test	NS	S	NS	NS	NS	NS
CD(0.05)	-	269.64	-	-	-	-
SE	650.47	125.71	842.97	699.46	1909.60	836.97

NS - Not significant.

S - Significant.

Table 47. Yield attributes of first crop of rice after cowpea

Treatments	Number of panicle/ m^2		Number of grains/ panicle		1000 grain weight (g)	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II yea 1986-8
T_1	294.5	283.3	47.3	33.0	25.0	24.6
T_2	294.4	274.0	45.3	32.7	25.2	24.7
T_3	350.0	283.3	55.4	38.5	24.9	24.5
T_4	327.8	266.7	58.6	34.3	25.1	24.7
T_5	311.1	341.1	53.5	29.5	25.8	25.4
T_6	283.3	317.8	49.4	27.5	25.6	25.2
T_7	366.7	250.0	54.2	36.0	25.6	25.2
T_8	277.8	241.1	46.1	30.7	25.2	24.8
F test	NS	S	NS	NS	NS	NS
CD(0.05)	-	41.27	-	-	-	-
SE	29.50	19.24	11.95	8.21	0.85	0.85

NS - Not significant.

S - Significant.

cant during the second year. Treatment T_5 recorded the highest number which was significantly superior to all the treatments except T_6.

4.4.2.2. Number of grains/panicle

The data on mean number of grains/panicle are presented in Table 47.

The data revealed that there was no significant difference between treatments during both the years.

4.4.2.3. 1000 grain weight

The data on mean weight of 1000 grains are presented in Table 47.

The data revealed that there was no significant difference between the different treatments during both the years.

4.4.3. Yield of rice after cowpea

4.4.3.1. Grain yield

The data on mean grain yield are presented in Table 48, and Fig. 12.

The data revealed no significant influence on grain yield by the different treatments during both the years.

4.4.3.2. Straw yield

The data on mean straw yield are given in Table 48.

Table 48. Grain yield and straw yield of first crop of rice after cowpea (kg/ha)

Treatments	Grain yield I year 1985-86	Grain yield II year 1986-87	Straw yield I year 1985-86	Straw yield II year 1986-87
T_1	2738.3	1899.3	4417.4	3622.4
T_2	2666.0	1763.8	4436.5	3008.1
T_3	2731.5	1822.5	4561.9	2734.9
T_4	2882.8	1607.9	4589.0	3230.6
T_5	3178.6	1510.8	4527.9	3748.9
T_6	2740.5	1560.5	4356.4	3398.8
T_7	2828.6	1624.9	4561.9	3206.8
T_8	2616.3	1501.8	4261.5	3028.4
F test	NS	NS	NS	NS
SE	382.52	182.66	667.92	614.42

NS - Not significant.

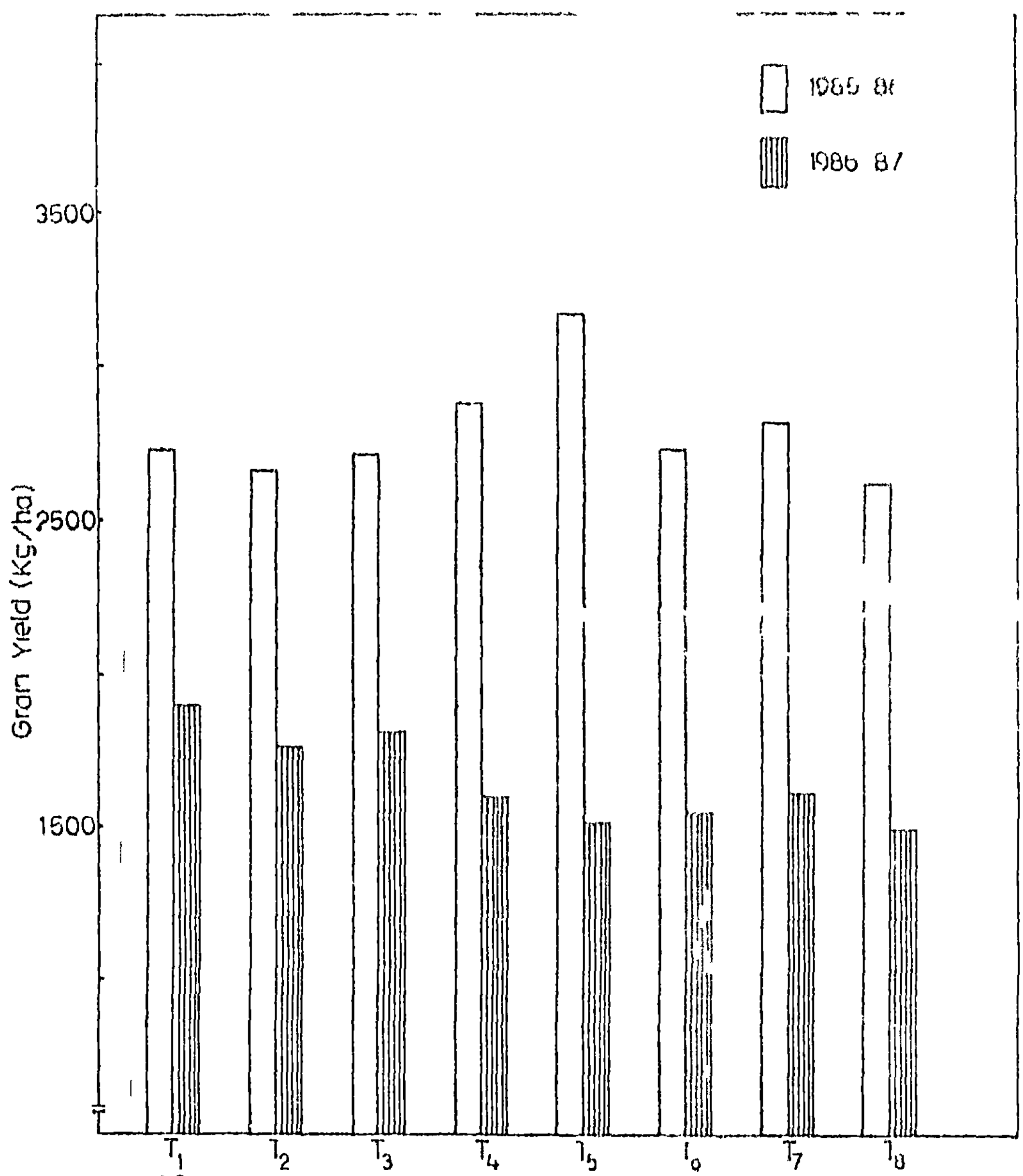


FIG. 12 GRAIN YIELD OF FIRST CROP OF RICE AFTER COWPEA

Table 49. Nitrogen and potassium uptake by the first crop of rice after cowpea (kg/ha)

Treatments	Nitrogen uptake		Potassium uptake	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	94.7	73.4	105.8	85.1
T_2	84.8	56.5	125.9	89.2
T_3	69.5	46.0	62.4	41.5
T_4	94.5	61.3	117.4	78.1
T_5	69.2	46.6	72.4	50.0
T_6	90.3	61.9	89.0	62.3
T_7	121.5	78.2	118.8	76.6
T_8	91.3	57.5	96.5	61.8
F test	NS	NS	S	S
CD(0.05)	-	-	19.15	24.47
SE	18.88	10.91	8.93	11.41

NS - Not Significant.

S - Significant.

There was no significant difference between the treatments with regard to straw yield during both the years.

4.4.4. Uptake of major nutrients by rice crop after cowpea

4.4.4.1. Nitrogen uptake

The data on mean uptake of nitrogen by rice crop at harvest are presented in Table 49.

The data revealed no significant difference between the treatments during both the years. However T7 recorded the highest uptake in both the years, though not significant.

4.4.4.2. Phosphorus uptake

The observations on phosphorus uptake were recorded at 30 DAT, at flowering and at harvest. The data on mean phosphorus uptake are presented in Table 50 and Fig. 13.

The phosphorus uptake by rice revealed no significant difference between treatments in any of the growth stages of the plant during both the years. However at 30 DAT, T_1, and at flowering and at harvest T_7 recorded the highest values during both the years.

4.4.4.3. Potassium uptake

The data on mean potassium uptake at harvest are recorded in Table 49.

Table 50. Phosphorus uptake by the first crop of rice after cowpea (kg/ha)

Treatments	30 D A T		Flowering		Harvest	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	4.9	4.4	17.1	13.9	27.9	21.3
T_2	4.6	3.6	18.7	12.7	28.8	19.6
T_3	4.2	3.2	18.2	11.7	20.5	13.6
T_4	3.9	3.1	18.5	13.1	28.1	18.3
T_5	3.5	3.0	14.7	11.6	25.9	17.2
T_6	3.6	3.0	17.5	11.9	24.0	16.6
T_7	3.8	3.3	20.3	14.3	33.4	21.8
T_8	4.6	3.5	17.3	11.3	23.7	15.1
F test	NS	NS	NS	NS	NS	NS
SE	0.88	0.88	2.67	2.11	5.24	2.49

NS - Not significant.

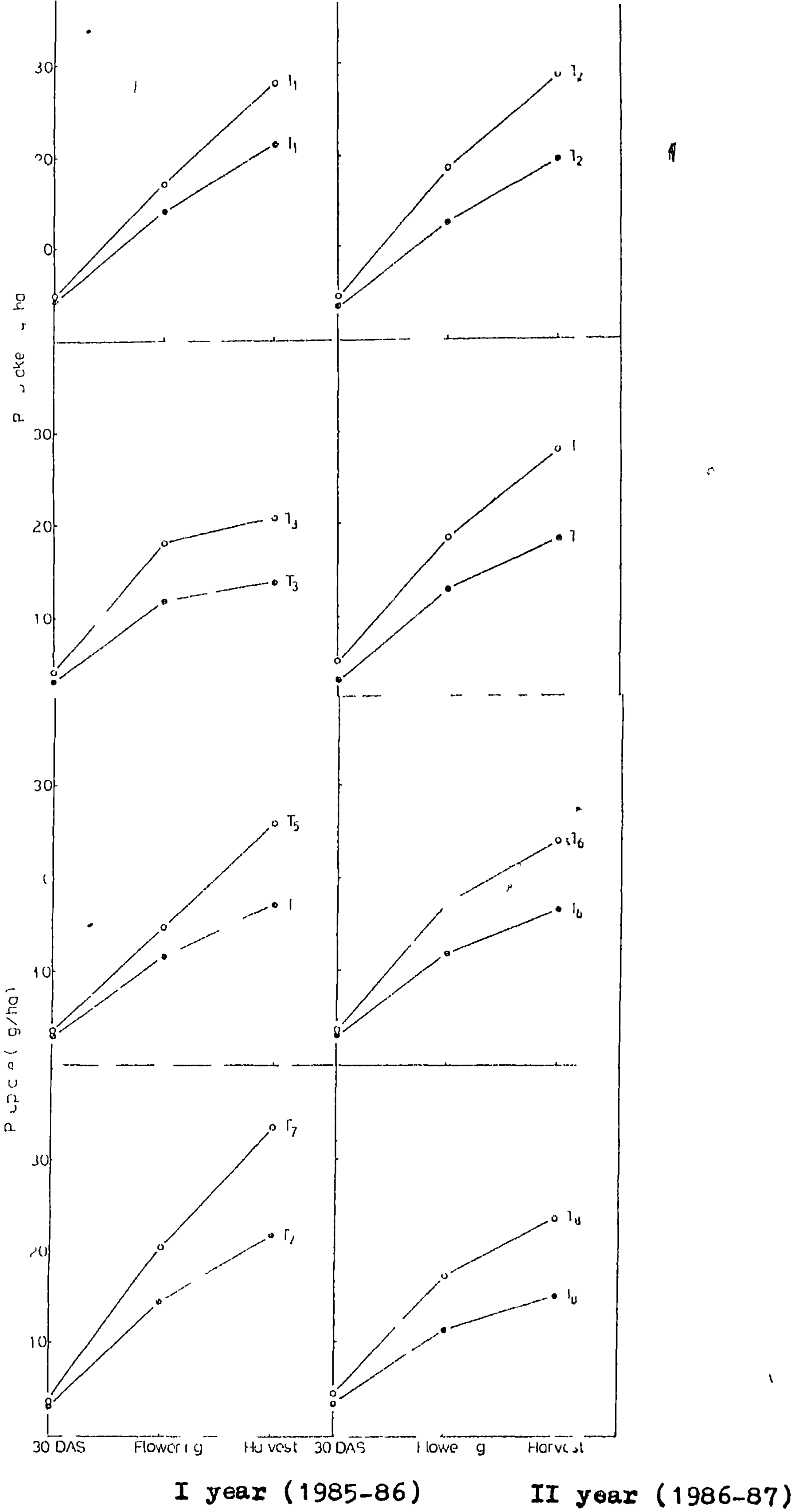


FIG. 13 PHOSPHORUS UPTAKE BY FIRST CROP OF RICE

The data revealed significant difference between treatments during both the years. T_2 recorded the highest value, which was on par with T_4 and T_7 in the first year and with T_1, T_4 and T_7 in the second year, but significantly superior to all the other treatments.

