PHOSPHORUS NUTRITION OF RICE

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THESIS

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DECLARATION

I hereby declare that this thesis entitled 'Phosphorus nutrition of rice' is a bonafide record of research work done by me during the course of research and this 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 nutrition of Rice' is a record of research work done independently by Kum. USHA L, 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

Rice, which provides a third of the world's population with more than half their calories and nearly half their protein, plays a part of no small importance in world's economy. It plays a vital role in the Indian economy too.

Rice yields are generally low in the tropics, national average yields range from 1.5 to 2.5 t/ha whereas the potential yields in the tropics is 13 - 15 t/ha. Tropical farmers are realizing only 10 to 20 per cent of their potential yields. With the introduction of high-yielding, fertilizer responsive rice varieties substantial increase in rice production has been achieved in India.

The object of getting higher yield cannot be met with by the introduction of high yielding varieties alone. Development of suitable agronomic practices assumes greater importance in giving full expression of the yield potential of these varieties. Therefore it is of great significance that the response of each variety to different levels of nutrients may be studied in detail with a view to find out the optimum levels of nutrients for each variety for maximum returns.

Among the major plant nutrients, the response to nitrogen has been found to be linear in most of the high yielding varieties of rice. The story of potash is also more or less the same except in certain localized pockets. However, trials conducted with phosphatic fertilizers either alone or in combination with organic or inorganic sources of nitrogen, indicate that unlike nitrogen or potash, phosphorus generally gives little or no response in most of the places.

The importance of phosphorus nutrition in crop production is recognised by the fact that a deficiency of this element is very often a limiting factor in many soil types. At the same time it is a very critical element in the plant nutrition in as much as it controls several vital metabolic processes within the plant.

More than 90 per cent of the soils of Kerala are acidic in reaction and as such are low in available phosphorus. The anomalous behaviour of fertilizer phosphorus has been sought to be explained as due to the fixation of this element in the soil. A number of known as well as unknown factors contribute to the lack of response to applied phosphorus in soils. One such factor in the wet land flooded condition being the increased availability of native phosphorus due to flooding. Plants may be able to obtain sufficient amount of this nutrient from the limited supply of available phosphorus in the soil, thereby making the application of phosphorus ineffective.

In rice phosphorus is usually applied as basal dressing. However, late application can be made if needed provided it is not applied later than the stage of tillering. Early application of phosphorus is essential for root elongation whereas phosphorus applied during the tillering stage is most efficiently utilized for grain production. Furthermore, the availability of soil phosphorus increases with time during submergence. This indicates that correct application of phosphatic fertilizers in early stages of growth will also take care of the phosphorus requirement of the crop during its later stages of growth. In spite of the comparatively greater availability of phosphorus in submerged soils, the recovery of applied phosphate by rice is still very low. This means that there is room for increasing phosphate efficiency or economising the rate of application, if the method of application can be improved. However, only very little work has been done on this subject.

Foliar fertilization of nitrogen has been the subject of studies since several years and its feasibility has been fully ascertained. This method provides more rapid utilization of nutrients and permits the correction of observed deficiencies in less time than would be required by soil treatments. When problem of fixation of nutrients exist, foliar application constitutes the most effective means of fertilizer placement. However, for foliar application of phosphorus the problem of adding sufficient amount becomes critical.

Another method for increasing the efficiency of phosphatic fertilizer is to treat the seeds with chemicals like Potassium dihydrogen phosphate or Diamonium phosphate. In a few field experiments the plants from pre-treated seeds significantly outscored those from untreated seeds Mehrotra et al. 1967, 1968; Basu and Prativa, 1978).

Several workers have cited experiments where dipping the seedling roots in a solution of phosphate or in a super phosphate - soil slurry prior to transplanting has significantly increased the yields of rice.

Adequate applications of phosphorus to the seedling nursery were found, in some cases, to increase the yield of rice in the main field. This has been found to reduce to a certain extent the requirement for phosphorus in the main field.

In order to assess the relative merits of various methods of phosphorus fertilization, an experiment has been laid out at the College of Agriculture, Vellayani with the following objectives.

1. To study the relative efficiency of different methods of application of phosphorus to rice variety Triveni.

2. To assess the level and method of phosphorus application.

3. To find out the effect of phosphorus application on the yield and quality of produce.

4. To find out the uptake of phosphorus as influenced by the levels and methods of phosphorus application.

5. To study the economics of various methods of phosphorus application.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Role of Phosphorus in Plant Growth

Phosphorus which is one of the three major plant nutrients is a constituent of the cell-nucleus, nucleic acids, phytin and phospholipids. Apart from contibuting greatly to high rice yield, phosphorus is necessary in several other ways (De Geus, 1954). (1) It stimulates root development, making plants more resistant to drought. (2) It promotes early flowering and ripening by means of which the unfavourable influence of late transplanting is eventually reduced or neutralized. (3) It encourages more active tillering which enables rice plants to recover more rapidly and more completely after any adverse situation. (4) It gives a higher food value to rice, owing to the higher phosphorus content of the grain. It has an important role to play in many of the metabolic processes such as synthesis and breakdown of carbohydrates, fats and proteins and in the transfer and conservation of energy (Anonymous, 1961).

An adequate supply of phosphorus is essential for cell-division, root development, early maturity and seed growth. Low phosphorus supply suppresses early nitrogen uptake and prevents the synthesis of proteins from nitrogenous substances. A plentiful supply in the early stages promotes early growth because such a high supply increases the content of nucleic acid phosphorus and phospholipid phosphorus. According to Fujiwara (1964) nucleic acids can actually promote heading in rice as it controls vegetative growth through protein biosynthesis and reproductive growth through flower initiation. Phosphorus plays its specific role in the metabolism of rice plant through ribose nucleic acid which in turn is known to be involved in protein synthesis.

Tamhane et al. (1964) reported that phosphorus imparts decreased resistance to plants as it induces normal cell development resulting in vigorous growth. Black (1967) observed that plant structure, metabolism and reproduction are controlled by phosphorus.

Phosphorus increases the number of tillers as well as the number of productive tillers. It is found essential for root development, flower primordia initiation, stimulation of growth, grain formation and early maturity of crops. An adequate supply of phosphorus is associated with greater strength of cereal straw (Tisdale and Nelson, 1975).

Recent investigations by Bhattacharyya and Chatterjee (1978) further revealed that phosphorus manuring increased early tiller formation greater part of which ultimately provided more grains of heavier weight. There was early and synchronous flowering as well.

Transformation of Phosphorus in Flooded Soils

Many workers have reported that the behaviour of phosphate in waterlogged soils is remarkably different from that in upland soils. The unique soil conditions created by waterlogging 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 response to phosphatic fertilizers even in soils low in phosphate.

Fujiwara (1950) observed that the response of lowland rice to iron and aluminium phosphate was markedly superior to that of barley. The better performance of ferric phosphate to lowland rice was due to its higher solubility under reducing conditions. The increase in solubility of phosphorus in a flooded soil may be attributed to (a) reduction of ferric phosphate to the more soluble ferrous phosphate and (b) displacement of phosphate from ferric and aluminium phosphate by organic anions.

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

Shapiro (1958 a) observed an increase in available phosphorus with flooding resulting from reducing conditions and an increased hydrolysis of iron and aluminium phosphate. Shapiro (1958 b) in a further experiment verified the role of ferric phosphate in phosphorus nutrition of rice and observed that the uptake of phosphorus by rice from added ferric phosphate was about 294 per cent greater in flooded than in non-flooded soils.

Davide (1960) observed that with $CaH_4\ (PO_4)_2$ as a phosphate source, response to rice was almost the same in flooded and non-flooded soil but with iron phosphate the response was much better in flooded soils than in non-flooded ones and therefore concluded that the beneficial effects of flooding on phosphate availability depended on the intensity of reduction and on iron content of the soil.

Basak and Bhattacharya (1962) observed that iron and aluminium and organic phosphorus decreased while available phosphorus increased from planting to tillering stage of rice. Chiang (1963) studied the availability of native and applied phosphate to rice grown on water-logged soils and observed that soon after flooding available phosphate increased, apparently through the hydrolysis of aluminium phosphate and the reduction of iron phosphate.

Datta and Datta (1963) from their studies with isotope P^{32} reported increased availability of soil phosphorus as measured by 'A' value due to flooding. Broeshart et al. (1965) working on soils from a number of rice growing countries of the world confirmed that the supply of soil phosphorus for rice increases if the soil is flooded.

An experiment conducted by Raghupathy and Raj (1973) to study the availability fluctuations of soil phosphorus fractions during paddy growth under flooded conditions showed that the available phosphorus and aluminium phosphate content were higher on the 15^{th} day after transplantation than at post-harvest stage.

Mosi et al. (1973) concluded that lowland rice was not likely to respond to addition of phosphatic fertilizers as upland crops which may be due not so much to a lower nutritional requirement for phosphorus 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 phosphorus 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. Shiga (1976) observed that in flooded alluvial, peat and volcanic ash soils in the field, extractable phosphorus content increased during tillering.

Gupta and Singh (1977) observed that the poor response of rice to applied phosphorus was attributed to the increase in labile phosphorus during flooding. Singh and Ram (1977) observed that available phosphorus in alluvial clay and red sandy loam soils increased upto tillering stage and then tended to decrease. The increase in available phosphorus in red soil was mainly related to decrease in iron phosphate and calcium phosphate concentration while in clay soil it was related to decrease in aluminium phosphate and calcium phosphate concentration. The decrease in available phosphorus was due to the reformation of insoluble iron phosphate and calcium phosphate in the red soil and of calcium phosphate and aluminium phosphate in the clay soil.

Mechanism of Phosphate Release in Flooded Soils

It has been demonstrated by various workers that fertilizers added to the well drained soils change gradually into ferric phosphate which upon reduction forms ferrous 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 and (5) anion exchange between clay and organic anions (Russell, 1962). Another possible process of increase in the availability of phosphorus has been explained by the following reaction, which occurs under highly reduced conditions (Sperber, 1958; Kawaguchi, 1965).

$$Fe_3 (Po_4)_2 + 3 H_2S \longrightarrow 3 FeS + 2H_3Po_4$$

This process prevails in soils poor in free iron.

Effect of Organic Matter on Phosphorus Transformation in Flooded Soils

Organic matter affects phosphate transformation in waterlogged soils through the mechanism of reduction and chelation. Both processes lead to increase in the solubility and availability of soil phosphate (Shapiro, 1958 b). The transformation of inorganic phosphate to organic form, observed in flooded soils (Bartholomew, 1961., Paul and Delong, 1949) results in decreased phosphate availability. Evidence of the formation of insoluble aluminium organic complexes of phosphorus due to anaerobic fermentation of rice straw has been provided by Gasser (1956).

Mandal and Mandal (1973) observed that application of organic matter significantly lowered the fixation of added phosphorus both as iron and aluminium phosphate in acidic lowland rice soils.

The Uptake of Native and Applied Phosphorus by Rice

Information on the behaviour of native and applied phosphorus as well as the stage of growth of the plant at which uptake of this element is maximum is useful in evaluating the best time for applying phosphatic fertilizers to low land rice.

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

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

In the early stages of growth, seedlings absorb phosphorus at a faster rate from the fertilizer than from the soil the net result being that in young plants a high proportion of the total phosphorus absorbed is that derived from the fertilizers. As the plants develop, the enlarging root system continuously increases the amount of soil phosphorus absorbed compared with that of fertilizer phosphorus (Dean and Fried, 1953).

Sahu (1955) observed that the absence of effect of applied phosphorus on rice under waterlogged conditions appears to be due to the increased availability of native and fixed phosphates and concluded that the phosphate requirement of rice could be met from native and fixed phosphates present in the soil.