4.4.5. Soil nutrient status after the first crop of rice raised after cowpea

4.4.5.1. Available nitrogen

The data on mean available nitrogen content of the soil are presented in Table 51. The data on available nitrogen content of the soil revealed significant difference betwcen the treatments during both the years. The treatment T_5 recorded the highest value which was significantly superior to all the other treatments.

4.4.5.2. Available phosphorus

The data on mean available phosphorus content of the soil are presented in Table 51.

The data revealed significant difference between treatments during both the years. In the first year T_2 recorded the highest available P content of soil which was significantly superior to all the other treatments.

In the second year T_1 recorded the highest value, which was on par with T_2 and T_4 but was significantly superior to all the other treatments.

Table 51. Available Nitrogen, available potassium, available phosphorus, total phosphorus and P fixing capacity of the soil after the first crop of rice raised after cowpea (kg/ha)

Treatments	Available nitrogen		Available potassium		Available phosphorus		Total phosphorus		P fixing capacity
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86
T_1	419.0	415.7	250.0	196.7	43.5	50.3	803.3	868.5	155.9
T_2	456.3	452.3	186.7	176.7	52.1	48.0	765.0	748.2	154.3
T_3	347.7	344.7	306.7	253.3	40.6	44.3	771.7	854.4	161.2
T_4	449.9	447.0	186.7	163.3	48.6	47.6	760.0	718.4	148.8
T_5	522.7	520.7	123.3	120.0	41.4	38.8	711.7	739.9	158.2
T_6	355.0	352.3	120.0	110.0	36.2	41.7	696.7	681.7	155.8
T_7	439.0	432.3	143.3	139.9	42.2	39.3	673.3	649.0	160.4
T_8	483.3	480.0	136.7	133.3	38.9	34.5	650.0	637.4	157.6
F test	S	S	S	S	S	S	S	S	S
CD(0.05)	2.09	2.56	13.98	33.34	0.69	3.63	13.09	61.61	0.35
SE	0.98	1.19	6.52	15.54	0.33	1.69	6.10	28.72	0.16

S - Significant.

4.4.5.3. Total phosphorus

The data on mean total phosphorus content of the soil are presented in Table 51.

The data revealed significant difference between treatments during both the years. In the first year T_1 recorded the highest total phosphorus which was significantly superior to all the other treatments followed by T_3 which was on par with T_2 and T_4.

In the second year also T_1 recorded the highest value which was on par with T_3 followed by T_2.

4.4.5.4. Phosphorus fixing capacity of the soil

The data on mean phosphorus fixing capacity of the soil are presented in Table 51.

The data revealed significant difference between treatments.

The treatment T_3 recorded the highest value which was significantly superior to all the other treatments, followed by T_7. Treatment T_4 recorded the lowest value.

4.4.5.5. Available potassium

The data on mean available potassium content of the soil are presented in Table 51.

There was significant difference between treatments during both the years. T_3 recorded the highest value which was significantly superior to all the other treatments followed by T_1.

4.4.6. Correlation studies

It was seen from the Table 52 that phosphorus uptake was positively and significantly correlated with the dry matter yield, nitrogen uptake and potassium uptake during both the years and also with available phosphorus content of the soil during the second year.

Dry matter yield was positively and significantly correlated with available phosphorus content of the soil, nitrogen uptake and potassium uptake during both the years.

Available phosphorus content of the soil was significantly and positively correlated with potassium uptake during both the years.

Potassium uptake was significantly and positively correlated with nitrogen uptake during both the years.

Grain yield was significantly and positively correlated with available phosphorus content of the soil during the second year.

4.4.7. Grwoth attributes on rice after sesamum

4.4.7.1. Plant height

The observations on plant height were recorded at 30 DAT, at flowering and at harvest. The data on mean plant height are presented in Table 53.

Table 52. Intercorrelation matrix involving the variables P-uptake (X_1), dry matter yield (X_2), grain yield (X_3), available phosphorus content of the soil (X_4), N-uptake (X_5) and K-uptake (X_6) - first crop of rice after cowpea

Variables	X_1	X_2	X_3	X_4	X_5	X_6
X_1		0.9281**	0.2351	0.2987	0.7700**	0.8076**
X_2	0.9499**		0.2252	0.4830*	0.5572**	0.8044**
X_3	0.0721	0.2099		-0.0767	-0.1258	-0.1624
X_4	0.4445*	0.5161*	0.6870**		-0.0877	0.5970**
X_5	0.7977**	0.6312**	-0.0159	0.1759		0.7170**
X_6	0.8410**	0.8329**	0.2154	0.5383**	0.6949**	

Figures in the upper and lower diagonals are respectively the correlations for First (1985-86) and Second (1986-87) years.

* Significant at 5% probability level.

** Significant at 1% probability level.

Table 58. Height of plants of first crop of rice after sesamum (cm.)

Treatments	30 DAT		Flowering		Harvest	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	38.3	36.0	70.1	64.7	73.2	68.4
T_2	38.5	33.7	70.8	61.3	71.0	64.5
T_3	37.7	36.4	66.3	65.4	71.5	69.3
T_4	41.8	34.8	72.6	62.4	72.3	66.1
T_5	39.8	35.2	68.1	63.1	72.5	66.8
T_6	40.4	36.0	69.4	64.6	73.6	68.4
T_7	41.2	33.5	72.1	61.3	76.3	63.8
T_8	40.8	33.5	72.8	60.1	73.7	63.8
F test	NS	NS	NS	NS	NS	NS
SE	2.94	1.25	3.35	2.10	2.88	2.34

NS - Not significant.

The data on plant height revealed that there was no significant difference between treatments at any of the growth stages during both the years.

4.4.7.2. Number of tillers per hill

The observations on tiller number were recorded at 30 DAT, at flowering and at harvest. The data on mean tiller number are presented in Table 54.

It was seen that there was no significant difference in tiller number between treatments at any of the growth stages during both the years.

4.4.7.3. Leaf area index (LAI)

The observations on LAI were recorded at 30 DAT and at flowering. The data on mean LAI are presented in Table 55.

From the data on LAI it could be seen that there was no significant difference between the treatments at 30 DAT during the first year, but the difference was significant during the second year. T_6 recorded the highest LAI which was on par with T_1 but was significantly superior to all the other treatments. In the first year also T_6 recorded the highest value eventhough not significant.

At flowering stage, there was no significant difference between the treatments in the first year, but the treatment effects were significant during the second

Table 54. Number of tillers per hill of first crop of rice after sesamum

Treatments	30 DAT		Flowering		Harvest			
					Total tillers		Productive tillers	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	7.0	5.5	8.4	6.5	5.7	5.0	5.7	5.0
T_2	5.8	5.9	7.8	6.8	5.4	4.4	5.4	4.1
T_3	6.0	5.9	6.4	6.6	5.3	4.4	4.4	4.4
T_4	6.1	6.1	7.4	7.3	5.1	5.0	4.6	4.1
T_5	5.5	5.5	6.6	6.4	4.7	4.5	4.6	4.4
T_6	6.1	5.8	8.1	6.6	4.8	4.6	4.7	4.3
T_7	7.1	5.5	6.9	6.3	5.5	4.6	5.5	4.6
T_8	6.8	5.9	7.9	6.5	5.4	4.3	6.3	3.9
F test	NS	NS	NS	NS	NS	NS	NS	NS
SE	0.94	0.31	0.63	0.31	0.69	0.29	0.60	0.29

NS - Not significant.

Table 55. Leaf area index (LAI) of first crop or rice after sesamum

Treatments	30 DAT		Flowering	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	1.7	1.7	2.4	2.4
T_2	1.3	1.2	2.4	2.3
T_3	0.88	0.88	1.6	1.6
T_4	0.64	0.60	2.1	2.1
T_5	1.3	1.1	2.3	2.2
T_6	1.9	1.9	2.5	2.4
T_7	0.83	0.80	1.6	1.6
T_8	1.4	1.3	1.8	1.8
F_{test}	NS	S	NS	S
CD(0.05)	-	0.54	-	0.50
SE	0.54	0.25	0.53	0.24

NS - Not significant.

S - Significant.

year. T_6 and T_1 recorded the highest value, which were on par with T_2, T_4 and T_5 but significantly superior to the other treatments. Eventhough not significant the same trend was observed in the first year.

4.4.7.4. Dry matter production

The observations on dry matter production were recorded at 30 DAT, at flowering and at harvest. The data on mean dry matter production are presented in Table 56.

The data on dry matter production at 30 DAT revealed no significant difference between the treatments in the first year. However the differences was significant in the second year with T_1 recording the highest value and was significantly superior to all the other treatments. In the first year, though not significant, T_1 recorded the highest dry matter production.

At flowering stage, there was no significant difference between the treatments in the first year, but significant difference was observed in the second year. The treatment T_1 recorded the highest dry matter production which was significantly superior to all the other treatments.

At harvest stage also the dry matter production was not significant in the first year. In the second year T_1 recorded the highest value, which was significantly superior to all the other treatments. Though not significant

Table 56. Dry matter production of first crop of rice after sesamum (kg/ha)

Treatments	30 DAT		Flowering		Harvest	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	2055.7	1965.0	6112.3	5842.7	10247.7	8154.1
T_2	1277.7	1047.4	5333.3	4372.0	9436.7	7168.6
T_3	722.3	480.4	5611.0	3731.7	7936.7	4993.8
T_4	1111.0	666.3	6111.3	3665.5	7560.0	4471.0
T_5	1444.7	1148.6	6333.3	5036.0	9134.3	6629.2
T_6	2000.0	1583.9	4277.7	3387.8	7549.0	5247.1
T_7	1000.0	691.1	5555.7	3839.3	9229.0	6027.2
T_8	1611.0	1018.2	4111.0	2597.9	8030.0	4946.1
F test	NS	S	NS	S	NS	S
CD(0.05)	-	229.50	-	793.66	-	955.83
SE	617.63	106.99	1063.07	370.00	1004.76	445.61

NS - Not significant.

S - Significant.

the treatment T_1 recorded the highest dry matter production in the first year.

4.4.8. Yield attributes of rice after sesamum

4.4.8.1. Number of panicle/sq.m.

The data on mean number of panicle/sq.m. are presented in Table 57.

The data revealed no significant difference between the treatments in the first year, but the treatment effects were significant in the second year. The treatment T_1 recorded the highest value which was on par with T_7, T_3 and T_5 but was significantly superior to the others. Though not significant, the highest number of panicle was observed in T_1 followed by T_7 in the first year.

4.4.8.2. Number of grains/panicle

The data on mean number of grains/panicle are presented in Table 57.

There was no significant difference between the treatments on the number of grains during both the years.

4.4.8.3. 1000 grain weight

The data on mean weight of 1000 grains are presented in Table 57.

The data revealed no significant difference between treatments during both the years.

Table 57. Yield attributes of first crop of rice after sesamum

Treatments	Number of panicle/ sq. m.		Number of grains/ panicle		1000 grain weight (g)	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	377.8	333.3	63.6	35.9	24.9	24.5
T_2	361.1	274.4	50.3	33.9	24.8	24.4
T_3	294.5	292.2	38.1	25.6	25.8	25.4
T_4	305.6	274.4	49.7	28.8	25.1	24.7
T_5	305.6	292.2	56.8	34.4	25.7	25.3
T_6	311.1	283.3	49.1	38.4	24.8	24.4
T_7	366.7	307.8	53.0	31.4	25.2	24.8
T_8	355.6	258.9	43.9	27.9	25.1	24.7
F test	NS	S	NS	NS	NS	NS
CD(0.05)	-	41.85	-	-	-	-
SD	39.77	19.51	11.99	6.54	0.58	0.58

NS - Not significant.

S - Significant.

Table 58. Grain and straw yield of first crop of rice after sesamum (kg/ha)

Treatments	Grain yield		Straw yield	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	3149.3	1793.1	4505.4	4306.7
T_2	2801.5	1883.5	4779.8	3337.9
T_3	3191.0	1592.1	4261.5	2834.2
T_4	3008.1	1741.2	4503.2	3020.5
T_5	2848.9	1889.1	4200.5	3340.1
T_6	3108.6	1736.7	4377.2	3366.6
T_7	3023.9	1795.4	4722.2	3263.3
T_8	2773.3	1675.7	4071.8	2701.0
F test	NS	NS	NS	S
CD(0.05)	-	-	-	617.52
SE	296.01	210.36	325.68	287.89

NS - Not significant.

S - Significant.

4.4.9. Yield of rice after sesamum

4.4.9.1. Grain yield

The data on mean grain yield are presented in Table 58 and Fig. 14.

The data revealed no significant difference between the treatments on grain yield during both the years.

4.4.9.2. Straw yield

The data on mean straw yield are presented in Table 58.