Maung - Mya - thuang (1960) from his studies on the effect of time of application and relative absorption of phosphorus from native and additive sources using radioactive phosphorus observed that during early stages of growth when the level of available phosphorus in the soil is still low, because of its gradual release, the young plants used more of the applied phosphorus. He also concluded that with the application of phosphorus either midway between transplanting and flower primorida initiation, the plants absorbed phosphorus from both native and applied forms. The studies also disclosed that, of the total phosphorus content of the plant more phosphorus came from the soil phosphorus.

Tanaka (1962) found that the rice plant grows normally when supplied with a nutrient solution in which the phosphorus is maintained at 0.1 ppm. Second, waterlogging releases phosphate from fixed forms to the soil solution as a result of the reduction reactions which probably ensure an adequate supply of phosphorus throughout most of the season in soils that are otherwise deficient in phosphate, but contain appreciable amounts of iron phosphate and reductant soluble phosphate.

Experimental evidences reported from the International Rice Research Institute, Manila (Anonymous, 1964) showed that the percentage of phosphorus in the plant increased with an increase in the phosphorus content of the soil. Savant and Ellis (1964) reported that soil moisture influenced the uptake of both native and applied phosphorus. In so far as phosphorus is concerned low-land rice differ from upland crops in that the rice plant can absorb adequate amount of phosphorus from a soil solution with a low concentration of phosphate (Okajima, 1965).

De Datta et al. (1966) from his experiments with an indica variety of rice (Milfer 6(2)) reported that only 8 to 27 per cent of the total phosphorus in the plant was derived from the applied phosphorus. Kalam et al. (1966) reported that the magnitude of response to phosphorus was much lower than that of nitrogen due to the high status of available phosphorus in the soil. Patrick and Mahapatra (1968) reported that drying of soil decreased the available phosphorus content in the soil.

Terman and Allen (1970) observed that the total uptake of phosphorus increased markedly with the amount of applied phosphorus on the low-P soil and slightly on the medium-P soil; there was no response on the high-P soil. Percentages of plant phosphorus from the 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. Uptake of soil phosphorus increased markedly with increase in soil phosphorus level.

George and Sreedharan (1970) from their experiments at Vellayani concluded that the basal application of phosphorus appears to have ensured an adequate supply of this element during the first and second months of plant growth while soil phosphorus was utilised only during later stages of growth.

Jose and Raj (1971) observed that the reduction in the phosphorus status of the soil may be due to greater removal of phosphorus by the growing crop from tillering to flowering time compared to the period from sowing to tillering. Alexander et al. (1973) found that application of different levels of phosphorus did not have any positive effect on any of the yield attributes. This lack of response to added phosphorus may be due to higher status of available phosphorus in the soil. Majumdar (1973) found that recovery of applied P_2O_5 was only 2 per cent. Matzel (1974) observed that only 55-60 per cent of the fertilizer phosphorus was used by the plants while the remainder was converted into unavailable forms which vary according to soil composition and pH.

Sinha et al. (1980) observed that the uptake of total phosphorus and fertilizer phosphorus increased with increasing rate of applied phosphorus from 0 to 90 kg/ha, while utilization percentage of the applied phosphorus decreased.

Uptake Pattern of Phosphorus by Rice Plant

Rao and Rao (1961) found that the absorption curve for phosphorus was sigmoidal with peaks occuring during the vegetative and reproductive stages. Reyes et al. (1962) found that 93 per cent of the total uptake of phosphorus occured from transplanting to booting stage and suggested an adequate supply of phosphorus during this stage.

At IRRI it was found that phosphoric acid supply increased the absorption of phosphorus and its content in straw (Anonymous 1964; 1965). Ishizuka (1964) from his studies on the relative uptake of native and applied phosphorus at different stages of plant growth reported that the absorption of nutrients was noticed fifteen days after germination. He found that the percentage of phosphorus in plant was high in the seedling stage, decreased rapidly after transplanting, then increased gradually corresponding to the recovery from the shock of transplanting and reached a high percentage at the time of initiation of flower primordia. Maximum uptake of phosphorus occurs during 50-60 days after germination. Patnaik et al. (1965) from his studies with short duration rice varieties found that in the case of phosphorus there was a tendency for lower absorption during the initial twenty to forty days after which there was vigorous uptake which continued upto flowering or a little later. In medium and long duration varieties, there was an increase in the rate of absorption of phosphorus till the maximum tillering phase only and slowed down considerably during the vegetative phase.

Gargantani and Blanco (1965) sampled rice plants at 10 day intervals to study the absorption of nutrients and found that the absorption of phosphorus was continuous throughout the period.

Mehrotra et al. (1968) found that the rate of phosphorus absorption continued to increase throughout the growth period. Chandrasekharan and Durairaj (1969) reported that the absorption of phosphorus was rather slow during the early stages of growth. Nearly 75 to 80 per cent of the total phosphorus was absorbed upto 52nd day after planting and thereafter there was a tendency for flattening in the uptake pattern graph. Naphade (1969) reported that the rate of phosphorus absorption was much higher at 40 to 90 days after transplanting than at other periods.

Jose and Raj (1971) reported that the reduction in the phosphorus status of submerged soils may be due to the greater removal of phosphorus by the growing crop from tillering to flowering time compared to the period from sowing to tillering. This is substantiated by the fact that even from the control plot the crop removed 4-7 kg phosphorus per hectare during the period as compared to 0.82 kg per hectare from sowing to tillering.

Ali and Morachan (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 b) 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 flowering stage and then a rapid increase from flowering to harvest. Mohanty and Patnaik (1974) also reported that absorption of phosphorus by rice was greatest from transplanting to flowering, irrespective of the soil type, after which uptake was very slow.

Thandapani and Rao (1974) observed that the phosphorus content of the root and shoot were highest at tillering stage and at the flowering stage there was a slight reduction in the phosphorus content in all the treatments and at the harvesting stage the phosphorus content was very low both in straw and root. At all these stages, the phosphorus content in the plants increased with increase in the level of phosphorus application.

In trials with rice given 2-80 kg P_2O_5/ha by two methods (top dressing and foliar spray) 25 days after transplanting, the total acid soluble phosphorus contents in plants increased upto flowering and decreased thereafter; they were higher with phosphorus applied as foliar spray than as a top dressing. The highest leaf contents of acid soluble inorganic phosphorus in early growth decreased with age (Vijayan and Rao, 1975).

Shiga (1976) observed that tiller number increased until phosphorus content reached about 0.8 per cent P_2O_5, while highest panicle number and grain yield were reached at 0.6 - 0.7 per cent P_2O_5. Shiga et al. (1976) reported that in rice grown on 3 soils with various rates of phosphorus applied to previous crops extractable phosphorus content in flooded soil increased during tillering.

Weeraratna (1976) reported that the rate of uptake increased from one to three months after sowing and was higher in the high than in the low yielding cultivars. An experiment conducted by Suseelan et al. (1978) to study the uptake pattern of phosphorus by rice revealed that the pattern of phosphorus absorption showed an increasing trend upto the primordia initiation stage, followed by a gradual depression thereafter.

Iruthayaraj and Morachan (1980) found that the uptake of phosphorus was high at harvest stage. Chaudhary and Uppal (1981) reported that the phosphorus accumulation was 4.2, 4.4 and 6.4 mg/pot upto tillering and 32.7, 30.2 and 38.5 mg/pot from tillering to maturity in cultivars - IR 8, Jaya and J-351 respectively without added phosphorus. Addition of 60 ppm phosphorus increased total phosphorus accumulation at maturity to 92.4 - 106.8 g/pot.

Rastogi et al. (1981) observed that increasing levels of applied phosphorus, increased the total uptake and fertilizer phosphorus uptake, but decreased available soil phosphorus uptake and utilization percentage of the applied phosphorus at the tillering, flowering and maturation stages.

Phosphorus Uptake at Different Stages of Growth in Relation to Yield

Many workers have attempted to evaluate the efficiency of phosphorus absorbed at different stages of growth for grain production for devicing a suitable schedule for phosphate application.

Kasai and Asada (1960) reported that at maturity 80 per cent of the phosphorus in the entire plant was present in the grain. Using isotope P^{32} these workers were able to conclude that 60 to 80 per cent of the total phosphorus absorbed at each stage of growth was translocated to the grain. They also found that most of the phosphorus brought to the grains from milky stage to maturity was translocated from the stem and leaves.

Ishizuka (1964) from his studies observed that after flowering the phosphorus content in the leaves and culm began to move to the grains, and continued upto the dough stage. This coincided with the translocation and accumulation of starch in the grain, showing a close relationship between carbohydrate metabolism and phosphorus uptake. Bredero (1965) observed a linear relationship between yield and phosphorus uptake.

Patnaik et al. (1965) from their solution culture studies on a short and medium duration variety (ptb-10 and T-141) concluded that with adequate supply, the phosphorus absorbed during the tillering stage is most efficiently utilised for grain production and is adequate to give an optimal yield. They have also found that phosphorus absorbed beyond this period tended to accumulate in the grains, straw and roots with no advantage to grain production.

Rao and Rao (1965) observed that available soil phosphorus level showed a significant positive correlation with the plant phosphorus content and grain yield. Naphade (1969) reported that there is significant correlation between grain yield and phosphorus uptake. Patnaik and Gaikawad (1969) observed that the peak of partial productive efficiency occured during the active vegetative growth period (upto 8 weeks after transplanting), indicating that the nutrients absorbed during this period were most effectively utilized by rice for grain production.

George and Sreedharan (1970) reported that application of full dose of phosphorus gave significantly higher grain yields while delay in grain yield was found to be proportionate to the period of delay in its application.

Terman and Allen (1970) observed that in low-P soil, yield and phosphorus uptake increased with rate of applied phosphorus, but decreased with delay in application. Mohanty and Patnaik (1974) also reported that low levels of phosphorus decreased yield and phosphorus uptake. Shiga et al.(1976) observed that tiller number increased with plant phosphorus content upto 0.8 per cent P_2O_5 but panicle number and grain yield increased only upto 0.6 to 0.7 per cent.

Katyal (1978) reported that the critical soil water soluble phosphorus content below which plants yielded little or no grain was 0.05 ppm and highest yields were obtained with 50 ppm. Sinha et al.(1980) observed that uptake of total phosphorus and fertilizer phosphorus increased from 0 to 90 kg per hectare while utilization percentage of the applied phosphorus decreased. Increase in phosphorus rates increased paddy and straw yields and decreased uptake of soil phosphorus.

Methods of Application of Phosphatic Fertilizers

The efficiency of fertilizer use, as reflected in the growth and yield responses, is to some degree influenced by factors such as kind or source, rate, time and method of application, or combination of some these. This is especially significant with phosphatic fertilizers because they react with various soil constituents giving products of varying availability to plants.

A. Single vs Split Application of Phosphorus

There are evidences that under upland conditions the placement of phosphatic fertilizer can affect yield more significantly than rates of application or sources. This may not be the case in flooded soils where reducing conditions exist.

Despite the greater availability of phosphorus in a lowland soil, the recovery of fertilizer-phosphorus by rice is generally less than 10 per cent. Where extensive fertilization is practised in the rice growing areas, phosphorus is usually applied as a basal dressing. It is usually broadcast, with or without mixing with the surface mud, either during final land preparation or puddling, immediately before sowing seeds or before transplanting the seedling (De Geus, 1954).

Maung-Mya-Thaung (1960) observed that in the early stages of growth, when the level of available soil phosphorus was still low because of its gradual release, the young plant used more of the fertilizer phosphorus. Consequently, with application either midway between transplanting and flower primordia initiation or at the flower primordia, the plant had two sources. He observed that more phosphate uptake came from the soil phosphorus.

Reyes et al.(1962) found that 93 per cent of the total uptake of phosphorus occured from transplanting to booting stage and suggested an adequate supply of phosphorus during this stage. Broeshart and Fried (1963) concluded that phosphate application may be made in a single dose at the time of transplanting.