From the data it could be seen that though there was no significant difference between the treatments in the first year, there occurred significant difference in the second year. The treatment T_1 recorded the highest straw yield which was significantly superior to all the other treatments.

4.4.10. Uptake of major nutrients by rice after sesamum

4.4.10.1. Nitrogen uptake

The data on mean uptake of nitrogen at harvest are presented in Table 59.

The nitrogen uptake revealed significant difference between the treatments during both the years, the treatment T_2 recording the highest nitrogen uptake during both the years which was significantly superior to all the other treatments.

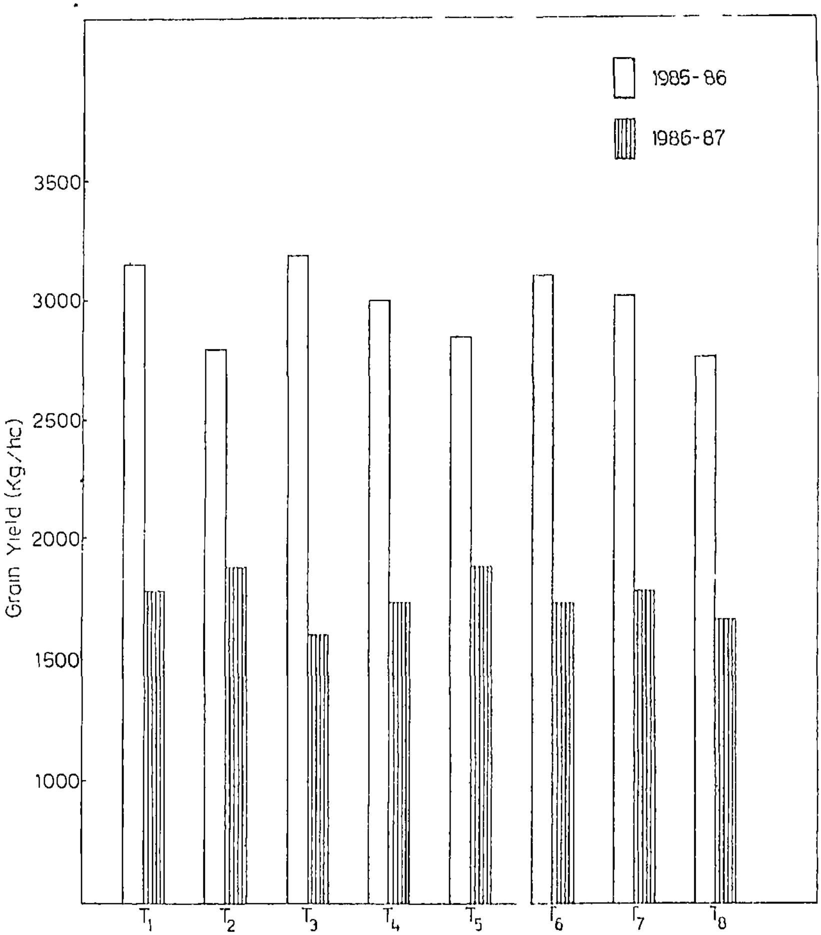


FIG. 14 GRAIN YIELD OF FIRST CROP OF RICE AFTER SESAMUM

Table 59. Nitrogen and potassium uptake by the first crop of rice after sesamum (kg/ha)

Treatments	Nitrogen uptake		Potassium uptake	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	88.6	70.5	132.1	105.4
T_2	127.4	96.6	122.2	93.1
T_3	85.7	54.2	101.0	63.8
T_4	66.1	39.0	74.3	44.3
T_5	71.7	52.0	96.2	69.8
T_6	66.9	46.3	102.6	71.6
T_7	86.8	56.4	90.4	59.9
T_8	90.0	54.6	92.4	57.4
F test	S	S	S	S
CD(0.05)	30.43	16.00	16.05	14.02
SE	14.19	7.46	7.48	6.54

S - Significant.

4.4.10.2. Phosphorus uptake

The observations on phosphorus uptake were recorded at 30 DAT, at flowering and at harvest. The data on mean phosphorus uptake are presented in Table 60 and fig. 15.

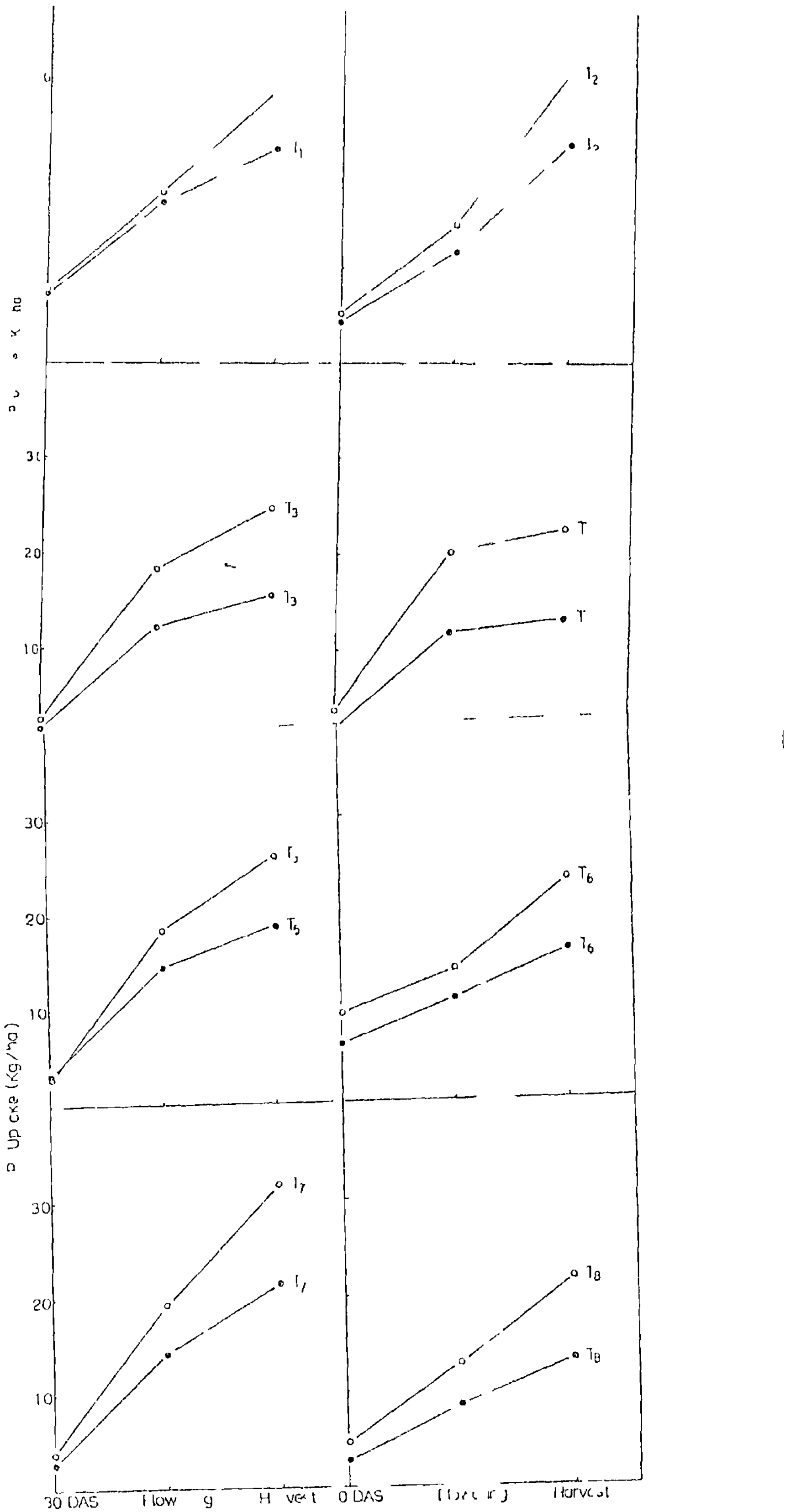
The phosphorus uptake by rice revealed that at 30 DAT there was significant difference between the treatments during both the years. In the first year treatment T_6 recorded the highest uptake which was on par with T_1 but was significantly superior to all the other treatments. In the second year T_1 recorded the highest value which was also significantly superior to all the other treatments.

At flowering stage there was no significant difference between the treatments in the first year, but significant difference was observed in the second year. Treatment T_1 recorded the highest value which was on par with T_5 and T_7 but significantly superior to all the other treatments. At harvest stage also there was no significance in the first year, but significance was observed in the second year. The treatment T_2 gave the highest value which was on par with T_1, T_5 and T_7 but was significantly superior to all the other treatments.

Table 60. Phosphorus uptake by the first crop of rice after sesamum (kg/ha)

Treatments	30 DAT		Flowering		Harvest	
	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87	I year 1985-86	II year 1986-87
T_1	7.9	7.5	18.1	17.2	28.7	22.8
T_2	5.2	4.5	14.6	11.9	30.4	23.0
T_3	2.9	1.9	18.3	12.4	24.8	15.6
T_4	3.7	2.2	20.3	12.2	22.6	13.4
T_5	2.9	3.1	18.4	14.5	25.9	18.8
T_6	9.3	6.0	13.6	10.8	23.0	15.9
T_7	3.7	2.6	19.5	14.2	31.6	21.3
T_8	4.7	2.9	12.9	8.3	21.7	13.1
F test	S	S	NS	S	NS	S
CD(0.05)	3.46	1.27	-	3.70	-	4.89
SE	1.61	0.59	3.18	1.73	3.56	2.28

NS - Not significant.
S - Significant.



I year (1985-86) II year (1986-87)

FIG 15 PHOSPHORUS UPTAKE BY FIRST CROP OF RICE

4.4.10.3. Potassium uptake

The data on mean potassium uptake at harvest are presented in Table 59.

The data revealed significant difference between the treatments during both the years. The treatment T_1 recorded the highest value of potassium uptake which was on par with T_2 but significantly superior to all the other treatments.

4.4.11. Soil nutrient status after the first crop of rice raised after sesamum

4.4.11.1. Available nitrogen

The data on mean available nitrogen content of the soil are presented in Table 61.

It was seen from the data that there was significant difference in available nitrogen content of soil with different treatments. During both the years T_5 recorded the highest available nitrogen content which was significantly superior to all the other treatments.

4.4.11.2. Available phosphorus

The data on available phosphorus content of the soil are presented in Table 61.

There was significant difference in available phosphorus content of the soil with different treatments during both the years. The treatment T_2 recorded the highest value of 46.8 kg/ha in the first year and 46.6 kg/ha in the

Table 61. Available nitrogen, Available potassium, Available phosphorus, Total phosphorus and phosphorus fixing capacity of soil after the first crop of rice raised after sesamum (kg/ha)

Treatments	Available Nitrogen		Availabe Potassium		Available Phosphorus		Total Phosphorus		P fixing capacity
	I Year 1985-86	II Year 86-87	I Year 85-86	II Year 86-87	I Year 85-86	II Year 86-87	I Year 85-86	IIYear 86-87	I Year 85 - 86
T_1	419.0	415.7	103.3	96.7	41.2	43.9	811.7	847.9	148.3
T_2	456.3	452.3	136.7	123.3	46.8	46.6	761.7	810.4	159.7
T_3	347.7	344.7	106.7	96.7	33.7	41.9	758.3	783.6	157.6
T_4	449.0	447.0	100.0	96.7	34.9	42.1	691.7	708.1	157.8
T_5	522.7	520.7	123.2	1[illegible]0.0	37.6	38.7	690.0	751.6	151.9
T_6	355.0	35[illegible].3	193.3	180.0	42.2	36.6	660.0	673.4	159.6
T_7	439.0	432.3	186.7	166.7	41.7	42.8	660.0	657.1	162.4
T_8	485.3	480.0	120.0	110.0	33.0	32.6	613.3	606.3	159.4
F test	S	S	S	S	S	S	S	S	S
CD(0.05)	2.09	2.56	11.70	12.68	1.28	4.85	15.02	49.59	0.42
SE	0.97	1.19	5.46	5.91	0.60	2.26	7.00	23.12	0.20

S - Significant

second year. In the first year T_2 was significantly superior to all the other treatments while the second year, T_2 was on par with T_1, T_4, T_7 and T_3.

4.4.11.3. Total phosphorus

The data on mean total phosphorus content of the soil are presented in Table 61.

The data revealed significant difference between treatments during both the years. In the first year T_1 recorded the highest total phosphorus content of 811.7 kg/ha which was significantly superior to all the other treatments. In the second year also T_1 recorded the highest value which was on par with T_2 but significantly superior to all the other treatments. T_8 recording the lowest value of total phosphorus during both the years.

4.4.11.4. Phosphorus fixing capacity of the soil

The data on mean phosphorus fixing capacity of the soil are presented in Table 61.

The data revealed significant difference between treatments. Treatment T_7 recorded the highest value which was significantly superior to all the other treatments. The lowest value was recorded by the treatment T_1.

4.4.11.5. Available potassium

The data on mean available potassium content of the soil are presented in Table 61.

The available potassium content of the soil showed significant difference between treatments during both the years. The treatment T_6 recorded the highest value in both the years which was on par with T_7 in the first year. and was significantly superior to all the other treatments.

4.4.12. Correlation studies

The Table 62 revealed that phosphorus uptake was positively and significantly correlated with dry matter yield, nitrogen uptake and potassium uptake during both the years and also with available phosphorus content of the soil during the first year.

Dry matter yield was significantly and positively correlated with nitrogen uptake and potassium uptake during both the years and also with available phosphorus content of the soil during the first year.

Available phosphorus content of the soil was positively and significantly correlated with nitrogen uptake and potassium uptake in the first year.

Nitrogen uptake was positively and significantly correlated with potassium uptake during both the years.

Table 62. Intercorrelation matrix involving the variables P-uptake (X_1), dry matter yield (X_2), grain yield (X_3), available phosphorus content of the soil (X_4), N-uptake (X_5) and K-uptake (X_6) - first crop of rice after sesamum

Variables	X_1	X_2	X_3	X_4	X_5	X_6
X_1		0.8216**	-0.3245	0.7305**	0.6498**	0.5025*
X_2	0.9123**		-0.0844	0.6114**	0.5003*	0.7057**
X_3	0.2606	0.2722		-0.1150	-0.3924	-0.0569
X_4	0.2652	-0.0477	-0.1617		0.5964**	0.6675**
X_5	0.7571**	0.7171**	0.5169**	0.2357		0.5671**
X_6	0.7918**	0.9076**	0.2547	-0.0251	0.7651**	

Figures in the upper and lower diagonals are respectively the correlations for First (1985-86) and Second (1986-87) years.

* Significant at 5% probability level.

** Significant at 1% probability level.

4.5. Balance sheet of available phosphorus

The data on the balance sheet of available phosphorus for the rice-rice-cowpea system for two years given in Table 63 revealed that skipping of phosphorus fertilizers continuously for six seasons (T_8) drastically reduced the soil available phosphorus to the extent of incurring a loss of 12.6 kg/ha. The highest build up of 12.8 kg/ha over the initial soil level was in the treatment where phosphorus was applied to all the three crops in the system (T_1), followed by the treatement (T_3) where phosphorus was applied to the first crop of rice and third crop of cowpea. There was not much change in the soil fertility due to the treatment where phosphorus was applied only to the third crop of cowpea (T_7) and also where phosphorus was applied to the second crop of rice and third crop of cowpea (T_5).

With regard to the rice-rice-sesamum system the data in Table 64, revealed that continuous skipping of phosphate fertilizer to all the three crops in the rotation reduced the soil available phosphorus drastically incurring a net loss of 12.9 kg/ha. The highest build up of 9.6 kg/ha was in the treatment (T_1) where phosphorus was applied to all the three crops in the system followed by the treatment (T_2) where phosphorus was applied to the first and second crops of

Table 63 : Balance sheet for available phosphorus under rice-rice-cowpea system over two years (1984-85 and 1985-86)

Treatments	Initial soil level of available phosphorus (kg/ha)	Quantity of phosphorus added through fertilizers (kg/ha)	Quantity of phosphorus removed by crops (kg/ha)	Computed balance of available phosphorus (kg/ha)	Actual balance of available phosphorus (kg/ha)	Net gain or loss over initial level (kg/ha)
T_1	45.0	200.0	155.3	89.7	57.8	12.8
T_2	45.0	140.0	145.5	39.8	45.9	0.9
T_3	45.0	130.0	139.8	35.2	50.6	5.6
T_4	45.0	70.0	148.3	-33.3	41.3	-3.7
T_5	45.0	130.0	149.0	26.0	45.8	0.8
T_6	45.0	70.0	147.1	-32.1	42.4	-2.6
T_7	45.0	60.0	164.9	-59.9	45.1	0.1
T_8	45.0	0.0	139.1	-94.1	32.4	-12.6

Table 64 : Balance sheet for available phosphorus under rice-rice-sesamum over two years (1984-85 and 1985-86)

Treatments	Initial soil level of available phosphorus (kg/ha)	Quantity of phosphorus added through fertilizers (kg/ha)	Quantity of phosphorus removed by crops (kg/ha)	Computed balance of available phosphorus (kg/ha)	Actual balance of available phosphorus (kg/ha)	Net gain or loss over initial level (kg/ha)
T_1	45.0	170.0	153.5	61.5	54.6	9.6
T_2	45.0	140.0	135.4	49.6	53.2	8.2
T_3	45.0	100.0	137.4	7.6	46.6	1.6
T_4	45.0	70.0	137.6	-22.6	40.2	-4.8
T_5	45.0	100.0	148.8	-3.8	45.5	0.5
T_6	45.0	70.0	142.4	-27.4	45.1	0.1
T_7	45.0	30.0	159.3	-84.3	44.2	-0.8
T_8	45.0	0.0	139.8	-94.8	32.1	-12.9

Table 66. Net return and benefit-cost ratio for the rice-rice-cowpea (R-R-C) and rice-rice-sesamum (R-R-S) systems

Treatments	Net return (Rs.)			Benefit-cost ratio		
	R-R-C	R-R-S	Mean	R-R-C	R-R-S	Mean
T_1	7566.60	9180.26	8373.43	1.61	1.74	1.67
T_2	7419.06	8811.56	8115.31	1.60	1.71	1.66
T_3	6693.16	8498.90	7596.03	1.54	1.70	1.62
T_4	7458.90	8720.80	8089.88	1.62	1.72	1.67
T_5	8395.90	8482.36	8439.13	1.69	1.70	1.69
T_6	7105.30	8923.26	8014.28	1.59	1.74	1.66
T_7	10292.00	10726.33	10509.17	1.85	1.90	1.87
T_8	5306.23	6937.10	6121.66	1.45	1.58	1.51
Mean	7529.64	8785.08		1.62	1.72	

$F_{(1,30)}$ System - S

$F_{(7,30)}$ Treatments - S

$F_{(7,30)}$ System x Treatment - NS

$CD_{(0.05)}$ System - 891.25

$CD_{(0.05)}$ Treatments - 1782.51

$F_{(1,30)}$ System - S.

$F_{(7,30)}$ Treatments - S.

$F_{(7,30)}$ System x Treatment - NS

$CD_{(0.05)}$ System - 0.07

$CD_{(0.05)}$ Treatments - 0.15

Table 65. Total grain yield of first and second crop of rice after cowpea/sesamum and grain equivalent (Kilocalories) for rice-rice-cowpea (R-R-C) and rice-rice-sesamum (R-R-S) systems

Treatments	Total grain yield of first and second crop of rice (t/ha)			Grain equivalent (Kilocalories)		
	After cowpea	After sesamum	Mean	R-R-C	R-R-S	Mean
T_1	12.6	13.7	13.2	11752	13551	12652
T_2	12.1	12.9	12.5	1 478	12630	12054
T_3	11.7	13.7	12.7	10823	132[illegible]	12083
T_4	13.0	13.2	13.1	11716	12929	12322
T_5	13.5	12.7	13.1	12479	12808	1[illegible]644
T_6	12.3	14.1	13.2	11479	13266	12373
T_7	12.8	13.1	13.0	12584	13597	13091
T_8	11.7	1[illegible].8	1[illegible].8	10399	11847	11123
Mean	1[illegible].5	13.2		11601	12984	

$F_{(1,30)}$ System - NS

$F_{(7,30)}$ Treatments - NS

$F_{(7,30)}$ System x Treatment - NS

$F_{(1,30)}$ System - S.

$F_{(7,30)}$ Treatments - NS.

$F_{(7,30)}$ System x Treatment - NS.

$CD_{(0.05)}$ System - 687.4

Rice-345 calories/100g. (Raw rice)

Cowpea-323 calories/100 g.

Sesamum-563 calories/100 g.

The data revealed that there was significant difference in net return and benefit-cost ratio between treatments and systems. But (System x Treatment) interaction was not significant. Significant increases in net return and benefit cost ratio were obtained from rice-rice-sesamum system compared to rice-rice-cowpea system. When the rice-rice-sesamum system had given a net return of Rs.8785/- and benefit-cost ratio of 1.72, the rice-rice-cowpea system had given only a net return of Rs.7529/- and benefit-cost ratio of 1.62. Maximum net return was obtained from T_7 in both the systems which was significantly superior to all the other treatments except T_1 for the rice-rice-sesamum system. Similarly maximum benefit-cost ratio was also obtained from T_7 which was significantly superior to all the other treatments in both the systems.

Table 67. Economics of phosphorus management for rice-rice-cowpea (R-R-C) and rice-rice-sesamum (R-R-S) systems

	Treatments	Cost of cultivation for first crop of rice Rs.	Cost of cultivation for second crop of rice Rs.	Cost of cultivation for third crop of cowpea/sesamum Rs.	Total cost of cultivation Rs.	Total gross return Rs.	Total Net return Rs.	Benefit cost ratio Rs.
	T_1	5000.00	5000.00	2400.00	12400.00	19966.60	7566.60	1.61
	T_2	5000.00	5000.00	2223.00	12223.00	19642.06	7419.06	1.60
	T_3	5000.00	4793.50	2400.00	12193.50	18886.66	6693.16	1.54
	T_4	5000.00	4793.50	2223.00	12016.50	19475.40	7458.90	1.62
R-C	T_5	4793.50	5000.00	2400.00	12193.50	20589.40	8395.90	1.69
	T_6	4793.50	5000.00	2223.00	12016.50	19121.80	7105.30	1.59
	T_7	4793.50	4793.50	2400.00	11987.00	22279.00	10292.00	1.85
	T_8	4793.50	4793.50	2223.00	11810.00	17116.23	5306.23	1.45
	T_1	5000.00	5000.00	2356.00	12356.00	21536.00	9180.26	1.74
	T_2	5000.00	5000.00	2267.50	12267.50	21079.06	8811.56	1.71
	T_3	5000.00	4793.50	2356.00	12149.50	20648.40	8498.90	1.70
	T_4	5000.00	4793.50	2267.50	12061.00	20791.86	8720.86	1.72
R-S	T_5	4793.50	5000.00	2356.00	12149.50	20631.86	8482.36	1.70
	T_6	4793.50	5000.00	2267.50	12061.00	20984.26	8923.26	1.74
	T_7	4793.50	4793.50	2356.00	11943.00	22669.33	10726.33	1.90
	T_8	4793.50	4793.50	2267.50	11854.50	18791.60	6937.10	1.58

Price of paddy grain-Rs.2/Kg. Cost of cowpea grain Rs.7/Kg.
Price of paddy straw-Rs.0.80/Kg. Cost of sesamum Rs. 10/Kg.

Cost of 1 Kg. N - Rs.5.10
Cost of 1 Kg. P_2O_5 - Rs. 5.90
Cost of 1 Kg.K_2O - Rs.2.15

5. DISCUSSION

The present investigation is an attempt to standardise an appropriate phosphorus management practice in a rice based cropping system involving rice-rice-cowpea/sesamu. The results obtained from the study are discussed here under.

5.1. Direct effect of phosphorus on the first crop of rice

5.1.1. Growth attributes

The results revealed that phosphorus had no significant influence on plant height at any of the growth stages. Since phosphorus is involved more on the reproduct development of the plant, it is quite natural that the vegetative development of the plant was not affected by the application of phosphorus. This is in agreement with the results of Kalyanikutty and Morachan (1974) and Bharadwaj et al. (1974).

Phosphorus application did not have any significan influence on tiller number at 30 DAT, flowering and at harvest. The lack of significance may be due to the fact

DISCUSSION

the soil was low (Davide, 1960; Terman and Allen, 1970; Alexander et al. 1973). Here the available phosphorus status of the soil was already medium at the beginning of the experiment which could have been further increased by submergence. This may be one of the reasons for not getting significant influence on dry matter production.

5.2.2. Yield attributes

The results revealed that phosphorus application had no significant indluence on the number of panicle/m^2. The lack of significance may be due to the fact that on submergence the availability of native phosphorus increased, thereby, showing no response to phosphorus application in increasing the panicle number.

Alexander et al. (1973) found that application of phosphorus did not have any positive effect on the percentage of productive tillers and thus the number of panicles.

The number of grains/panicle significantly increased due to phosphorus application. Higher availability of phosphorus from the soluble source like super phosphate and better phosphorus uptake played a vital role in improving the dry matter production at the later stage and ultimately would have resulted in better grain filling. It has been well established that phosphorus has a very important role in grain filling. Similar result was obtained by Singh and Varma (1971) who reported an increase in the number of grains per panicle with higher rates of phosphorus application.

There was significant difference in 1000 grain weight as revealed from the data. The application of phosphorus resulted in a higher thousand grain weight as compared to control (no phosphorus). Better filling and bolder grains due to increased phosphorus absorption from the readily available source of superphosphate might have influenced the test weight of grains. Similar results were reported by Thandapani and Rao (1976). Chowdhury et al. (1978) reported that thousand grain weight increased with increasing phosphorus application.