Ishizuka (1964) observed that phosphorus is absorbed from the beginning of growth to the earing stage; but after this stage absorption is slight or absent. He suggested the necessity of synchronizing application of phosphorus within this period for maximum efficiency. The data suggest that there should be adequate supply of phosphorus from transplanting to booting stage.

Dobrunov et al. (1968) concluded that fertilizers were most effective when applied before sowing. Axenova et al. (1969) found that soil phosphorus content decreased as plants developed and was not affected by split application of phosphorus. Chandrasekharan and Durairaj (1969) reported that single application of nutrients at planting recorded higher yield of both grain and straw. Single application at planting made higher amount of phosphorus available for the uptake of the crop in the initial stages, compared to split applications and hence yield would be higher in single than in split applications. Patnaik and Gaikwad (1969) also had stressed the importance of providing adequate available phosphorus at early stages to ensure maximum production.

George and Sreedharan (1970) observed that basal application of full dose of phosphorus gave significantly higher grain yields than the treatments which received phosphorus as top dressing. It was also seen that reduction in grain yield due to delayed application of phosphorus was proportionate to the period of delay in their application; the basal application of phosphorus appears to have ensured adequate supply of this element during the first and second months of plant growth while soil phosphorus was utilised during later stages of growth.

Patnaik et al. (1974) reported that in field experiments over several years in lowland rice, drill application of phosphate at seeding was superior to early season top dressing. Higher yields were obtained with top dressing two weeks after seeding than with top dressing later in the season. Rao et al. (1974) observed that higher yields were obtained with application of phosphorus as a basal dressing before transplanting than by applying in a single top dressing or as basal + top dressing.

Katyal (1978) observed that higher yields were obtained with phosphorus broadcast than when mixed with top 15 cm of soil and with single than split applications. Delaying phosphorus application for more than 14 days after transplanting reduced yields and increased time to maturity with a greater effect in the dry than in the wet season. Agarwal (1980) also reported that splitting of phosphorus did not have any advantage over basal application.

There are also evidences to show that split application of phosphorus is superior to single application. Yang et al. (1968) reported that split application of phosphorus was more effective for first than for second crop and more effective for light than heavy soils. Halappa et al. (1970) reported that the application of 60 kg P_2O_5 per hectare in 2 split dressings at transplanting and tillering resulted in highest (average) number of ear-bearing tillers per hill (11.9), grains per ear (73), paddy yields (9.77 t/ha) and 1000 grains weight (29.8 g) Kuo (1973) also reported that on poorly drained soils in first crop of 1970, '71 and '72 application of (a) 72 kg P_2O_5 per hectare (50 per cent as a basal dressing and 25 per cent each as top dressing) gave the highest yield increases of 7.5 -12.1 per cent (290-527 kg/ha) over (b) the control treatment given 36 kg P_2O_5 per hectare as basal dressing. In the second crop of 1970 and 1972 application of (c) 72 kg P_2O_5 per hectare (50 per cent as a basal dressing and 50 per cent at the first top dressing) increased yields from 13.8 to 32.8 per cent (295-1142 kg/ha). Results from field experiments conducted by Rao et al.(1973) on split and foliar application of complex fertilizers on IET-1991 rice, showed that most suitable schedule was 25 per cent of the fertilizer as a basal application followed by 50 per cent 21 days after planting and 25 per cent at panicle initiation. Chaudhary and Uppal (1981) on the effect of time of application of phosphatic fertilizers showed that their application in one single dose at the time of puddling was the best treatment for varieties IR-8 and Jaya, but variety J-351 which accumulates high amounts of phosphorus both upto tillering and from tillering to maturity stages, responded significantly to split application of phosphorus; half at puddling and half at tillering.

B. Foliar Fertilization

Certain of the fertilizer nutrients soluble in water may be applied directly to the aerial portion of the plants. The nutrients must penetrate the cuticle of the leaf or the stomata and then enter the cells. This method provides more rapid utilization of nutrients and permits the correction of observed deficiencies in less time than would be required by soil treatments. When problem of soil fixation of nutrients exists, foliar application constitutes the most effective means of fertilizer placement. For foliar application of phosphorus, the problem of adding sufficient amount becomes critical.

Studies on the comparative efficiency of soil and foliar application of phosphorus by Yatazawa (1954) indicated that the uptake and absorption of phosphorus was better through foliage. Narayanan and Vasudevan (1957) found that superphosphate at one per cent foliar spray (11 kg/ha) increased the grain yield by 14.4 per cent over control at Coimbatore. Straw yield responses follow the same trend, but in a slightly larger measure than grain. According to them foliar application of phosphates represent the most efficient method of fertilizer placement yet devised, because upto 95 per cent is utilized by the plant and quantities used is very much less than the quantity necessary to produce the same yield by soil application.

Bodade (1966) studied the effect of foliar application of nitrogen and phosphorus on the yield of jowar.

Foliar dressing of 3 per cent solution of urea plus triple superphosphate (at 16.87 kg N plus 11.25 kg P_2O_5/ha) applied at 1.5 and 2.5 months after sowing gave similar increases in yield as double these amounts applied to the soil at sowing. The results of trials conducted by Ramiah et al. (1970) with ragi showed that band placement and foliar methods recorded a significantly higher grain yield, the increase being 6.6 per cent over broadcast method. However, the straw yield was not significantly altered by any of these methods.

Rajat De (1971) found that application of the entire quantity of phosphorus through the soil is often associated with lower utilization whereas maximum absorption and utilization of phosphorus were observed when foliar application was resorted to.

Field experiments conducted by Jha et al.(1973) at I.A.R.I., New Delhi during the Kharif season of 1970 and 1971 with rice varieties Sabarmati and Jamuna showed that uptake of phosphorus was increased with foliar sprays of different nutrients alone and in combination. They also observed that land submergence would be dispensed with by foliar sprays of phosphorus in moist conditions in so far as phosphorus concentration and uptake were concerned. Increased P_2O_5 concentration and uptake in rice grain and straw was due to the contribution of this element directly through the foliage in addition to native soil phosphorus.

Bhuiya et al.(1975) assessed the effect of foliar and soil application of N, P and K fertilizers on the growth, yield and quality of rice and found that phosphorus content of the grain increased with higher P_2O_5 levels. Grain yields and quality were higher with foliar than soil applications.

Vijayan and Rao (1975) studied the uptake pattern of phosphorus in rice related to modes of application and observed that the total acid soluble P content in plants increased upto flowering, and decreased thereafter; they were higher with phosphorus applied as foliar spray than as top dressing. Vijayan and Rao (1977) observed that medium level of phosphorus of 60 kg/ha had more influence on tiller production, number of grains per panicle and 1000 grains weight. Medium level of 60 kg/ha through soil and 40 kg/ha through foliage recorded high yields of grain and straw. The total number of whole grains and less number of chaffs per panicle recorded higher values at optimum level of 60 kg/ha through soil and 40 kg/ha through foliage. But there was very little influence on 1000 grains weight between modes of application.

A pot culture study carried out by Mahapatra and Gupta (1978) to observe the efficiency of foliar spray on rice showed that the foliar spray of 1.81 per cent triple superphosphate solution gave more yield during the Rabi season compared to the _Kharif_ season. Foliar application produced significantly more number of grains per pot and the grain yield was nine per cent more over the control.

Although there are many reports revealing the response of crops to foliar application of phosphorus, there are reports showing negative or no response also.

The results of trials conducted by Krishnamoorthy et al. (1973) on the efficacy of soil and foliar application of N and P to IR-8 rice revealed that under certain soil conditions, soil application of N and P was as good as foliar application and equally efficient since leaching losses and fixation etc. were negligible. Top dressing of both 1/2 N and 1/2P through soil was as good as top dressing both 1/2 N and 1/2 P through sprays.

The results of trials conducted by Ramakrishnan (1974) on the response of rice to foliar and soil application of nitrogen and phosphorus showed that foliar spray application was not superior to soil application. Though soil application had significantly increased the number of tillers over the foliar, yet it remained on par with split application. Both foliar and soil application significantly increased the length of panicle over split treatment. Neither foliar nor soil application expressed superiority over each other in increasing the productive tillers. There was no response in the number of grains per panicle. The split application of 1/2 soil + 1/2 foliar was significant in case of thousand grain weight, but was on par with soil application. Grain yield and straw yield differences were not significant under different methods of application.

Robinson and Rajagopalan (1977) observed that in rice basal application of full dose of P and K recorded significantly higher yield than foliar spray at 2 per cent concentration. This treatment recorded 19.6 per cent (1114 kg/ha) more yield than control. Abraham and Koshy (1978) studied the comparative efficiency of foliar and soil application of complex fertilizers in paddy. They concluded that highest grain yield of 35.8 g/pot was given by soil application of fertilizers compared with yield of 30.2 and 32.4 g/pot with foliar application at tillering and panicle initiation respectively.

Gupta and Seth (1978) reported that in wheat there was no significant response to P applied by soil and foliar methods.

Shirval et al. (1978) made a comparison of soil and foliar application of fertilizer elements on the yield of paddy variety - Madhu. There was a significant difference in grain yield due to basal dressing or foliar application although yields were slightly reduced when part of N, P and K was applied as a foliar spray.

Abdulgalil et al. (1979) reported that in field trials with rice, plant height and panicle length were not affected by foliar compared to soil fertilizer application. Grain yield of Giza 159 was increased by soil P compared with foliar P. Bacha and Scherer (undated) reported that there was no significant difference between various foliar fertilizers applied either on three dates at intervals of 15 days beginning at budding or at 40 days after emergence. Yields tended to be highest with both normal and foliar fertilizers.

Thom et al. (1981) observed that in rice application at post-flowering stages reduced yields. Vahl and Gomes (undated) also reported that difference in yield was not significant with N, P and K applied as basal fertilizer, split dressing and foliar fertilizers.

C. Treatment with chemicals

Mehrotra et al. (1967) studied the effect of soaking paddy seeds in nutrient solutions of phosphate on germination, growth and yield. Soaking the seeds in 15 and 20 per cent solutions of KH_2PO_4 for 18 hours before sowing raised the estimated grain yield to 22.3 kg/ha compared with 19 kg/ha for water soaked seeds and 16.6 kg/ha for non-soaked seeds. The yield increase was ascribed to an increase in the number of grains per panicle. Mehrotra et al. (1968) reported that in laboratory experiments, germination of wheat cultivar K 68 was little affected by soaking seeds in 2.5-7.5 per cent KH_2PO_4 for 12 hours, but was decreased when concentration was increased to 10-20 per cent and duration to 18-24 hours. Soaking seeds in 7.5 per cent KH_2PO_4 slightly accelarated maturation and gave the highest grain yield, 7-9 per cent more than the unsoaked control. Treatments had little effect on the number of ears/plant, number of grains/ ear or 1000 grain weight.

Sinha (1969) noted that soaking seeds of rice var. Br. 34 in 1 molar solution of K_2HPO_4 for 24 hours before sowing resulted in longer panicle than untreated ones. K_2HPO_4 also increased the drymatter weight significantly in the first year.

drymatter production and uptake of P and K upto 17 days.

However, Singlachar and Chandrasekhar (1978) reported that treatment of rice seeds with KH_2PHo_4 had no effect on the growth and paddy yields compared to untreated seed.

Mujumdar and Somawanshi (1979) reported that seed water absorption by wheat decreased with increasing concentration of the solution and was greater from the KH_2Po_4 solution. The P content of treated seeds increased with increasing concentration of both compounds but seed K levels increased with treatments involving KH_2PO_4. High P concentration reduced plant drymatter yields and plant P uptake decreased with increasing solution concentration. The results indicated that seeds soaked in water or solution containing less than 1000 ppm P produced significantly higher plant drymatter yields upto 17 days of growth than unsoaked seeds.