5.1.3. Yield

The results revealed that phosphorus application did not show any significant influence on grain yield.

This is in agreement with the findings by Kalam _et al_. (1966) and Sood _et al_. (1969). Rajendran _et al_. (1971) reported that there was lack of significant response in soils with medium to high available phosphorus status. The lack of response to applied phosphate can be explained by the findings of Davide (1960) and Kalam _et al_. (1966) who reported that unless a soil is deficient in phosphate, yield response to its addition in field experiments would not be detected. Thus the lack of response in grain yield can be attributed to the relatively increased status of available phosphorus in the soil compared to the phosphorus requirement of the crop. Increased availability of phosphorus during submergence reported by Datta and Datta (1963), Mosi _et al_. (1973) and Gupta and Singh (1977) could be another possible reasonofor the lack of response to added phosphorus.

The result on straw yield revealed lack of influence of phosphorus on this character. The number of tillers and the height of plants are the two contributing factors which determine the yield of straw and since these factors are unaffected by the treatments as discussed earlier, it is quite reasonable to expect same trend with respect to straw yield also. Lack of response to straw yield was reported by Loganathan and Raj (1971), Sasidhar and Sadanandan (1971), Alexander _et al_. (1973) and Suseelan _et al_. (1977).

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nutrition in maintaining the soil fertility status.

The phosphorus fixing capacity of the soil in terms of added phosphorus was higher in plots where no phosphorus was applied which indicate that control plots with no phosphorus have to fix more phosphorus in order to equilibrate the phosphate pool.

5.2. Effect of phosphorus on the second crop of rice (Direct, residual and cumulative effects)

5.2.1. Growth attributes

From the result it can be seen that neither direct, residual nor cumulative application of phosphorus had any significant influence on plant height during both the years except at 30 DAS during the second year. However, the residual effect of phosphorus produced tallest plants at all the growth stages.

Direct, residual and cumulative effect of phosphorus did not have any significant influence on tiller number at any of the growth stages during both the years, except at 30 DAT during the second year. At 30 DAT during the second year, cumulative effect of phosphorus gave the highest tiller number which was on par with direct effect, but significantly superior to all the other treatments. As the requirement of phosphorus by the crop could not be met from the soil supply alone, the readily available source of phosphorus would have been used for rooting, growth and tiller production. Nair et al. (1972) and Bharadwaj et al. (1974) observed that tillering was markedly influenced by phosphorus application.

The LAI was not significantly influenced by the direct, residual and cumulative effect of phosphorus. However, the increasing trend shown by the direct and cumulative effect of phosphorus may be due to the increase in tiller number in direct and cumulative phosphorus treatment

The result on dry matter production at different growth stages revealed no significant effect by the direct, residual and cumulative application of phosphorus. Phosphorus did not reveal any positive effect on the vegetative characters at any of the growth phases studied. Plants could show response to added phosphorus only when the available phosphorus status of the soil was low (Terman and Allen 1970) Alexander et al. (1973)

5.2.2. Yield attributes

The results revealed that the different treatments had no significant influence on the number of panicle/sq. m. Because of the relatively higher availability of native phosphorus on submergence the different treatments failed to show any significant difference between them.

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The results revealed that the different treatments had no significant influence on the number of panicle/sq. m. Because of the relatively higher availability of native phosphorus on submergence the different treatments failed to show any significant difference between them.

The number of grains/panicle did not differ significantly due to direct, residual and cumulative phosphorus application during both the years. It may be noted that at the time of grain setting, the full requirement of phosphorus might have been satisfied by the native soil phosphorus (also enriched by the previous applications of phosphorus) solubilised under the reduced condition which can be attributed to the lack of response to the direct, residual and cumulative phosphorus application. Bhattacharya and Chatterjee (1978) and Suseelan *et al.* (1978) also could not get any positive influence of phosphorus on the number of grains/panicle.

The data on 1000 grain weight also recorded no significant difference between different treatments. Several rice workers have reported that thousand grain weight was unaffected by phosphorus application (Rao *et al.* 1974, Kalyanikutty and Morachan, 1974 and Bhattacharyya and Chatterjee, 1978).

5.2.3. Yield

It was seen that the direct, residual and cumulative phosphorus application had no significant influence on the grain yield. The data on the yield attributes like number of panicle/sq. m., number of grains/panicle and thousand increase from maximum tillering to flowering and thereafter there occured a rapid increase from flowering to harvest. This is in agreement with the findings of Patnaik *et al.* (1965) Alexander *et al.* (1974) also reported that there was a gradual increase in phosphorus uptake from maximum tillering to flowering and then a rapid increase from flowering to harvest.

Potassium uptake by the crop at harvest recorded significant difference between treatments. Direct, residual and cumulative phosphorus application had recorded significantly higher potassium uptake as compared to control plots Agarwal (1978) reported that Nitrogen, Phosphorus and Potassium increased the grain crude protein and Potassium content. The increase in the uptake of nitrogen, phosphorus and potassium was highest with applied nitrogen, followed by phosphorus and potassium. Singh and Prakash (1979) reported that addition of phosphorus was beneficial for potassium uptake and a consistent increase in potassium uptake was observed upto 80 kg P_2O_5/ha. Agarwal (1980) reported that increase in the potassium uptake was from 35.5 to 129.9 kg/ha due to phosphorus application.

5.2.5. Soil nutrient status after the second crop of rice

The available nitrogen content of the soil was highest in the plots having residual phosphorus which was significantly superior to cumulative phosphorus, direct phosphorus and control. This is in agreement with the finding of Omana (1986) who observed that residual phosphorus was suffidient to maintain the available nitrogen status of the soil.

Available phosphorus content of the soil after the second crop was higher under cumulative phosphorus in the first year and continuous phosphorus application in the second year which was significantly superior to residual phosphorus, direct phosphorus and control. The next higher value was recorded by residual phosphorus. Phosphorus application would have enriched the available pool in the soil as all the quantity supplied through them was not taken up by the crop. Build up in available soil phosphorus under continuous application of superphosphate has been reported by Deka and Singh (1984), Saggar et al. (1986).

Total phosphorus content of the soil was significantly higher in cumulative phosphorus applied plots, followed by residual phosphorus. Phosphorus applied to increase from maximum tillering to flowering and thereafter there occured a rapid increase from flowering to harvest. This is in agreement with the findings of Patnaik et al. (196' Alexander et al. (1974) also reported that there was a gradual increase in phosphorus uptake from maximum tillering to flowering and then a rapid increase from flowering to harvest.

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5.2.5. Soil nutrient status after the second crop of rice

The available nitrogen content of the soil was supply could increase plant height in pulse crop like cowpea. This is in agreement with Rajendra Prasad (1985) who reported that adequate phosphorus in the soil helped in the initial vigorous growth and improved plant height in pulses.

The results on number of leaves revealed no significant difference between treatment at 20 DAS during both the years. However, it could be seen that cumulative treatment had given the maximum number of leaves followed by direct Phosphorus and continuous Phosphorus in the first year where as in the second year continuous phosphorus gave the maximum number followed by direct Phosphorus.

At flowering stage direct application of phosphorus gave the highest number of leaves which was significantly superior to all the other treatments. The results clearly indicate the essentiality of phosphorus for cowpea crop. Tarila et al. (1977) observed that in cowpea increasing levels of phosphorus enhanced growth, flower, fruit number as well as leaf number. Samuel Mathew and Koshy (1982) also observed increased leaf number with increase in the level of phosphorus.

The data on LAI revealed that there was significant difference in LAI at 20 DAS due to cumulative phosphorus which was on par with continuous phosphorus, and the continuous phosphorus was on par with direct phosphorus. At flowering though the effect was not significant, direct application of phosphorus recorded the highest LAI. This shows that the residual effect of phosphorus applied to the preceeding rice crop was not influencing the succeeding cowpea crop. Rollin Bhaskar (1979) observed that plant height and LAI of green gram was significantly increased by application of phosphorus.

The results revealed that there was no significant difference between direct, residual and cumulative phosphorus with respect to number of branches per plant. However, direct phosphorus gave the maximum number of branches, indicating the positive role of phosphorus on legumes. Panda (1972) observed that in Pusa Baisakhi mung increasing the phosphorus increased the number of branches. Samuel Mathew and Koshy (1982) also observed higher number of branches with phosphorus application in cowpea.

The dry matter production at 20 DAS recorded no significant difference between direct, residual and cumulative phosphorus application. In the early stages of growth the available phosphorus content of the soil was sufficient to meet the requirement of the crop. Eventhen direct application of phosphorus gave the highest dry matter yield, indicating the importance of phosphorus on legumes.

At flowering and harvest stage there was no significant difference in dry matter production due to different treatments in the first year, but significant difference observed in the second year, which might be due to repeated crop removal by continuous cropping. In the second year direct phosphorus applied plots recorded the highest dry matter production. Since all the growth attributes likee plant height, number of leaves per plants etc., were favoured by direct phosphorus it is quite natural that the dry matter production also was increased by direct phosphorus. Venugopal and Morachan (1974) in trials with green gram reported that P increased the dry matter production. Samuel Mathew and Koshy (1982) also observed increase in dry matter with increase in phosphorus application.

5.3.2. Yield attributes of cowpea

The results revealed that the yield attributes of cowpea was not significantly influenced by the treatments of direct, residual and cumulative phosphorus except length of pod during both the year, mean number of grains per pod in the second year and thousand grain weight in the first year. However, all these yield attributes, recorded higher values by direct and cumulative application of phosphorus. Subramanian 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. Ahlawat et al. (1979) reported that application of phosphorus had marked effect in increasing the yield attributes (No. of pods/plant, pod length and hundred grain weight) and grain yield in cowpea. This is also in agreement with the findings of Geethakumari and Kunju (1984).

5.3.3. Yield of cowpea

Grain yield of cowpea revealed significant differenc between treatments in the first year. The direct effect of phosphorus recorded the highest yield which was significantly superior to all the other treatments followed by continuous phosphorus application to all the crops in the rotation. Eventhough the effect was not significant in the second year, direct phosphorus gave the highest grain yield. Venkateswarlu and Bhaskara Rao (1979) bring out the point that if a legume (Cowpea) is taken up as the first crop in sequence, all the phosphates for the system need to be applied to cowpea while the nitrogen could be supplied to the planting cereal with reduced phosphate dose.

Haulm yield revealed no significance with direct, residual and cumulative phosphorus application. Since most of the growth characters of cowpea were unaffected by the different phosphorus application, it is quite natural that the haulm yield was also not affected by the direct, residual and cumulative phosphorus application.

5.3.4. Uptake of major nutrients by cowpea

It is seen that nitrogen uptake was highest in residual phosphorus treatments in the first year which was on par with continuous, direct and cumulative phosphorus but significantly superior to control. In the second year although not significant, direct phosphorus gave the highest nitrogen uptake. This clearly indicates the positive influence of phosphorus on nitrogen uptake. Sahu and Behera (1972) reported that in cowpea, nitrogen content in shoot, root and grains increased significantly by phosphorus manuring. Rollin Bhaskar (1979) observed that uptake of N, P, K in green gram were higher with increased levels of phosphorus.

The different treatments failed to influence the phosphorus uptake at 20 DAS which may be due to the relative availability of phosphorus in the soil during the early stages of crop growth. Moreover, the dry matter production in this stage also failed to show any response to the different treatments. Although not significant the direct phosphorus recorded the highest value of phosphorus uptake. Phosphorus uptake at flowering also failed to show any response in the first year. However, during the second year the available phosphorus status of the soil decreased due to continuous cropping resulting in significant response to the various treatments. Here again, the direct phosphorus application gave the highest phosphorus uptake, may be because of increased absorption with higher quantity of available phosphorus and also due to better growth and dry matter production.

At harvest stage also, the different treatments could not influence phosphorus uptake during the first year, which may be due to the relative availability of phosphorus in the soil. Legumes have a high P requirement and are able to utilise P from relatively insoluble compounds. (Kumar, 19[illegible]6 but during the second year as stated earlier due to continuous cropping the available phosphorus status of the soil was reduced resulting in the response to phosphorus application and direct application of phosphorus recorded the highest value which was on par with cumulative phosphorus. This may be because of the increased absorption of phosphorus which resulted in better growth and dry matter production. This is in agreement with the findings of Sharma *et al.* (1974) who reported that in cowpea, application of phosphorus ...

increased the uptake of phosphorus. Singh and Sharma (1980) reported that in chick pea higher doses of phosphorus were effective in increasing the uptake of phosphorus in plants at maturity. Phosphorus application resulted in root proliferations which might have helped in better no dulation more nitrogen fixation and better utilisation of phosphorus. It is seen that the uptake recorded a steady increase from 20 DAS to harvest, except in the control plot.