Padole (1979) observed that pre-soaking of wheat seeds in KH_2PO_4 (1-2 per cent) for 6 hours increased the grain yield and uptake of N, P and K compared with unsoake or water soaked seeds.

The results of trials conducted by Singh and Chatterjee (1980) indicated that soaking seeds of upland rice in Na_2HPO_4 (10^{-3}M) increased average paddy yields by 20-25 per cent by increasing growth, root development and different yield components.

D. Application of Phosphorus in the Nursery

In an experiment conducted in Sapporo, the variety Chusei-Eiko (medium duration) was subjected to varying fertilizer applications of 60 g N/3.3 m^2, 60 g P_2O_5/3.3 m^2 and 60 g K_2O/3.3 m^2. The seedling weight did not increase 15 days after germination but did so markedly 20 days after. The absorption of nutrients, however, was already notable 15 days after germination. No marked difference in growth was observed between a plant which received 60 g of fertilizer and that which received none. However, the plants differed significantly in nutrient contents. Nutrient absorption was observed to occur earlier when nutrients were supplied in sufficient amounts in the nursery (Ishizuka, 1964).

Celton and Velly (1966) concluded that fertilization of the nurseries resulted in greater number of healthy transplants suitable for transplanting, and in making them available in a shorter time. Fertilization of the nursery had no effect on tillering, number and weight of ears or on yield.

Enyi (1966) observed that fertilizing rice at the rate of 112 kg N, 67 kg P_2O_5 and 70 kg K_2O/ha increased the grain yields from 292 g/m^2 for the unfertilized control to 1012 g and was more effective than fertilizing the nursery alone, which increased seed yields to 336 g/m^2. The combined field plus nursery fertilizing resulted in a yield of 1077 g/m^2.

Padalia and Mahapatra (1970) tested the effects of nursery treatments on the yield and growth of rice and found that yields were not affected by rate or application of fertilizers to the nursery.

Nair et al. (1977) observed that in one trial phosphorus applied in the nursery did not have any significant effect on the shoot and root length and dry weight of seedlings. It also did not exert appreciable influence on plant height, number of ear bearing tillers per hill and grain yield in the transplanted field. In a second trial, phosphorus by itself had no effect on the seedlings. Neverthless in combination with nitrogen, these nutrients produced healthy and vigorous plants. In contrast, seedlings from unmanured plot were apparently weak with slender stems and pale green leaves. Their establishment in the main field seemed to be slow, but once established, they tillered fast and produced nearly as much tillers as did the seedlings from manured plots. At the end of reproductive period, there was no significant variation between the manured and unmanured seedling on the production of ear-bearing tillers per hill. Phosphorus had no influence on flowering.

Rajagopalan et al. (1979) reported that yields were highest when 2 kg DAP/40 m^2 of seedbed was applied giving yield of 6.1 t/ha compared with 5.5 t/ha in the untreated control. When rice cultivar IR-20 was given DAP in the seedbed and NPK in the mainfield, application of DAP alone yielded 4.8 t/ha compared with yield of 4.9 t/ha with DAP + NPK and 3.8 t/ha with NPK alone.

E. Treatment with Superphosphate Slurry

In some of the volcanic soils of Japan which have a strong tendency to fix phosphate, dipping the roots of seedlings into a thin mud paste containing 1 part superphosphate and about 5 parts of soil before transplanting was found to be effective. (De Gues, 1954). This practice was claimed to concentrate phosphate around the roots and partially compensate for the loss of phosphates through fixation.

In India, field experiments were conducted at seven stations from 1954 to 1957 to compare various methods of application of ammonium phosphate and triple superphosphate like (a) broadcasting and puddling immediately before planting (b) drilling at puddling before planting, (c) dipping the seedlings in a slush of fertilizer and mud and (d) application in pellet form. Pellet application was consistently better than broadcast at two stations; while other stations found no significant variation among methods (Anonymous, 1965).

Mariakulandai and Chamy (1967) reported that in systematic trials laid out from 1956 to 1959 under the scheme of Model Agronomic Experiments at Aduthurai, there was no significant different between broadcasting, dipping the seedling in mudslush containing phosphatic fertilizers and placement of pellets of phosphatic fertilizer.

Sharma and Singh (1967) reported that applying fertilizers in pellet form near the root-zone gave higher yield increases than dipping the seedling before transplanting in a slurry containing the fertilizers or applying them broadcast at puddling.

Katyal and Ramavataram (1973) observed that root dipping in superphosphate slurry, promoted root growth and tillering and the quantity of fertilizer required was reduced from 26 kg P to 14 kg per hectare to get the same yields.

Results of trials conducted by Ramaswamy et al. (1974) showed that placement of phosphate fertilizer by dipping the seedlings in phosphate slurry gave yields which were on par with broadcast application. They inferred that rice plant can extract soil phosphorus under submerged conditions if soil phosphorus status is not too low, provided a starter effect is given by dipping the seedlings in phosphate slurry and then planted in the field.

Katyal et al. (1975) reported that in field trials paddy yields were similar with 26 kg P/ha applied to soil at transplanting as 14-25.2 kg P/ha as soil-superphosphate slurry in which the seedling roots were dipped before transplanting. Katyal (1978) also observed that 50 per cent less P was needed to avoid P deficiency when it was applied at transplanting as a superphosphate-soil slurry to seedling roots singly or in bundles than when it was broadcast.

Mirza et al. (1979) found that utilization of P was 17.3 - 28.4 per cent when applied as superphosphate-soil slurry and 4.98 to 7.8 per cent when applied to soil. The net profit was 3-4 fold higher on the investment of fertilizer P applied as slurry than when applied to soil. Reddy et al. (1979) observed that application of 50 kg N in the form of mudballs + 30 kg P_2O_5/ha as slurry in combination with Azotobacter culture treatment of seedling roots gave paddy yields similar to those obtained with 100 kg N + 60 kg P_2O_5/ha applied broadcast. It also resulted in a saving of 50 per cent of fertilizer N and P.

In trials with rice cultivar <u>Tella Hamsa</u> by Mirza et al. (1980) paddy yield obtained by dipping roots in superphosphate slurry at 30 kg/ha was similar to those with 90 kg P_2O_5/ha applied to the soil before transplanting and were 8.13 - 11.1 per cent higher than 30 kg P_2O_5 applied to soil. Rabindra and Deshpande (1980) reported that higher paddy yields were obtained by dipping roots of seedlings before transplanting in a slurry of superphosphate + soil + water than by applying 60 kg P_2O_5 to the soil.

In a trial conducted by Raju et al. (1980) it was found that dipping the seedling roots in 1 and 2 per cent MAP or DAP or KH_2PO_4 solution gave 2 year average paddy yields (3.33 -3.74 t/ha) similar to those obtained with 30 kg P_2O_5/ha applied to the soil (3.11 t/ha). Yields without P were 2.05 t/ha. Dipping the roots in superphosphate -soil slurry (30 kg P_2O_5/ha) or application of 60 kg P_2O_5/ha gave yields of 3.8 and 4.45 t/ha respectively. Subramanian and Subramanian (1980) conducted an experiment to study the influence of root treatment with phosphate slurry as compared to the usual method of soil application on the yield of rice. Only the yield and 1000 grain weight were significantly influenced by the treatments. It was found that all the treatments and control were on par and significantly superior to the soil slurry treatment without P. The results showed that P had no influence on enhancing the yield as control ranked first among the treatments.

Rao et al. (1982) reported that rice grain yields were increased from 3.9 t/ha with only NK fertilizer to 4.2 t/ha by root dipping in phosphate nutrient solution or by P fertilizer. When 30 kg P_2O_5/ha was applied in addition to seedling treatment with 2 per cent solution, grain yields were higher than when seedlings were dipped in 2 per cent solution without the added soil P but equal to yields with 60 kg P_2O_5/ha applied to the soil.

I. Effect of Phosphorus on the Uptake of Major nutrients

Williams (1948) found that phosphorus deficiency greatly depressed the nitrogen uptake in the early stages of growth of roots and shoots. Kimuara and Okajima (1951) and Okajima and Kimuara (1952, 1962) observed that a low phosphorus supply supresses early nitrogen uptake and prevents the synthesis of proteins from nitrogenous materials. Thomas et al. (1951) demonstrated a direct phosphorus nitrogen relation in plants.

Mohankumar (1967) observed a decrease in nitrogen content with increase in phosphate application in rice. Similar results were obtained by Nair (1968).

Mehrotra et al.(1968) observed that applying phosphorus without nitrogen gave a slight initial depression in nitrogen uptake in rice. Varma (1971) reported that N uptake in grain and straw increased with increasing rates of both N and P.

Loganathan and Raj (1972) reported that nitrogen content in grains was highest in plants receiving 80 kg phosphorus per hectare. Thandapani and Rao (1974) observed that increase in rates of applied phosphorus from 0 to 75 kg per hectare was accompanied by linear increase in nitrogen content in roots, shoots and grains. Reddy et al. (1978) reported that nitrogen uptake increased with increase in rates of NPK from 100 + 50 + 50 to 200 + 100 + 100 kg per hectare. Singh and Prakash (1979) found that application of P increased the uptake of N significantly over the 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 upto the tillering stage.

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

Sanyasi raju (1954) observed that increased application of phosphorus to soil increased the phosphorus content of paddy grain in laterite soil of Pattambi. In their study of the nutritive value of rice, Basak et al. (1961) found that application of phosphorus along with calcium had a negative influence on the protein, phosphorus and calcium content of grain. Rao and Rao (1965) reported that phosphorus uptake was increased significantly by increasing the rate upto 45 lb P_2O_5 per acre and by 2 oz Mo/ac.

Trials conducted by De Datta et al.(1966) showed that the percentage of plant phosphorus derived from applied phosphorus ranged from 8 to 27 per cent. Mohankumar (1967) observed an increase in the phosphorus content with increase in the rate of phosphate application. Similar results were obtained by Nair (1968).

Naphade (1969) reported that the rate of P absorption increased with increase in phosphorus supply. Terman and Allen (1970) reported that the percentages of plant phosphorus from the 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. Oomen et al.(1972) revealed that the percentage of total phosphorus content in the plant increased with an increased dose of phosphorus from 25.75 to 51.5 kg per hectare. 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. Krishnaswamy et al.

(1974) revealed that application of 180 kg phosphorus per hectare gave the highest grain phosphorus content. Agarwal (1978) revealed that phosphorus content was increased with phosphorus application upto 120 kg per hectare. Chowdhary et al. (1978) also reported that P content increased with increasing P application. Suseelan et al.(1978) too reported that there was significant increase in the uptake of phosphorus by the plant with increasing levels of phosphorus. Rabindra (1978) reported that in rice cultivar Mangala grown in the wet and dry season; the plant P content increased with increasing level of P application. Singh and Prakash (1979) reported that P application brought about an increased uptake of P. Bora and Goswamy (1980) reported that phosphorus application. Sinha et al. (1980) while working on the utilization of fertilizer by rice cultivars Jaya, Ratna and Sona observed that the uptake of total P and fertilizer P increased with increasing rates of applied P from 0 to 90 kg/ha, while the utilization percentage of this applied P decreased.

Chaudhary and Uppal (1981) observed that in pot trials addition of 60 ppm P increased the total P accumulation at maturity to 92.4 -106.8 g/pot. 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. Bora and Goswamy (1983) showed that when rice plant was supplied with 0,26.4 or 52.8 kg per hectare of phosphorus, its concentration in rice grain was increased with increase in rate of phosphorus, in submerged soils.

Loganathan and Raj (1972) reported that levels of phosphorus did not influence potassium uptake by grains. Kalyanikutty and Morachan (1974) concluded that application of P_2O_5 did not influence the K content in plants either alone or in combination with N. Krishnaswamy et al. (1974) suggested that application of potassium in combination with phosphorus slightly increased the potassium content of the grain. Thandapani and Rao (1974) found that applied phosphorus had no effect on the potassium content of plants and grain. Kothandaraman et al. (1975) reported that maximum grain content of potassium was given by 180 kg phosphorus per hectare. Lal and Mahapatra (1975) observed that potassium content was generally high with fertilizer rich in water soluble phosphorus. Agarwal (1978) reported that N, P and K increased the grain crude protein and K contents. The 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.

II. Effect of Phosphorus on Growth Characters

1. Plant height

Tanaka et al. (1960) observed increased plant height with increase in levels of phosphorus upto 10 ppm. Aaron et al. (1971) reported that increased application of phosphorus increased the plant height. Chowdhury et al. (1978) reported that plant height increased with increasing phosphorus application.

However, Sreenivasalu and Pawar (1965) reported that phosphorus had no effect on the plant height at any of the growth stages. Similar results were also reported by Suseelan (1969) and Ahammad (1970). Place et al. (1970) reported that increasing phosphorus from 0 to 56 kg/ha decreased plant height. 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. Rao et al. (1974) noted that height of plants was not significantly influenced by the levels of phosphorus. Kalyanikutty and Morachan (1974) reported that phosphorus did not have any marked effect on the height. Bharadwaj et al. (1974) reported that there was no significant difference between the rates of phosphorus application in influencing the plant height.

2. Tiller number

Mohankumar (1967) reported that phosphorus application increased tiller production. Nair (1968) also reported similar results.

De Rege and Leonzio (1969) observed that tiller number increased with increasing levels of phosphorus application. Terman and Allen (1970) observed that tillering increased markedly with amount of applied P on the low-P soil and slightly on the medium-P soil; there was no response on the high-P soil. Nair et al. (1972) and Bharadwaj et al.(1974) noted that tillering was markedly influenced by phosphorus application. Katyal et al.(1975) observed that tillering in many cultivars increased with increasing rates of applied P_2O_5 from 20 to 40 kg/ha. No cultivar produced tillers in the absence of P and some cultivars produced a few tillers with 10 kg P_2O_5/ha. Rai and Murthy (1975) reported that phosphorus concentration had no effect on tiller mortality. Shiga (1976) reported that in rice, tiller number increased until the P content reached about 0.8 per cent P_2O_5. Bhattacharyya and Chatterjee (1978) reported that early tillering in wetland transplanted rice grown on alluvial soils low in N and P but high in K were favoured by the application of P. Early tillers contributed more to yield than late ones. Chowdhury et al. (1978) observed that tiller number per plant increased with increasing P application.

However, Sreenivasalu and Pawar (1965) obtained no effect for phosphorus on the number of tillers. 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. Suseelan et al. (1977, 1978) reported that phosphorus had no effect on tiller production.

III. Effect of Phosphorus on Yield Attributes

1. Productive tillers and panicles

Halappa et al. (1970) reported that application of 60 kg P_2O_5/ha in 2 split dressings at transplanting and tillering resulted in the highest number of ear-bearing tillers/hill. In field trials with increasing rates of applied P from 0 to 90 kg per hectare, Place et al. (1970) reported that the number of panicles was increased with increase in levels of phosphorus. Majumdar (1971) observed that phosphorus nutrition effected a significant increase in the number of productive tillers by an application of 59.7 kg P per hectare. Nair et al. (1972) reported that number of productive tillers per hill was highly influenced by the phosphorus application. Kuo (1973) reported that application of 72 kg P_2O_5/ha gave the highest increase in the number of panicles/hill over the control given 36 kg P_2O_5/ha. Shiga (1976) reported that the highest panicle number was reached when the plant P_2O_5 content reached 0.6-0.7 per cent. Bhattacharyya and Chatterjee (1978) reported that application of P aided early tillering which resulted in more panicle bearing tillers.

Aaron et al. (1971) reported that there was no increase in the number of panicles/plant with applied P beyond 30 kg P_2O_5/ha. Alexander et al. (1973) found that application of different levels of phosphorus did not have any positive effect on the percentage of effective tillers. Rao et al. (1974) also observed that number of productive tillers was not significantly influenced by the levels of phosphorus. Sadanandan and Sasidhar (1976) also observed that increasing rates of applied P had no significant effect on the number of productive tillers per plant.

2. Panicle length and panicle weight

Enyi (1964) reported increase in panicle weight with increase in levels of phosphorus. Rajappa and Krishnamoorthy (1969) reported that rice given 0, 15, 30 and 45 lb N/ac and 0,20 and 40 lb P_2O_5/ac in all combinations resulted in increase in mean panicle weight by some fertilizer treatments but a decrease by others. Place et al.(1970) found that graded levels of phosphorus from 0 to 56 kg per hectare increased panicle weight. Chowdhury and Mian (1978) reported that panicle weight increased with increasing levels of applied P.

Majumdar (1971) reported that panicle length was significantly enhanced with higher levels of phosphorus application upto 59.7 kg per hectare. Singh and Varma (1971) reported that length of panicle was not influenced by phosphorus nutrition at 60 or 90 kg per hectare. Alexander et al.(1973) obtained no difference in panicle length by phosphorus application. Rao et al.(1974) reported that length of panicle was not significantly influenced by levels of phosphorus.

3. <u>Number of grains per panicle</u>

Oh and Lee (1968) reported that low yield of rice plants grown in sandy and gravelly soil was due to low grain number per panicle caused by a low supply of phosphorus during tillering. Aaron et al.(1971) reported that increased dressing of phosphorus increased the number of grains per panicle. Majumdar (1971) revealed that number of grains per panicle was significantly increased by application of 59.7 kg phosphorus per hectare. Singh and Varma

(1971) reported an increase in the number of grains per panicle with higher rates of phosphorus application. Kuo (1973) reported that application of 72 kg P_2O_5/ha increased the number of grains/panicle. 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.

Reddy (1967) stated that there was no significant effect of phosphorus on the number of filled or unfilled grains. Gately (1968) also obtained similar results. Suseelan (1969) and Ahammad (1970) obtained no effect of phosphorus on percentage sterility in rice. Alexander et al. (1973) reported that the grain number/panicle was unaffected by phosphorus. Rao et al.(1974) also found that the number of filled and chaffy grains were not significantly influenced by the levels of phosphorus. 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. The results of trials by Suseelan et al.(1977) revealed that phosphorus had no effect on the percentage of filled grains. Bhattacharyya and Chatterjee (1978) opined that phosphorus application induced early tillering which in turn gave more number of filled spikelets per panicle.

Suseelan et al. (1978) reported that phosphorus application did not significantly influence the percentage of filled grain.

4. Thousand grain weight

Halappa et al. (1970) reported that application of 60 kg P_2O_5/ha resulted in highest thousand grain weight (29.8 g). Majumdar (1971) noticed that thousand grain weight was increased with increase in phosphorus application. Singh and Varma (1971) could observe distinct increase in the thousand grain weight with the application of 60 and 90 kg P over 30 kg P per hectare. Kuo (1973) observed that application of 72 kg P_2O_5/ha resulted in increase in thousand grain weight. 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.

Reddy (1967) found that there was no significant effect of phosphorus on thousand grain weight. Similar results were also obtained by Gately (1968), Suseelan (1969) and Ahammad (1970). Padmakumari et al. (1969) found that phosphorus had no consistent effect on thousand grain weight. Place et al. (1970) recorded a decrease in thousand grain weight with increase in levels of phosphorus applied from 0 to 56 kg per hectare. 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. Bhattacharyya and Chatterjee (1978) found that application of phosphorus aided early tillering resulting in higher test weight.

IV. Effect of Phosphorus on Yield

1. Grain yield

Naphade (1969) obtained significant grain yield responses to 45 and 90 kg P_2O_5 per hectare. There was significant positive correlation between percentage grain yield and total phosphorus uptake. Padmakumari et al. (1969) reported that grain yield response upto 100 kg P_2O_5/ha was observed.

Khatua and Sahu (1970) reported that application of 40 kg phosphorus per hectare resulted in increased paddy yields compared to no phosphorus application. Yields were not further increased with P_2O_5 rates more than 40 kg/ha. Pande and Tilak (1970) also observed that application of 40 kg P_2O_5/ha significantly increased the grain yield/ha.

Terman et al. (1970) reported that in a flooded soil very low in available phosphorus, marked yield responses were obtained from applied phosphorus. Yields were highest in soils containing only 40 ppm P.

Trials by Aaron et al. (1971) showed that increased dressing of phosphorus increased the yields of paddy. Majumdar (1971) also noticed increase in paddy yields with incremental doses of phosphorus application. Varma (1971) reported that increasing phosphorus rates from 30-90 kg P_2O_5/ha increased the paddy yields from 3.75 to 4.36 t/ha. Kuo (1973) stated that in poorly drained soils, yield was increased by 7.5 -12.1 per cent on increasing the P_2O_5 rates from 36 kg to 72 kg P_2O_5 per ha.

Mohanty and Patnaik (1974) reported that low levels of phosphorus decreased the yield of paddy. Increase in grain yields with phosphorus application were also reported by Kalyanikutty and Morachan (1974). Gupta et al. (1975) reported that average paddy yields increased from 45.06 g/pot without applied phosphorus to 66.63 g with 100 ppm phosphorus. According to Gopala krishnan et al. (1975) grain yield was influenced by phosphorus application. Katyal et al. (1975) observed that paddy yields in many cultivars increased with increasing rates of applied P_2O_5 from 20 to 40 kg/ha. Ram Singh and Dubey (1975) reported that increasing the rates of applied

P_2O_5 from 0 to 60 to 120 kg/ha increased average paddy yields from 1.63 to 4 and 4.86 t/ha respectively.

In field trials in 1974 and 1975, Dixit and Singh (1977) observed that grain yields were increased from 2.4 t/ha with no phosphorus to 2.7 t/ha with 40 kg P_2O_5/ha. Lal and Mahapatra (1977) reported that application of 120 kg N/ha and 60 kg P_2O_5/ha gave average paddy yields of 5.52 - 6.23 t/ha compared with 3.29 t/ha without N or P.

Agarwal (1978) observed that grain yields were increased from 4.54 to 4.94 t/ha with increase in P_2O_5 from 0 to 120 kg per hectare. Ageeb and Yousif (1978) and Chowdhury et al. (1978) reported that phosphorus application influenced paddy yield significantly. Gowda et al. (1978) observed that response to phosphorus was 11.32 and 27 kg grain/kg P_2O_5 in the wet and dry season respectively. With application of 60 kg P_2O_5/ha. Rabindra (1978) stated that grain yield was increased with increasing levels of phosphorus application. Raju et al. (1978) reported that response to phosphorus was 23.6 and 20.6 kg grain/kg P_2O_5 with application of 60 and 90 kg P_2O_5/ha in the wet and dry seasons.

Ittiyavarah et al. (1979) reported that yields were adversely affected by omitting the applications of phosphorus in alternate years. Singh and Prakash (1979) reported that applied phosphorus increased the yield from

0-80 kg P_2O_5/ha. Agarwal (1980) reported that significant increase in grain yield was obtained upto 180 kg P_2O_5/ha. Sadanandan et al. (1980) reported that paddy yields were higher with 50 ppm applied P than with 25 ppm P. Shiota et al. (1980) observed that without phosphorus, yields were reduced by 40-50 per cent. Sinha et al. (1980) also reported that increase in phosphorus rates upto 90 kg/ha increased paddy yields.

Contrary to the above findings in several experiments phosphorus could not increase the yield. Sahu (1955) observed that there was no significant effect of phosphate application on the yield of rice. Velley (1959) reported that response to added phosphorus can be obtained only if the percentage of phosphorus as shown by leaf analysis is 0.28 per cent P_2O_5 or less. Kalam (1966) reported that the magnitude of yield increase due to phosphorus was much lower than that of nitrogen. Sood et al. (1969) also 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.