The different treatment could not exert any influence over potassium uptake as there was no significant difference to the direct, residual and cumulative phosphorus application. This may be due to the relative availability of phosphorus in the soil giving higher potassium uptake due to increased dry matter production. The uptake of potassium while recording a gradual increase upto flowering, dropped to a lower level by harvest time possible due to a return of a part of the uptake at flowering back to the soil during ripening period. This may be the reason for the non significance observed by the different treatment in potassium uptake at harvest.

5.3.5. Soil nutrient status after the third crop of cowpea

The data on the available nitrogen content of the soil revealed that the different phosphorus treatments could not exert any significant influence on this character and the control plot recorded the highest value. This means that the available phosphorus content of the control plots after the second crop of rice are more than sufficient for the cowpea crop for the rhizobial multiplication and thus nitrogen fixation, giving a higher available nitrogen status of the soil.

The available phosphorus content of the soil recorded significant difference during both the years. In the first year, residual phosphorus recorded the highest value of available phosphorus in the soil. It was seen that the residual phosphorus recorded a lower grain yield, probably due to the reduced uptake of phosphorus from the soil (Tables 28 and 30) which might have resulted in the higher value of available phosphorus in the soil. Grain yield was significantly and negatively correlated with available phosphorus content of the soil. In the second year, continuous phosphorus recorded the highest value of available phosphorus in the soil. The continuous application of phosphorus fertilizer would have increased the available phosphorus status in the soil. Rao and Bhardwaj (1981) in studying the direct, residual and cumulative effect of phosphorus in wheat-pigeon pea rotation found that application of 18 kg to each crop maintained the initial phosphorus status, whereas 36 kg incresed soil phosphorus by 42%.

A significantly high value of total phosphorus was obtained in continuous phosphorus treatment. By the continuous addition of phosphorus, the total phosphorus pool of the soil might have increased.

The available potassium content of the soil recorded significantly higher values by the residual phosphorus treatment during the first year. But during the second year, residual phosphorus treatment was on par with cumulative phosphorus and direct phosphorus. This means that increase in phosphorus content of the soil could increase the potassium content of the soil also.

The phosphorus fixing capacity of the soil with respect to added phosphorus was higher in the plot where phosphorus was supplied only to one crop in the sequence, followed by the treatment where phosphorus was applied to both the first crop of rice and third crop of cowpea. Since cowpea is a crop which can utilise P from insoluble compounds, and thus reducing the phosphorus saturation of the soil resulting in greater phosphorus fixation.

5.3.6. Growth attributes of sesamum

There was significant difference in plant height at 30 DAS, due to direct, residual and cumulative phosphorus treatments. In the first year, direct application of phosphorus gave the maximum plant height which was on par with continuous phosphorus, and cumulative phosphorus. In the second year also, cumulative phosphorus recorded the highest value which was on par with continuous phosphorus and direct phosphorus treatments.

At 50 DAS, though the effect was notisignificant in the first year, maximum height was recorded by the direct treatment. In the second year, residual phosphorus recorded the highest value but was on par with cumulative phosphorus and direct phosphorus. At harvest stage also, direct phosphorus recorded the tallest plants.

Thus it is seen that the direct application of phosphorus was always helpful to increase the height of sesamum plant as compared to residual phosphorus and control plots. According to Sirry et al. (1979) increase in the rate of phosphorus application increased height of plants in sesamum.

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The phosphorus fixing capacity of the soil with respect to added phosphorus was higher in the plot where phosphorus was supplied only to one crop in the sequence, followed by the treatment where phosphorus was applied to both the first crop of rice and third crop of cowpea. Since cowpea is a crop which can utilise P from insoluble compounds, and thus reducing the phosphorus saturation of the soil resulting in greater phosphorus fixation.

5.3.6. Growth attributes of sesamum

There was significant difference in plant height at 30 DAS, due to direct, residual and cumulative phosphorus treatments. In the first year, direct application of phosphorus gave the maximum plant height which was on par with continuous phosphorus, and cumulative phosphorus. In the second year also, cumulative phosphorus recorded the highest value which was on par with continuous phosphorus and direct phosphorus treatments.

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Thus it is seen that the direct application of phosphorus was always helpful to increase the height of sesamum plant as compared to residual phosphorus and control plots. According to Sirry et al. (1979) increase in the rate of phosphorus application increased height of plants in sesamum.

The results revealed that at 30 DAS direct phosphorus application recorded significantly higher number of leaves in the first year, and cumulative phosphorus treatment recorded the highest number of leaves in the second year although it was on par with direct phosphorus. At 50 DAS again, the direct phosphorus which was on par with cumulative phosphorus and residual phosphorus, recorded significantly higher number of leaves in the first year. Even though the effect was not significant during the second year, the cumulative phosphorus followed by direct phosphorus recorded the highest number of leaves.

This again explains the importance of direct phosphorus application to the seamum crop. Raveendran Nair (1987) found that applied phosphorus could exert significant influence on number of leaves/plant at all stages of growth.

The LAI at 30 DAS was significantly higher under direct phosphorus treatment during the first year. During the second year also direct phosphorus treatment recorded the higher LAI values although not significant.

At 50 DAS, direct phosphorus which was on par with residual phosphorus and cumulative phosphorus, recorded significantly higher LAI in the first year. In the second year cumulative phosphorus followed by direct phosphorus recorded the highest LAI though the effect was not significant.

The above result again calls for the necessity of direct phosphorus application to sesamum crop. Girija Devi (1985) reported that there was significant influence of phosphorus on leaf area. According to Raveendran Nair (1987), phosphorus had significant influence on the LAI of sesamum crop at 40 DAS and 60 DAS.

The results revealed that direct application of phosphorus significantly increased the number of branches during both the years. This is in agreement with the findings of Rahman _et al._ (1978) who indicated that the number of branches/plant in safflower increased with increased levels of phosphorus. Ahmed _et al._ (1985) observed significant response in number of branches with phosphorus in safflower. Raveendran Nair (1987) also observed that applied phosphorus and significant influence on branches.

The dry matter production of sesamum at 30 DAS was significantly influenced by the direct phosphorus treatment which was on par with continuous phosphorus treatment to all the crops in the rotation, in the first year, but no significant difference was observed in the second year. At 50 DAS, the treatment effect was not significant in the first year but during the second year, significant effect was observed by the direct phosphorus treatment which was on par with cumulative phosphorus. At harvest stage again, direct application of phosphorus recorded the highest DMP which was on par with cumulative phosphorus in the second year. Since all the growth attributes were significantly influenced by the direct effect of phosphorus it is but natural that the dry matter production also was influenced by the direct application of phosphorus. Daulay and Singh (1980) observed a linear increase in dry matter production with an increase in phosphorus level. Jalaludeenkutty (1985) reported that phosphorus and potassium along with nitrogen had a positive effect on dry weight of plants. Raveendran Nair (1987) also observed that phosphorus had significant influence on total dry matter production at all stages of growth.

5.3.7. Yield attributes of sesamum

The number of pods per plant could not be influenced by any of the treatment during the first year, but in the second year direct effect of phosphorus recorded significantly higher number of pods per plant which was on par with cumulative effect of phosphorus. Even in the first year, cumulative effect followed by direct effect of phosphorus recorded the highest number of pods per plant. This is in agreement with the findings of Rehman <u>et al</u>.(1978) who observed that number of heads of safflower increased with increased levels of phosphorus. Girija Devi (1985) reported that there was significant influence of phosphorus on weight of pod per plant.

5.3.8. Yield of sesamum

Seed yield of sesamum did not vary significantly due to the different treatments. Rai and Srivasteva (1968) conducted nutrient trials in sesamum on red loam soil and found that there was not much response to phosphorus application with respect to seed yield. Sadanandan and Sasidhar (1978) reported that the effect of phosphorus was not significant in increasing the seed yield of sesamum. Raveendran Nair (1987) also observed that seed yield was not influenced by the application of phosphorus.

Although the treatment effects could not be significant the direct application of phosphorus recorded the highest yield in the first year and cumulative phosphorus in the second year. Singh and Kaushal (1975) studied the response of rainfed sesamum to fertilizer levels and found that application of 50 kg P_2O_5/ha along with nitrogen increased yield from 431 kg to 617 kg/ha. Maiti <u>et al</u>. (1981)

pointed out that seed yield of six sesamum cultivars was increased by the application of phosphorus at the rate of 40 kg/ha.

There was no significant difference with yield of bhusa due to different treatments. However, in the second year direct effect of phosphorus gave the highest bhusa yield followed by cumulative phosphorus. Since all the growth attributes increased with direct phosphorus application it is but natural that the bhusa yield also increased. Ravoendran Nair (1987) reported that application of phosphorus had significant effect on bhusa weight per plant, highest bhusa yield was obtained with 25 kg P_2O_5/ha beyond which there was no effect.

5.3.9. Nutrient uptake by sesamum

The data on nitrogen uptake revealed significant difference between treatments during both the years. In the first year, cumulative phosphorus treatment recorded the highest nitrogen uptake which was on par with direct effect of phosphorus. In the second year, direct phosphorus recorded the highest uptake which was on par with residual effects of P and cumulative phosphorus. These results indicate clearly that phosphorus application can increase N uptake in sesamum Vir and Varma (1979) conducted trials on phosphorus content and their uptake in rainfed mustard and found that application of P_2O_5 @ 30 kg/ha increased uptake of nitrogen. Raveendran Nair (1987) reported that the highest level of phosphorus ie. 35 kg/ha recorded the maximum uptake of nitrogen in sesamum.

The data on phosphorus uptake by sesamum at 30 DAS, 50 DAS and at harvest revealed that at all stages, direct effect of phosphorus recorded significanlty higher phosphorus uptake. Ramirez *et al.* (1975) reported that phosphorus uptake was highest when phosphorus was placed below seed. Regression coefficient calculated for phosphorus uptake and dry weight was significant indicating the effect of phosphorus on the growth components. Girija Devi (1985) reported that phosphorus uptake was increased significantly with applied phosphorus. Raveendran Nair (1987) also observed that the highest level of phosphorus ie. 35 kg P_2O_5/ha recorded highest phosphorus uptake. It is seen that phosphorus uptake recorded a gradual increase from 30 DAS to 50 DAS and thereafter occured a rapid increase upto harvest.

It is seen that the direct effect of phosphorus recorded the highest uptake of potassium at harvest in both the years. It may be remembered in this connection that the direct application of phosphorus could increase the majority of growth attributes including DMP resulting in an increased uptake of potassium. Raveendran Nair (1987) reported that the uptake of potassium was influenced by applied phosphorus.

5.3.10. Soil nutrient status after the third crop of sesamum.

The available nitrogen content of the soil recorded highest value in residual phosphorus treatment. The data on nitrogen uptake (Table 39.) and dry matter production revealed lessor values under residual phosphorus treatment and this might have resulted in high nitrogen status of soil. Raveendran Nair (1987) reported that phosphorus failed to produce any significant effect on nitrogen content of soil.

The available phosphorus content of the soil was also highest in the residual phosphorus treatment in the first year. However, during the second year the continuous phosphorus treatment and residual phosphorus treatments recorded highest values. Raveendran Nair (1987) in trial with sesamum reported that soil phosphorus was influenced by applied phosphorus. This high values observed in the residual phosphorus treatment may be due to the low uptake of phosphorus from this treatment (Table 40) In the second year due to the continuous application of phosphorus the available phosphorus status of the soil would have been increased, resulting in higher available phosphorus content of the soil. It was seen that phosphorus uptake was significantly and negatively correlated with available phosphorus content of the soil during the second year.

Total phosphorus content of the soil was highest in the continuous phosphorus applied plots. By the addition of phosphorus fertilizers to every crops in the sequence the total phosphorus status of the soil might have increased. In the second year cumulative phosphorus treatment also recorded a higher value comparable to the continuous phosphorus applied plots. This may be due to the fact that out of the six crops raised, phosphorus was applied to four crops and this might resulted in a higher total phosphorus content of the soil.

The phosphorus fixing capacity of the soil with respect to added phosphorus was higher in the treatment where phosphorus was applied only to the first and second crops of rice.

The available potassium content of the soil was significantly higher under residual phosphorus during both the years and was on par with direct phosphorus in the first year. It can be seen from the table 39 that residual phosphorus recorded lower values of potassium uptake which might have resulted in higher values of available potassium in the soil. Raveendran Nair (1987) reported that phosphorus failed to produce any significant effect on available potassium of the soil after sesamum crop.

5.4. Effect of phosphorus on the first crop of rice after cowpea and after sesamum
(Direct residual and cumulative effects of phosphorus)

5.4.1. Growth attributes of rice after cowpea

The results revealed that direct, residual and cumulative phosphorus application had no significant influence on plant height at any of the growth stages during both the years. It was seen that there was no significant difference in the nitrogen content of soil after cowpea crops with different treatments indicating that the nitrogen availability for the succeeding rice crop was almost equal. Therefore significant difference in any of the growth attributes of rice need not be expected also as the vegetative development of the plant was mostly controlled by the and residual phosphorus. This again substantiate the ability of rice plant to utilize residual phosphorus left in the soil. The lack of significance observed at the other growth stages may be due to the transformation of native phosphorus under submergence which leads to considerable increase in its availability.