In trials with three rice cultivars, Biswal and Mishra (1970) observed that application of 22.5 kg P_2O_5/ha increased yields from 2.76 t/ha on plots given no P to 2.93 t/ha; further increases in P_2O_5 rates gave no additional yield. Analysis of data from six field trials in 1933-'68 with rice on laterite sandy loam soil by Nair and Pisharody (1970) showed that paddy yields were not increased with 22.4 to 56 kg P_2O_5/ha. Place et al. (1970) reported that in field trials, increasing the rate of applied P from 0 to 56 or 90 kg/ha reduced yields of rice in 1964, but had no effect in 1965.

Loganathan and Raj (1971) reported that yields of paddy were not affected by the application rates 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. Sasidhar and Sadanandan (1971) reported that application of phosphorus has not given any significant increase in yield of rice var. Rohini even at 60 kg P_2O_5/ha.

No significant effect on grain yield was noticed by the application of different levels of phosphorus by Alexander et al. (1973). In trials with rice cultivars IR-8, China-4 and TN-1 or Padma, Lal et al. (1973) observed that phosphorus had no effect on yields of any cultivars. It was concluded from the results of experiments by Mosi et al. (1973) that IR-5 failed to give any response to the application of phosphorus.

Studies conducted by Rao et al.(1974) to study the response of IR-5 rice for phosphorus showed that there was no response for phosphorus beyond 40 kg P_2O_5/ha. The results of Kolandaiswamy et al.(1974) revealed that phosphorus and time of application did not significantly influence the yield.

Padalia (1975) reported that application of phosphorus had no significant effect on the yield of paddy. Prabha et al. (1975) reported that at higher doses of phosphorus paddy yields decreased slightly. Sadanandan and Sasidhar (1976) observed that there was no significant difference in the yield of grain due to various levels of phosphatic fertilizers tried in the experiment.

Shiga (1976) reported that there was no grain yield response to phosphorus application. Long term fertility experiments at IRRI revealed that rice cultivars IR-8, IR-36 and IR-26 gave no significant response to added phosphorus (Anonymous 1976). The results of experiments by Suseelan et al.(1977) revealed that the grain yield was not influenced by phosphorus application. Dargan and Chhillar (1978) reported that crops showed no response to the application of phosphorus. Mandal and Sahu (1978) reported that application of 50-60 kg P_2O_5/ha produced no significant increase in grain yield.

Dhillon et al. (1979) reported that the critical level of soil below which yield response of crops to applied phosphorus can be obtained as 12 kg/ha for rice. The results of long-term fertility experiments conducted at IRRI showed that there was no response to phosphorus since the commencement of the trial (Anonymous, 1979). Krishnamoorthy et al. (1979) reported that in rice cultivar IR-20, out of 13 crops, applied phosphorus increased the yields of only 6 crops. Mahatim Singh et al. (1979) reported that application of 60 and 90 kg P_2O_5/ha gave similar yields of 3.87 to 3.91 t/ha.

Dargan et al. (1980) reported that applied phosphorus had no effect on the grain yield. In field trials by Chhabra and Abrol (1981) application of 50 kg P/ha had no effect on the yields of rice. The results of 20 field trials by Rojas and Alvarado (1982) revealed that phosphorus had no effect on the yield.

2. Straw yield

Patel (1967) in a field experiment given 20,40 and 60 kg P/ha reported that straw yield increased with increasing fertility. Place et al. (1970) observed that increasing phosphorus application increased straw yield but decreased plant height.

Gupta et al. (1975) obtained highest straw yield with 60 ppm phosphorus. Prabha et al. (1975) reported that in a pot trial given 0, 20, 40, 60 and 100 kg phosphorus per hectare, application of phosphorus increased straw yield. Singh and Prakash (1979) reported that the crop showed significant response to phosphorus application. Increase in straw yield due to application of 40 and 80 kg P_2O_5/ha over no P was of the order of 11.0 and 15.4 per cent respectively. Sinha et al. (1980) also reported increase in straw yields with phosphorus application.

However, Boatwright and Viets (1966) found that supply of phosphorus for the first five weeks was adequate to produce maximum drymatter. Digar and Mandal (1957) and Kampath (1967) reported that response to phosphorus can be obtained only in those plots where phosphorus had not been applied for 2 or 3 years. Loganathan and Raj (1971) reported that straw yields were not affected by the application rates of phosphorus. The results of Sasidhar and Sadanandan (1971) showed that there was no significant response in case of straw yield to phosphorus even at higher level. Alexander et al. (1973) observed no significant effect on straw yield by the application of different levels of phosphorus. Rao et al. (1974) reported that there was no significant effect in straw yield due to phosphorus application. Sadanandan and Sasidhar (1976) found that increasing the rate of applied phosphorus had no significant effect on the yield of straw. The grain and straw yield were not influenced by phosphorus application as observed by Suseelan et al. (1977).

V. Effect of Phosphorus on Quality of Grain

Akhundov (1968) reported that in fertilized plots the total nitrogen content in grain was increased to 2.41-2.97 per cent, soluble nitrogen content to 0.22-0.73 per cent and protein nitrogen content to 2.16-2.21 per cent compared to 2.27, 0.22 and 2.04 per cent respectively for unfertilized controls. Rajappa and Krishnamoorthy (1969) reported that fertilizer treatments increased the grain protein contents. Place et al. (1970) reported that application of phosphorus before sowing improved the cooking quality compared to midseason application. Chavan and Magar (1971) reported that increasing the rates of fertilizers from 40 kg N + 20 kg P_2O_5 + 20 kg K_2O/ha to 80 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha increased the grain protein contents of 5 rice cultivars. Gill et al. (1971) observed that the grain protein content depended on cultivar, fertilizer application and location. Average protein content varied from 6.62 to 7.21 per cent on plots given no fertilizer and from 7.25 to 8.51 per cent in those given 120 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha. Varma (1971) reported that N and P uptake in grain increased with increasing rates of phosphorus. The percentage of phosphorus translocated to the grain was highest with 30 kg P_2O_5/ha. Thandapani and Rao (1974) reported that increasing phosphorus favourably influenced the protein N in grain. Kadrekar and Mehta (1975) opined that optimum rate of phosphorus application for satisfactory grain content was 40 kg per hectare in the case of all cultivars. Agarwal (1978) reported that increasing the rate of applied phosphorus from 0 to 120 kg per hectare increased the crude protein content of grain from 9.76 to 10.28 per cent. Singh and Prakash (1979) reported that applied phosphorus increased the nitrogen uptake in the grain.

Karim et al.(1968) noticed a decreased crude protein content of the husked grain with increased levels of phosphorus application from 0 to 120 kg per hectare. Taira (1970) reported that phosphorus did not affect grain protein content. Verkhotin (1974) reported that grain protein content decreased with applied phosphorus. Ageeb and Yousif (1978) reported decreased grain protein content from 7.11 to 5.81 per cent by increased phosphorus level from 0 to 107 kg per hectare, but the total protein yield seemed unaffected. Bhuiya et al.(1979) reported that phosphorus had no significant effect on the grain crude protein content.

MATERIALS AND METHODS

MATERIALS AND METHODS

Object

A field experiment was carried out to determine the relative efficiency of different levels and methods of application of phosphorus on the growth and yield of a short duration rice variety, Triveni. The various methods employed and the materials used are given below.

Location

The experiment was laid out at the Instructional Farm, College of Agriculture, Vellayani. The low-land rice fields of Palappur area on the western side of the Instructional farm was used for the trial.

Cropping History:

The experimental area was under bulk cultivation of rice for the last five years.

Season:

The experiment was conducted for two seasons, during the first (Virippu- from June/July to Sept./Oct.) and second (Mundakan- from Sept./Oct. to Dec./Jan.) crop seasons of the year 1983-'84.

Soil:

The soil belongs to the textural class of sandy-clay-loam and the data on mechanical analysis are presented below.

Coarse sand	-	49.16%
Fine sand	-	24.90%
Silt	-	7.30%
Clay	-	25.70%

Climate:

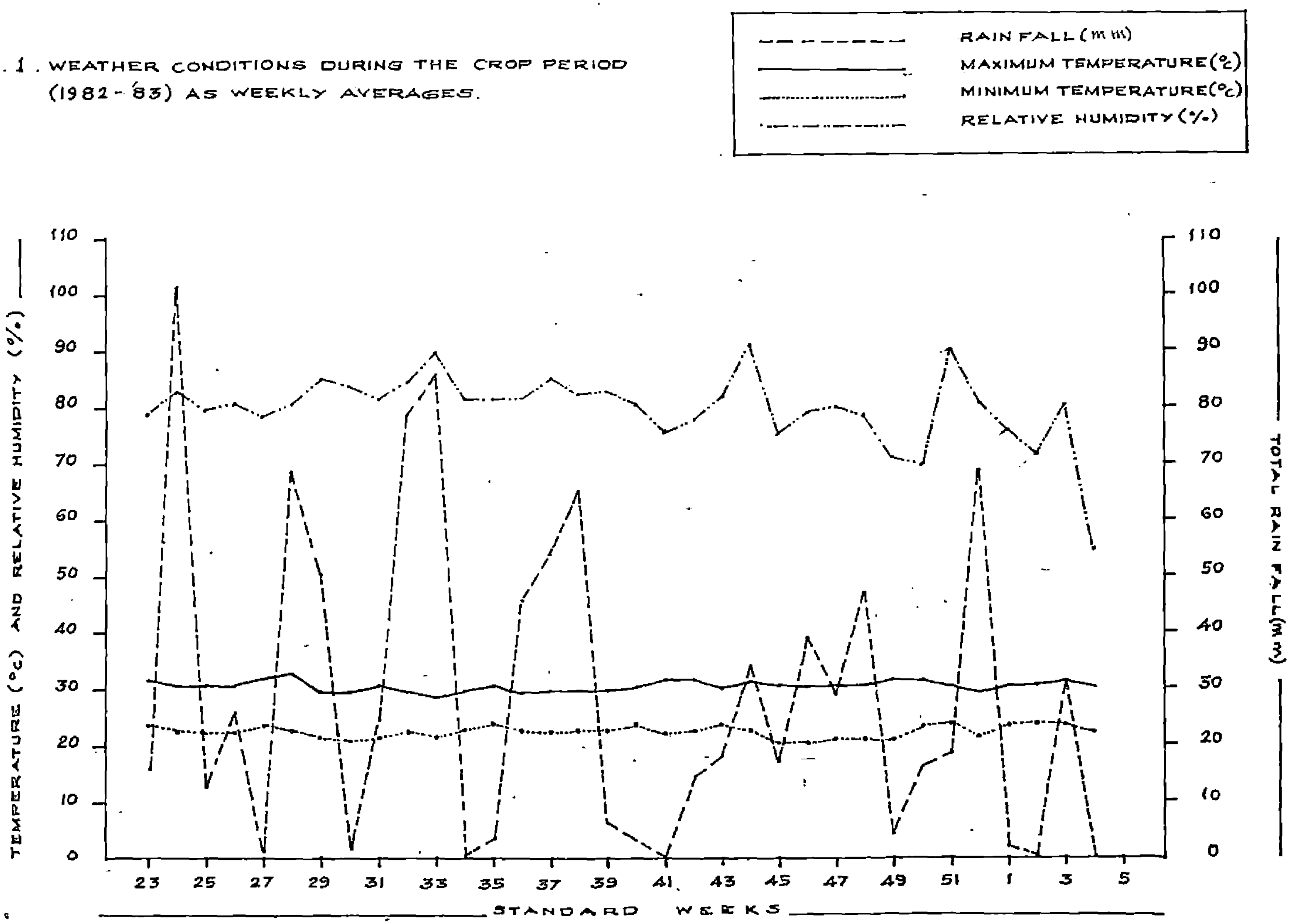
The tract enjoys a warm, humid tropical climate and receives a good amount of rainfall through South-West and North-East monsoons. The meteorological parameters like rainfall, minimum and maximum temperature and the relative humidity pertaining to the period of field experimentation were recorded from the meteorological observatory of the farm and are presented as weekly averages in Appendix Ia and monthly averages for the past 24 years are presented in Appendix I b.