5.4.2. Yield attributes of rice after cowpea

Among the different yield attributes, only the number of panicle/sq. m. was found to be significant, during the second year. The residual phosphorus recorded the highest number of panicle/sq. m. The lack of significance observed in the various yield attributes suggest the adequacy of phosphorus in the soil, showing no difference between direct phosphorus and residual phosphorus treatments.

5.4.3. Yield of rice after cowpea

The grain yield of rice could not be altered by the different treatments during both the years. However, residual phosphorus recorded the highest grain yield. As stated earlier, the above findings reveals the capacity of rice plant to utilize residual phosphorus. Pathak et al. (1978) observed a low response of applied phosphorus by rice crop. This is primarily because of of native phosphorus under submergence which leads to considerable increase in its availability. Srivastava and Pathak (1976) have reported that total response to phosphorus in a paddy-gram cropping sequence was higher when phosphorus fertilizer was applied to gram crop and the residual amount of phosphorus was utilized by succeeding paddy crop.

Phosphorus application had no significant influence on LAI except at flowering stage in the second year. At the flowering stage, residual phosphorus recorded the highest value which was on par with continuous phosphorus and cumulative phosphorus treatments. This means that residual phosphorus left in the soil was sufficient to produce the leaf area, equivalent to that in continuous phosphorus and cumulative phosphorus treatments. Meelu and Rekhi (1981) observed that in rice-legume system there was no response of rice to phosphorus in this system indicating thereby that phosphorus application to berseem was sufficient to meet the equivalent of the succeeding rice crop.

The dry matter production was significant only at 30 DAT in the second year. In all other cases the effect was no significant. At 30 DAT in the second year, continuous phosphorus application recorded the highest dry matter production which was on par with direct phosphorus uptake value which may be due to the higher DMP recorded by the residual phosphorus treatment.

Phosphorus uptake also recorded no significant difference between treatments, in any of the growth stages of the plant. This may be due to the already explained reason that the native phosphorus available in the soil was sufficient for proper growth and absorption and thus phosphorus uptake.

The potassium uptake recorded significant difference due to different treatments during both the years. The direct and residual phosphorus treatments recorded the highest potassium uptake during both the years but was on par with continuous phosphorus in the second year. This indicates that K uptake increases with phosphorus application. Agarwal (1980) reported that increase in K uptake was from 35.5 to 129.9 kg/ha due to phosphorus application. Correlation studies revealed that available phosphorus content of the soil was positively and significantly correlated with potassium uptake during both the years.

5.4.5. Soil nutrient status after the first crop of rice grown after cowpea

The available nitrogen status of soil recorded significant difference due to the different treatments the submerged condition obtained in rice which makes the Fe-P and occluded P available to rice crop. Moreover, Srivastava and Pathak (1976) have reported that total response to phosphorus in a paddy-gram cropping sequence was higher when phosphorus fertilizer was applied to gram crop and the residual amount of phosphorus was utilised by the succeeding paddy crop as compared to its application to paddy crop and observing residual effect on gram.

The straw yield also recorded no response to the different treatments. However, residual phosphorus recorded the highest straw yield. Since the majority of the growth attributes were not significant due to different treatments it is natural that the straw yield, which is a reflection of the cumulative influence of all the vegetative attributes was also not significant.

5.4.4. Uptake of major nutrients by rice after cowpea

The results revealed no significant difference between treatments in the case of nitrogen uptake by plants. As the previous crop grown was cowpea there would have considerable fixation of nitrogen, thus increasing the nitrogen content of the soil uniformly in all the treatments, resulting in uniform nitrogen uptake in all treatments. However, residual phosphorus treatment recorded the maximum years which was on par with cumulative phosphorus application in the second year. As already mentioned under available phosphorus, phosphorus application through fertilizer must have enriched the total phosphorus content of the soil as all the quantity was not utilized by the rice crop.

The phosphorus fixing capacity of the soil with respect to added phosphorus was higher in plots where phosphorus was applied to the first crop of rice and third crop of cowpea closly followed by the treatment where phosphorus was applied to the third crop of cowpea alone, As already mentioned, legumes can utilize more Ca and P from insoluble calcium phosphate, thus increasing the availability, and decreasing the fixed phosphorus content, adding in more fixation of the added phosphorus.

Available potassium content of the soil showed significant difference between the different treatments. Cumulative phosphorus treatment gave the highest value of available potassium, followed by continuous phosphorus application and direct phosphorus application. This points out the need for balanced NPK fertilization for maintaining sustained productivity of the soil.

5.4.6. Growth attributes of rice after sesamum

The results revealed that direct, residual and cumulative phosphorus treatments had no significant effect during both the years. The residual phosphorus recorded the highest available nitrogen. The lowest value of available nitrogen was obtained in cumulative phosphorus treatment. This means that residual P may be sufficient to maintain the available nitrogen status of the soil. This is in agreement with the findings of Omana (1986).

The result revealed significant difference in the available phosphorus status of soil due to the different treatments. The direct and residual phosphorus recorded higher values of available phosphorus during the first year. In the second year, continuous phosphorus treatment recorded the highest value which was on par with direct phosphorus treatment. Phosphorus application through fertilizer must have enriched the available phosphorus pool in the soil as the entire quantity supplied through them was not taken up by the crop. Build up in available soil phosphorus under continuous application of super phosphate has been reported by Deka and Singh (1984).

Total phosphorus content of the soil showed significant variation due to the direct, residual and cumulative phosphorus. As in the case of available phosphorus status total phosphorus was also significantly higher in continuous phosphorus treatment during both the years which was on par with cumulative phosphorus application in the second year. As already mentioned under available phosphorus, phosphorus application through fertilizer must have enriched the total phosphorus content of the soil as all the quantity was not utilized by the rice crop.

The phosphorus fixing capacity of the soil with respect to added phosphorus was higher in plots where phosphorus was applied to the first crop of rice and third crop of cowpea closely followed by the treatment where phosphorus was applied to the third crop of cowpea alone. As already mentioned, legumes can utilize some Ca and P from insoluble calcium phosphate, thus increasing the availability, and decreasing the fixed phosphorus content, aiding in more fixation of the added phosphorus.

Available potassium content of the soil showed significant difference between the different treatments. Cumulative phosphorus treatment gave the highest value of available potassium, followed by continuous phosphorus application and direct phosphorus application. This points out the need for balanced NPK fertilization for maintaining sustained productivity of the soil.

5.4.6. Growth attributes of rice after sesamum

The results revealed that direct, residual and cumulative phosphorus treatments had no significant effect on plant height at any of the growth stages. Native build up of phosphorus after three crops would have been sufficient to meet the requirements of rice for growth. Moreover plant height which is a vegetative character of the plant was not affected by the application of phosphorus.

As in the case of height, tiller number was also not influenced by the different treatments at any of the growth stages of the plant. The non-significant response may be due to the increased availability of native phosphorus as explained earlier.

The LAI was significant at 30 DAT and at flowering during the second year but was not significant during the first year. The residual phosphorus recorded the highest LAI at 30 DAT which was on par with continuous phosphorus treatment. At flowering stage again the residual phosphorus and continuous phosphorus recorded the highest values which were on par with direct phosphorus. This again explains the capacity of rice plant to utilize residual phosphorus which could give the same effect as that of direct phosphorus.

The dry matter production recorded no significant difference at the various growth stages during the first year, but significant difference was observed at all recorded the highest value of phosphorus uptake which indicate the adequacy of residual phosphorus for the growth and absorption of phosphorus. In the second year continuous phosphorus application recorded highest values of phosphorus uptake both during 30 DAT, and flowering which was on par with residual phosphorus while direct phosphorus recorded higher phosphorus uptake during the harvest stage, which was on par with continuous phosphorus and residual phosphorus application. This again explains the capacity of rice plant to utilize residual phosphorus. Singh and Prakash (1979) observed that phosphorus application brought about an increased uptake of phosphorus.

The uptake of potassium recorded significant differences with different treatments both during the first and second year. Continuous phosphorus recorded the highest potassium uptake which was on par with direct and residual phosphorus application. Singh and Prakash (1979) reported that addition of phosphorus proved beneficial for potassium uptake by rice. Correlation studies revealed that there was positive significant correlation of potassium uptake with available phosphorus content of the soil.

5.4.10. Soil nutrient status after the first crop of rice

The available nitrogen status recorded significant

significant could have resulted in a more or less uniform grain yield under different treatments.

There was no significant difference between treatments on the straw yield. As stated earlier there was no significant difference between treatments with respect to growth attributes which might have resulted in a more or less uniform straw yield under different treatments.

5.4.9. Uptake of major nutrients by rice after sesamum

The nitrogen uptake of rice at harvest recorded significant difference due to different treatments. The direct effect of phosphorus recorded the highest nitrogen uptake during both the years. Better availability of phosphorus from superphosphate increased nitrogen uptake, as with adequate phosphorus supply, rooting and plant growth would have been vigorous enhancing dry matter production and better absorption of nitrogen in the presence of phosphorus. This is in agreement with the findings of Velu et al. (1987). Available phosphorus content of the soil was positively and significantly correlated with nitrogen uptake.

The uptake of phosphorus recorded significant differences between treatments at 30 DAT during both the years and at flowering stage and at harvest stage during the second year. At 30 DAT, in the first year residual phosphorus recorded the highest value of phosphorus uptake which indicate the adequacy of residual phosphorus for the growth and absorption of phosphorus. In the second year continuous phosphorus application recorded highest values of phosphorus uptake both during 30 DAT, and flowering which was on par with residual phosphorus while direct phosphorus recorded higher phosphorus uptake during the harvest stage, which was on par with continuous phosphorus and residual phosphorus application. This again explains the capacity of rice plant to utilize residual phosphorus. Singh and Prakash (1979) observed that phosphorus application brought about an increased uptake of phosphorus.

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5.4.10. Soil nutrient status after the first crop of rice

The available nitrogen status recorded significant difference due to the different treatments. The residual phosphorus recorded the highest value during both the years. This also showed that residual build up of phosphorus is enough to maintain the available nitrogen status of the soil. Also from the table 59 it could be seen that the residual phosphorus treatment recorded the lowest values of nitrogen uptake which might resulted in a higher value of available nitrogen of the soil.

Direct and residual phosphorus recorded significantly higher available phosphorus content of the soil during both the years but was on par with continuous, cumulative and residual phosphorus in the second year. Phosphorus application through fertilizers must have enriched the soil available phosphorus. From the data it can be seen that cumulative phosphorus application was also on par with direct phosphorus and residual phosphorus. This shows that in a cropping system involving sesamum as one of the crops in the rotation, application of phosphorus to sesamum and its residual effect being utilized by the succeeding rice crop proved to be as efficient as continuous application of fertilizer to all the crops in the sequence, in enriching the available phosphorus status of soil.

Thus the results revealed that the various phosphorus management treatments behaved consistently similar over the two seasons for both the rice-rice-cowpea and rice-rice-sesamum systems. This means that rice yield was not affected by the continuous, direct, cumulative and residual application of phosphorus.

The total grain yield of the rice-rice-cowpea and rice-rice-sesamum systems in terms of calories (grain equivalent) revealed significant increase for the rice-rice-sesamum over rice-rice-cowpea system. It is revealed that the treatments and system x treatment interaction had no significant influence on grain equivalent. Here again the results revealed that the treatments behaved consistently similar for both rice-rice-cowpea and rice-rice-sesamum systems.

5.7. Economics of phosphorus management in terms of net return and benefit-cost ratio for the rice-rice-cowpea and rice-rice-sesamum systems

The results revealed that signifidant increases in net return and benefit-cost ratio were obtained in rice-rice-sesamum system as compared to rice-rice-cowpea system. From the Table 66 it is seen that an additional net return of Rs.1255/- was obtained from the rice-rice-sesamum system over rice-rice-cowpea system in one year.

It is seen that significantly higher net return and benefit-cost ratio were obtained from the treatment where phosphorus was applied only to the third crop of cowpea/sesamum and the residual effect of phosphorus being utilized by the succeeding rice crops (T_7). Since there was no response of rice to the direct application of phosphorus it is enough that phosphorus need be applied to the third crop of cowpea/sesamum so that the residual phosphorus could be utilized by the succeeding rice crops successfully. This is in agreement with the result obtained by Purushothaman (1979) who observed that in a rice based multiple cropping experiment, application of P to summer upland crop gave similar yield as application of recommended level of NPK to each crop. Venkateswarlu and Bhaskara Rao (1979) pointed out that if a legume crop is taken up as the first crop in sequence all the phosphate for the system to be applied to the legume in which the N would be supplied to the planting cereal with reduced phosphate dose.