MATERIALS

Variety:

Triveni, a high-yielding, photo-insensitive, short duration (95-100 days) variety was used for the experiment. Triveni has been evolved at the Central Rice Research Station, Pattambi by crossing the dwarf *indica* strain *Annapurna* and tall *indica* Ptb-15.

FIG. 1. WEATHER CONDITIONS DURING THE CROP PERIOD (1982-'83) AS WEEKLY AVERAGES.



Seeds:

Triveni seeds were obtained from the Instructional farm, College of Agriculture, Vellayani. The seeds were tested for viability and were found to give 97.6 per cent germination.

Manures:

Farm-yard manure having the following analysis was used for the experiment.

N	-	0.44%
P_2O_5	-	0.21%
K_2O	-	0.42%

Fertilizers:

Fertilizers with the following analysis were used

Urea	- 46 per cent N
Superphosphate	- 16 per cent P_2O_5
Muriate of Potash	- 60 per cent K_2O
Potassium dihydrogen phosphate	- 22 per cent P
Diamonium phosphate	- 21 per cent P

METHODS

The doses of nitrogen, phosphorus and potash were fixed according to the recommendations in the Package of practices of Kerala Agricultural University (1983) (70 kg nitrogen, 35 kg P_2O_5 and 35 kg K_2O per hectare). Nitrogen and Potash were applied uniformly to all plots. The phosphorus was applied according to the treatments.

Treatments:

1. Control (No phosphorus)
2. Full basal
3. 3/4 basal + 1/4 foliar
4. 3/4 basal
5. 1/2 basal + 1/4 foliar
6. 1/4 basal + 1/4 foliar
7. 1/2 basal
8. Soaking seeds in KH_2PO_4 (Potassium dihydrogen phosphate) - 20 per cent solution and no phosphorus in the main field.
9. Dipping the seedling roots in KH_2PO_4 - 1.5 per cent solution and no phosphorus in the main field.
10. Dipping the seedling roots in 2.0 per cent Diamonium phosphate and no phosphorus in the main field.
11. Dipping the seedling roots in superphosphate slurry and no phosphorus in the main field.
12. Application of 35 kg P_2O_5/ha to nursery and no phosphorus in the main field.

Treatments

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2. Full basal
3. 3/4 basal + 1/4 foliar
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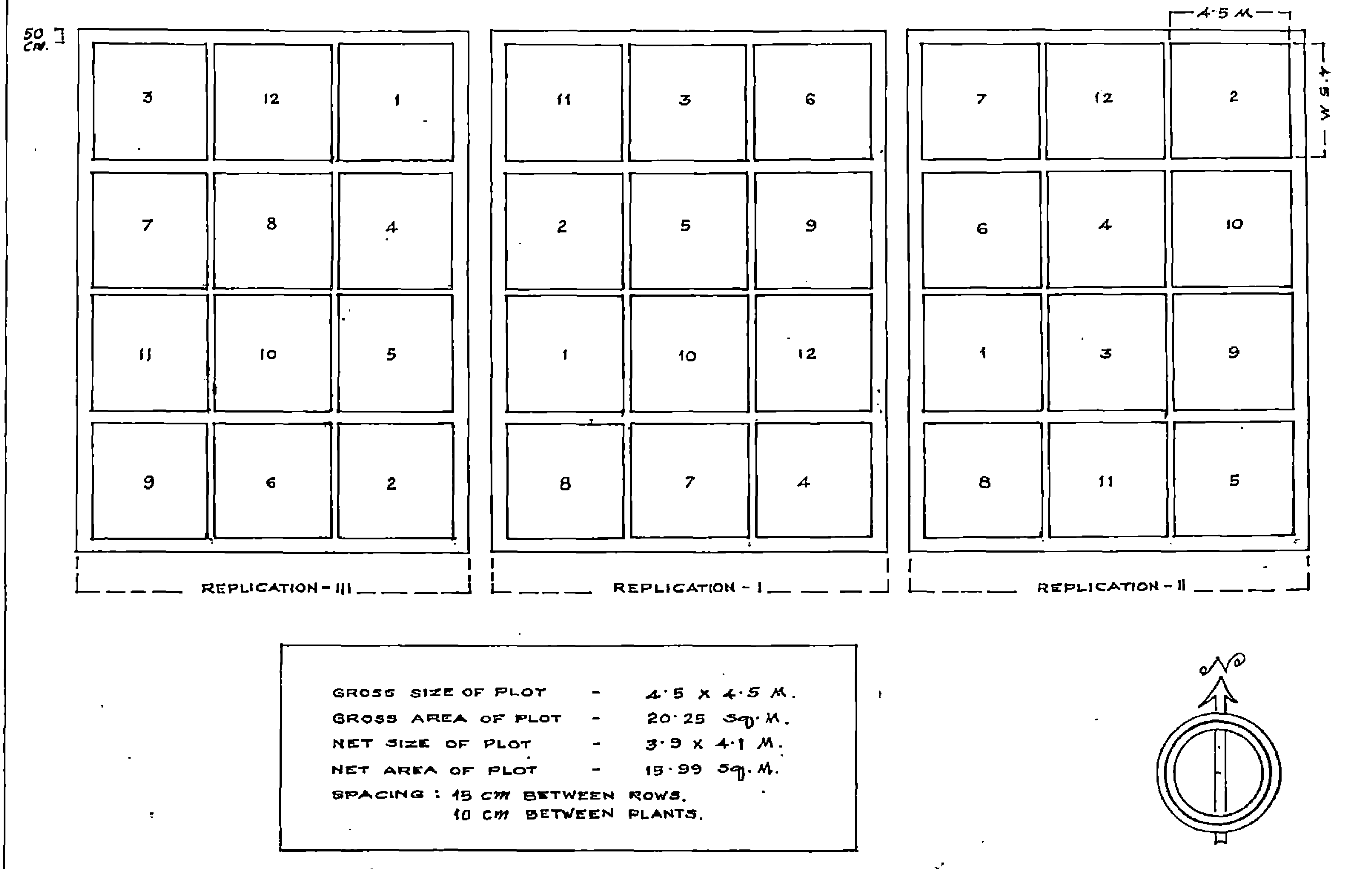
9. Dipping the seedling roots in KH_2PO_4 - 1.5 per cent solution and no phosphorus in the mainfield.
10. Dipping the seedling roots in 2.0 per cent Diamonium phosphate and no phosphorus in the main field.
11. Dipping the seedling roots in superphosphate slurry and no phosphorus in the main field.
12. Application of 35 kg P_2O_5/ha to the nursery and no phosphorus in the main field.

FIG.2. LAY OUT PLAN RANDOMISED BLOCK DESIGN.



Time of application:

Nitrogen and Potash were applied in two split doses, 1/2 as basal and the rest 1/2 at maximum tillering. The foliar spray of phosphorus was given at the beginning of maximum tillering stage at a concentration of 2.2 per cent P_2O_5 using superphosphate.

Design and layout of experiment

The experiment was laid out in a Randomised Block Design with three replications. The plan of layout is presented in Fig.1. The details of the layout are furnished below:

Design	: RBD
Replications	: 3
Treatments	: 12
Total number of plots	: 36
Spacing	: 15 x 10 cm
Gross plots size	: 4.5 x 4.5 M
Net plot size	: 3.9 x 4.1 M

Two rows of plants were left out from four sides of each plot as border rows.

FIELD CULTURE

A. Nursery:

An area of 70 square metre was prepared for a wet nursery and an area of 6 square metre each was prepared separately for treatment No.8 and 12. At the time of land preparation, cattle manure at the rate of one kg per square metre was added and incorporated thoroughly. For treatment No.12, 0.443 kg superphosphate was applied separately to 6 square metre of nursery area. A total of five kg of seeds were sown to get sufficient number of healthy seedlings. Four kg of seeds were treated with Agrosan GN and then soaked in water for 24 hours and kept for sprouting. For treatment No.8, 0.5 kg of seeds were treated with Agrosan GN soaked in 20 per cent solution of potassium dihydrogen phosphate for 6 hours and kept for sprouting. For treatment No.12, 0.5 kg seeds were treated with Agrosan GN, soaked separately in water for 24 hours and then kept for sprouting.

The germinated seeds were sown on the third day. Irrigation was commenced on the 5th day after sowing and continued upto the 7th day to a depth of about 5 cm. At this period, the seed bed was irrigated continuously to a depth of about 5 cm, depending upon the height of seedlings in order to control weeds. The seed bed was drained occasionally to encourage production of vigorous seedlings with short roots.

A protective spraying against thrips with sevin at the rate of 4 g in one litre was given to the nursery.

B. Main field

1. Land preparation

The experimental area was ploughed thoroughly. The layout of the experiment was made after measuring out the area for each plot. One soil sample was collected from each plot. The plots were separated with bunds of 30 cm width and individual blocks were given an outer bund of 50 cm width. Irrigation channels were provided between alternate plots. The area within the plot was perfectly levelled.

2. Basal dressing

Farmyard manure was applied to each plot at the rate of 5000 kg per hectare as basal dressing.

3. Fertilizers

Urea and muriate of potash were applied as basal dressing to all the plots to supply 70 kg N and 35 kg K_2O respectively per hectare. Superphosphate was applied as a basal dressing as per the schedule of treatments fixed.

4. Transplanting

Healthy seedlings of 21 days growth were uprooted from the nursery and transplanted in the main field at the rate of two seedlings per hill at a depth of 2 to 3 cm with a spacing of 10 x 15 cm. For treatment No. 9, the seedlings were uprooted the roots were thoroughly washed free of mud and dipped in 1.5 per cent solution of KH_2PO_4 for exactly one minute before transplanting. For treatment No.10, the seedlings were uprooted, the roots were thoroughly washed free of mud and dipped in 2.0 per cent solution of Diamonium phosphate before transplanting. For treatment No.11, the seedling roots were dipped in superphosphate slurry before transplanting. Superphosphate, soil and water were mixed in the ratio of 1:2:3 and the slurry was allowed to stand for one hour, the contents were thoroughly stirred and the roots of the uprooted seedlings were dipped in the slurry for one minute before transplanting (Katyal and Ramavataram, 1973).

5. Gap filling

Gap filling was done wherever needed one week after transplanting following the same procedure. The seedlings corresponding to that particular treatment were used for gap filling.

6. Irrigation and Drainage

The water level was maintained at about 1.5 cm during transplanting. Excess water was drained off seven days after transplanting. Controlled irrigation and drainage was given thereafter.

The water level was increased gradually to about 5 cm until maximum tillering stage. The field was drained 10 days before harvest and the dry condition was maintained till harvest.

7. Plant protection

Two protective sprayings were given with Ekalux @ 10 ml/100 square metre, the first 25 days after transplanting and the second 40 days after transplanting. A dusting with B.H.C. 10 per cent was given at the ear-filling stage @ 25 kg/ha as a prophylactic measure against rice bug.

8. Foliar application of phosphorus

The method suggested by Singh and Pandey (1969) was used for preparing superphosphate solution. A dose of 110.75 g of single superphosphate per plot (1/4 of the recommended dose of phosphorus) was taken for making a solution for spraying. This quantity was soaked in equivalent quantity of water (111 ml) for five days. The material was stirred twice every day. On the sixth day more water was added and the supernutent solution was separated. The process was repeated by adding small quantities of water, stirring and decanting the solution. Finally the solution thus collected was made upto 806.0 ml with water to provide 2.2 per cent concentration of P_2O_5 for spraying in each plot.