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SUMMARY

Field experiments were conducted to develop an appropriate phosphorus management practice in a rice based cropping system involving rice-rice-cowpea/sesamum in the rice fields of the Instructional Farm, College of Agriculture, Vellayani from June 1984 to September 1986. The experiment was laid out in a randomized block design with three replications. There were eight treatments. The treatments comprised of (1) continuous phosphorus application to all the three crops in the system (2) phosphorus application to the first and second crops of rice (3) phosphorus application to the first crop of rice and third crop of cowpea/sesamum (4) phosphorus application to the first crop of rice only (5) phosphorus application to the second crop of rice and third crop of cowpea/sesamum (6) phosphorus application th the second crop of rice only (7) phosphorus application to the third crop of cowpea/sesamum only (8) control plot with no addition of phosphorus to any of the crops in the system.

Phosphorus was applied according to the treatments based on the package of practices recommendations of KAU for each crop. The recommended dose of nitrogen and potassium for the respective crops for the respective seasons were applied uniformly to all the plots.

SUMMARY

Phosphorus uptake could not show any significant variation due to the different treatments. Potassium uptake increased with phosphorus application, direct, residual and cumulative phosphorus recording significantly higher values as compared to control plots.

6. Available nitrogen content of the soil was highest under residual phosphorus. Available and total phosphorus content of the soil were highest under cumulative phosphorus treatment in the first year and continous phosphorus treatment in the second year.

III. Direct, residual and cumulative effects of phosphorus on the third crop of cowpea/sesamum

A. Effect on cowpea

7. All the growth attributes like height, number of leaves, LAI, Number of branches and dry matter production were influenced by the direct application of phosphorus to the cowpea crop.

8. All the yield attributes like number of pods, number of grains per pod, length of pod and thousand seed weight were increased by either direct effect or cumulative effect of phosphorus.

9. Grain yield of cowpea was significantly increased by the direct application of phosphorus to the cowpea crop.

10. Regarding the uptake of major nutrients, the uptake of nitrogen was influenced by the direct, residual and cumulative phosphorus and a significantly higher value was obtained than control plots. Phosphorus uptake showed no significant variation due to the differenttreatments except during the flowering and harvest stage of the second year. Even then the highest uptake was observed by the direct effect of phosphorus.

11. Available and total phosphorus content of the soil was increased by the continuous application of phosphorus to all the three crops in the sequence. Available potassium content increased with increase in available phosphorus.

B. Effect on sesamum

12. Direct and cumulative effects of phosphorus had significantly increased the height, number of leaves, LAI, number of branches and dry matter productionat all stages of sesamum crop.

13. Number of pods per plant was highest in direct and cumulative phosphorus applied plots. Though not significant the highest seed yield was recordedd by the direct application of phosphorus in the first year and cumulative phosphorus in the second year.

Phosphorus uptake could not show any significant variation due to the different treatments. Potassium uptake increased with phosphorus application, direct, residual and cumulative phosphorus recording significantly higher values as compared to control plots.

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11. Available and total phosphorus content of the soil was increased by the continuous application of phosphorus to all the three crops in the sequence. Available potassium content increased with increase in available phosphorus.

B. Effect on sesamum

12. Direct and cumulative effects of phosphorus had significantly increased the height, number of leaves, LAI, number of branches and dry matter productionat all stages of sesamum crop.

13. Number of pods per plant was highest in direct and cumulative phosphorus applied plots. Though not significant the highest seed yield was recorded by the direct application of phosphorus in the first year and cumulative phosphorus in the second year.

14. Nitrogen uptake was highest in cumulative phosphorus which was on par with direct phosphorus in the first year. In the second year direct phosphorus recorded the highest nitrogen uptake which was on par with cumulative phosphorus application. Phosphorus uptake in all the stages of crop growth was highest in direct phosphorus applied plots. The highest uptake of potassium was also recorded by the direct effect of phosphorus.

15. Residual phosphorus recorded higher values of available nitrogen and available phosphorus and available potassium content of the soil. The total phosphorus content was highest in continuous phosphorus applied plots which on par with cumulative phosphorus in the second year.

IV. Direct, residual and cumulative effects of phosphorus on the first crop of rice after cowpea and after sesamum

A. Effect on rice after cowpea

16. Plant height was not affected by the direct, residual and cumulative phosphorus application.

17. Tiller number recorded significant difference, with residual phosphorus recording the highest number of tillers at 30 DAT during the second year, at flowering stage during both the years, and at

harvest stage during the second year. LAI at flowering stage during the second year recorded higher value by residual phosphorus.

18. Among the yield attributes only number of panicle/m^2 was significant during the second year with residual phosphorus recording the highest number.

19. Grain and straw yields were not significantly influenced by the different treatments of direct, residual and cumulative phosphorus.

20. Nitrogen and phosphorus uptake at flowering and harvest was the highest in residual phosphorus, potassium uptake was significantly higher in direct and residual phosphorus treatments which were on par with continuous phosphorus application in the second year.

21. Residual phosphorus was sufficient to maintain the available nitrogen status of the soil. With regard to available phosphorus, direct phosphorus application in the first year and continuous application and direct application of phosphorus in the second year recorded higher values. Total phosphorus content was highest under continuous phosphorus and under cumulative phosphorus. Available potassium was highest in cumulative phosphorus treatment followed by continuous and direct phosphorus application.

31. Grain equivalent (kilocalories) for the rice-rice-cowpea and rice-rice-sesamum systems revealed that the different treatments behaved consistently similar for the rice-rice-cowpea and rice-rice-sesamum systems.

VII. Economics

32. The highest net return of Rs.10292/- and benefit-cost ratio of 1.85 for the rice-rice-cowpea system and a net return of Rs.10726/- and benefit-cost ratio of 1.90 for the rice-rice-sesamum system were obtained where phosphorus was applied only to the third crop of cowpea/sesamum. An additional net return of Rs.1255/- was obtained from rice-rice-sesamum system over rice-rice-cowpea system in one year.

From the present investigation, it can be concluded that for the best management of phosphorus for the rice-rice-cowpea and rice-rice-sesamum systems, phosphorus need to be applied only to the third crop of cowpea/sesamum.

Future line of work

(1) Experiments with less soluble phosphatic fertilizers like rock phosphate in addition to superphosphate are to be carried out in order to study the relative

efficiency and residual value in râce based cropping systems.

(2) Management of other major nutrients like nitrogen and potassium along with phosphorus in cropping systems can also be undertaken in order to study the fertilizer management practices for rice based cropping systems.

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* Originals not seen.

APPENDIX

Appendix I

Meteorological data for the cropping period from June 1984 to September 1986.

Sl. No.	Months		Rainfall (m.m)	Temperature °C Maximum	Temperature °C Minimum	Relative humidity (%)	Number of rainy day
1.	June	1984	215.8	30.3	22.9	72.5	12
2.	July	"	131.6	28.9	23.7	80.0	16
3.	August	"	22.4	28.8	23.8	69.5	4
4.	September	"	83.2	30.3	23.8	75.5	8
5.	October	"	201.8	28.6	22.1	71.5	10
6.	November	"	120.6	30.7	23.8	79.5	12
7.	December	"	5.4	30.6	22.6	78.0	1
8.	January	1985	61.2	30.7	22.9	80.5	2
9.	February	"	26.0	31.8	23.8	82.0	4
10.	March	"	8.1	32.4	25.6	82.5	4
11.	April	"	38.4	33.5	22.3	77.5	5
12.	May	"	8.1	33.7	22.1	79.0	4
13.	June	"	322.1	28.5	23.1	79.0	20
14.	July	"	71.0	28.2	22.4	71.5	7
15.	August	"	21.7	28.6	23.6	83.0	3
16.	September	"	0.0	30.3	23.6	81.0	0
17.	October	"	594.0	30.6	22.8	85.0	13
18.	November	"	240.0	29.8	23.0	79.0	12
19.	December	"	104.8	30.9	23.0	72.4	10
20.	January	1986	21.6	31.9	21.8	75.0	2
21.	February	"	86.0	31.9	20.8	76.0	3
22.	March	"	8.6	31.8	20.8	59.0	2
23.	April	"	125.5	33.9	23.6	73.6	9
24.	May	"	132.1	33.7	22.7	73.8	5
25.	June	"	224.3	31.2	22.6	76.0	15
26.	July	"	94.4	30.5	22.9	79.0	13
27.	August	"	449.3	30.3	22.4	74.0	13
28.	September	"	102.4	30.3	23.4	74.0	11

APPENDIX

Appendix I

Meteorological data for the cropping period from June 1984 to September 1986.

Sl. No.	Months		Rainfall (m.m)	Temperature 8C Maximum	Temperature 8C Minimum	Relative humidity (%)	Number of rainy day
1.	June	1984	215.8	30.3	22.9	72.5	12
2.	July	"	131.6	28.9	23.7	80.0	16
3.	August	"	22.4	28.8	23.8	69.5	4
4.	September	"	83.2	30.3	23.8	75.5	8
5.	October	"	201.8	28.6	22.1	71.5	10
6.	November	"	120.6	30.7	23.8	79.5	12
7.	December	"	5.4	30.6	22.6	78.0	1
8.	January	1985	61.2	30.7	22.9	80.5	2
9.	February	"	26.0	31.8	23.8	82.0	4
10.	March	"	8.1	32.4	25.6	82.5	4
11.	April	"	38.4	33.5	22.3	77.5	5
12.	May	"	8.1	33.7	22.1	79.0	4
13.	June	"	322.1	28.5	23.1	79.0	20
14.	July	"	71.0	28.2	22.4	71.5	7
15.	August	"	21.7	28.6	23.6	83.0	3
16.	September	"	0.0	30.3	23.6	81.0	0
17.	October	"	594.0	30.6	22.8	85.0	13
18.	November	"	240.0	29.8	23.0	79.0	12
19.	December	"	104.8	30.9	23.0	72.4	10
20.	January	1986	21.0	31.9	21.8	75.0	2
21.	February	"	86.0	31.9	20.8	76.0	3
22.	March	"	8.6	31.8	20.8	59.0	2
23.	April	"	125.5	33.9	23.6	73.6	9
24.	May	"	132.1	32.7	22.7	73.8	5
25.	June	"	224.3	31.2	2[illegible].6	76.0	15
26.	July	"	94.4	30.5	22.9	79.0	13
27.	August	"	449.3	30.3	22.4	74.0	13
28.	September	"	102.4	30.3	23.4	74.0	11

PHOSPHORUS MANAGEMENT IN A RICE BASED CROPPING SYSTEM

BY

ANNAMMA GEORGE

ABSTRACT OF A THESIS

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ABSTRACT

In order to standardise an appropriate phosphorus management practice in a rice based cropping system involving rice-rice-cowpea/sesamum, field experiments were carried out in the rice fields of the Instructional Farm, College of Agriculture, Vellayani from June 1984 to September 1986. The experiment was laid out in a randomized block design with three replications. There were eight treatments. The treatments comprised of (1) continuous phosphorus application to all the three crops in the system (2) phosphorus application to the first and second crops of rice (3) phosphorus application to the first crop of rice and third crop of cowpea/sesamum (4) phosphorus application to the first crop of rice only (5) phosphorus application to the second crop of rice and third crop of cowpea/sesamum (6) phosphorus application to the second crop of rice only (7) phosphorus application to the third crop of cowpea/sesamum only (8) control plot with no addition of phosphorus to any of the crops in the system.

The salient findings of the experiment are as follows:

Phosphorus application had no significant influence on grain and straw yield of first crop of rice. But

available nitrogen, available and total phosphorus and available potassium of the soil were increased with phosphorus application.

Direct, residual and cumulative effects of phosphorus had no significant ifluence on grain and straw yield of second crop of rice. Phosphorus uptake could not show any variation due to the different treatments. Available and total phosphorus content of the soil were highest under cumulative phosphorus treatment.

All the growth and yield attributes of third crop of cowpea and sesamum were increased by the direct and cumulative effects of phosphorus. Grain yield of cowpea was significantly increased by the direct application of phosphorus. Eventhough not significant the highest sesamum yield was accorded by the direct and cumulative application of phosphorus. Phosphorus uptake in all the growth stages of the crop was highest in direct phosphorus plots. Available and total phosphorus content of the soil was highest in continuous phosphorus applied plots.

There was no significant influence on grain and straw yield of first crop of rice after cowpea and sesamum in the direct, residual and cumulative effects of phosphorus. Residual phosphorus was sufficient to maintain the available nitrogen status of the soil. Available phosphorus of the soil was increased by the direct, cumulative and continuous application of phosphorus and total phosphorus by continuous application of phosphorus.

Balance sheet of available phosphorus revealed that the soil phosphorus level almost maintained, where phosphorus was applied only to the third crop of cowpea or sesamum.

The highest net return and benefit-cost ratio for the rice-rice-cowpea and rice-rice-sesamum system was obtained when phosphorus was applied only to the third crop in the rice fallow and the residual effect being utilised by the succeeding rice crops.