Foliar spray of superphosphate was given at a concentration of 2.2 per cent P_2O_5 at the maximum tillering stage for treatment No. 3,5 and 6.

9. General

In general, the stand of the crop was good. No lodging was noticed in any of the treatments.

10. Harvest

The crop was harvested after 100 days of growth. The border rows of all plots were harvested and threshed separately. The crop in each net plot was harvested, threshed, winnowed and cleaned. The grain and straw of each plot were sundried separately for two days and the plot var yield of grain and straw were recorded.

OBSERVATIONS

All observations on growth characters, yield and yield components were taken as suggested by Gomez (1972).

A. Observation on Growth Characters

The observation on growth characters were taken at fortnightly intervals.

1. Plant height and tiller number

Three 2 x 2 hill sampling unit was used. Tillers were counted on all four hills of each unit, but plant height was measured only on one hill per unit.

2. Leaf Area Index

Plants from four hills were cut from the base and the leaves were separated from the culms. The maximum length and breadth of 10 leaves were measured and weight was computed after drying in the oven. Other leaves and culms were dried and weighed separately and total leaf area was calculated. From the total leaf area, LAI was calculated using the following formula.

$$LAI = \frac{S\ (L \times B) \times F \times DWL}{\text{Dry weight of 10 leaves} \times 600}$$

S (L x B)	=	Sum of products of length and breadth
600	=	Total area occupied by 4 hills in sq. cm
F	=	Factor which is 0.67 in the initial and final stages and 0.75 at other stages
DWL	=	Total dry weight of leaves

3. Dry matter production

The total weight of oven dry plant samples were found out and from this dry matter production in kg per hectare was computed and recorded.

B. Observation on Yield Components

The observation on yield components were taken at harvest.

1. Number of panicle per square metre

Three, 2 x 2 hill sampling units were selected and the total number of panicles (P) from all sample hills were counted.

Number of panicles per hill $= \frac{P}{4n}$ (n = 3)

Number of panicles per sq.m. $= \frac{P}{4n \times 0.015}$

2. Length of panicle:

Length in cm from neck of panicle to the tip was measured in the 12 panicles selected at random from each observation unit and the average was found out.

3. Panicle weight

Weight of 12 panicles selected at random from each observation unit was taken and average expressed in g.

4. Number of grains per panicle:

From each sample hill, the centre or middle panicle (based on height) was separated from the rest of the panicles. 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 (f) and the unfilled grains (u) were counted and the weight of the filled grains (w) was recorded. The grains from the rest of the panicles of all sample hills were threshed and filled grains were separated from the unfilled grains. The number of filled grains (U) were counted and the weight of the filled grains (W) was recorded.

Number of filled grains per panicle $= \frac{f}{w} \times \frac{W+w}{p}$

RESULTS

RESULTS

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani during the Virippu and Mundakan seasons of 1983-'84 for studying the relative efficiency of different levels and methods of application of phosphorus to rice variety, Triveni. The results of the present investigation are presented in Tables 1 to 27 and the analysis of variance in Appendices II to XIV.

A. GROWTH CHARACTERS

1. Height of Plants

Data on the mean height of the plants for the Virippu and Mundakan seasons at fortnighly intervals are presented in Tables 1 and 2 and the analysis of variance in Appendix II.

It was observed that the different treatments had no significant influence on the height of the plants at any of the stages in both the seasons.

2. Tiller Number

The data on the mean values for the number of tillers per square metre at fortnightly intervals for the Virippu and Mundakan seasons are presented in Tables 3 and 4 and the analysis of variance in Appendix III.

Table-1

Mean height of plants at fortnightly intervals in cm

- *Virippu* season

Treatment	I	II	III	IV	V
1	38.6	50.5	65.0	77.0	79.9
2	38.3	51.5	68.7	79.8	79.9
3	40.0	52.5	68.6	78.4	83.0
4	37.9	49.9	64.9	78.7	82.7
5	43.8	53.4	67.1	79.5	79.7
6	42.5	52.9	72.3	75.9	79.6
7	42.2	50.5	66.4	74.4	80.4
8	35.1	50.3	63.2	79.1	82.5
9	43.9	51.6	69.0	77.7	80.9
10	43.6	53.9	71.7	77.5	80.5
11	39.9	50.0	65.5	77.0	80.9
12	41.2	53.5	69.3	81.1	84.2
Mean	40.6	51.7	67.6	78.0	81.2
Treatment comparison	N.S.	N.S.	N.S	N.S.	N.S.
S.E. of Mean (0.05)	3.139	1.972	3.062	2.150	2.309

Table -3

Mean number of tillers per square metre at fortnightly intervals

- Virippu season

Treatment	I	II	III	IV	V
1	568	604	716	683	607
2	544	650	691	717	633
3	561	639	750	768	695
4	598	672	728	726	661
5	622	700	739	696	650
6	602	644	684	747	687
7	585	630	765	707	672
8	563	671	756	745	674
9	594	632	735	717	678
10	565	672	752	683	626
11	552	635	731	742	689
12	605	637	739	726	650
Mean	580	649	732	721	660
Treatment comparison	N.S	N.S	N.S	N.S	N.S
S.E. of Mean (0.05)	40.834	40.937	40.070	38.340	34.382

Table -2

Height of plants at fortnightly intervals in cm.

- Mundakan season

Treatment	I	II	III	IV	V
1	37.5	55.1	62.3	83.9	87.9
2	40.3	61.2	64.3	82.8	82.0
3	40.9	55.4	65.1	83.1	83.7
4	36.7	62.4	64.2	89.3	94.1
5	40.3	67.1	61.7	87.4	90.3
6	34.9	59.7	62.9	92.1	92.5
7	36.9	56.3	58.5	86.8	88.8
8	39.4	60.9	67.7	87.8	89.6
9	37.0	57.0	62.7	85.8	90.0
10	39.1	60.2	59.9	89.8	93.4
11	37.6	59.4	63.7	89.4	90.6
12	39.8	57.9	64.3	91.3	92.0
Mean	38.4	59.4	63.1	87.5	89.6
Treatment comparison	N.S	N.S	N.S	N.S	N.S
S.E. of Mean (0.05)	1.807	5.035	3.605	4.564	3.939

Table -3

Mean number of tillers per square metre at fortnightly intervals

- Virippu season

Treatment	I	II	III	IV	V
1	568	604	716	683	607
2	544	650	691	717	633
3	561	639	750	768	695
4	598	672	728	726	661
5	622	700	739	696	650
6	602	644	684	747	687
7	585	630	765	707	672
8	563	671	756	745	674
9	594	632	735	717	678
10	565	672	752	683	626
11	552	635	731	742	689
12	605	637	739	726	650
Mean	580	649	732	721	660
Treatment comparison	N.S	N.S	N.S	N.S	N.S
S.E. of Mean (0.05)	40.834	40.937	40.070	38.340	34.382

Table -4

Mean number of tiller per square metre at fortnightly intervals.

- Mundakan season

Treatment	I	II	III	IV	V
1	357	526	566	540	503
2	381	576	610	583	535
3	409	618	617	585	575
4	384	579	593	566	515
5	372	585	594	541	525
6	375	582	634	583	529
7	376	554	588	551	520
8	399	566	597	573	512
9	399	580	627	550	537
10	376	579	599	566	528
11	405	554	594	551	533
12	395	621	629	616	584
Mean	386	577	604	567	533
Treatment comparison	N.S	N.S	N.S	N.S	N.S
S.E of Mean (0.05)	23.978	47.696	38.318	33.210	31.519

It is seen from the data that increase in the nutrient levels had no significant influence on the number of tillers per square metre at all stages of growth. The different methods of phosphorus application also showed no significant influence on the number of tillers per square metre.

3. Leaf Area Index

The data on the mean values for the leaf area index at fortnightly intervals for the Virippu and Mundakan seasons are presented in Tables 5 and 6 and the analysis of variance in Appendix IV.

The results revealed that there was no significant difference between the levels and methods of phosphorus application on the leaf area index of rice variety -Triveni.

4. Dry matter production

The data on the mean values for dry matter production at fortnightly intervals are presented on Tables-7 and 8 and the corresponding analysis of variance in Appendix- V.

The data revealed that the effect of different levels of phosphorus in increasing the dry matter production was not significant eventhough there was slight significant difference for the first two fortnights for the Virippu season. The effect of different methods of phosphorus application also was not significant at any of the stages.

Table -5

Leaf Area Index at fortnightly intervals

Virippu season

Treatment	I	II	III	IV	V
1	1.94	2.98	4.18	3.57	2.76
2	2.23	3.94	4.57	3.67	2.52
3	2.36	3.52	4.33	3.56	2.82
4	2.20	3.09	4.26	3.74	2.86
5	2.16	3.39	4.73	4.11	2.91
6	2.24	3.20	4.28	3.89	3.05
7	2.00	3.52	4.39	4.09	3.07
8	2.53	3.09	4.66	4.00	3.19
9	1.92	3.10	4.60	3.81	3.19
10	1.75	3.29	4.45	3.95	2.59
11	2.36	3.28	4.34	3.70	2.45
12	2.08	3.17	4.32	4.01	2.73
Mean	2.15	3.30	4.43	3.84	2.85
Treatment comparison	N.S	N.S	N.S	N.S	N.S
S.E. of Mean (0.05)	0.340	0.437	0.351	0.290	0.281

Table-6

Leaf Area Index at fortnightly intervals

Mundakan season

Treatment	I	II	III	IV	V
1	1.44	2.30	5.02	2.91	2.52
2	1.64	2.61	5.87	3.77	2.57
3	1.46	2.50	4.89	3.52	2.62
4	1.48	2.80	5.16	4.66	2.92
5	1.77	2.81	5.32	4.24	3.06
6	1.48	2.62	4.83	3.96	2.95
7	1.22	2.77	4.86	3.90	2.73
8	1.44	2.85	4.95	3.93	2.86
9	1.44	2.52	4.57	4.39	2.94
10	1.55	2.66	4.96	3.66	2.53
11	1.18	3.17	4.43	3.78	2.22
12	1.47	2.55	5.25	3.64	2.58
Mean	1.46	2.68	5.02	3.86	2.71
Treatment comparison	N.S	N.S	N.S	N.S	N.S
S.E. of Mean (0.05)	0.321	0.305	0.436	0.473	0.367

Table -7

Dry matter production at fortnightly intervals in kg/ha

<u>Virippu</u> season

Treatment	I	II	III	IV	V
1	741	981	2800	7055	8722
2	822	1078	3083	7667	8944
3	867	1253	2878	7278	8889
4	758	1217	2867	7778	8500
5	697	997	2828	8055	8778
6	829	1025	2861	8777	9111
7	778	997	2794	7056	9444
8	816	1003	2917	8167	9111
9	670	1044	2716	7333	9278
10	725	975	2717	6678	9278
11	808	992	2689	7334	8333
12	809	1133	2739	7333	8944
Mean	784	1058	2824	7543	9019
Treatment comparison	Sig.	Sig	N.S	N.S	N.S
S.E. of Mean (0.05)	-	-	227.743	570.878	582.055
C.D. (0.05)	78.27	174.6	..	..	..

Table -8

Dry matter production at fortnightly intervals in kg/ha

Mundakan Season

Treatment	I	II	III	IV	V
1	416	2056	2843	4333	8300
2	694	2167	2954	4333	8555
3	722	2278	3187	4889	8944
4	467	2061	2833	4722	8000
5	711	2167	2833	4389	8222
6	569	2277	3167	4833	8444
7	472	1833	2954	4611	8000
8	578	2055	3000	4778	8055
9	550	2278	3111	5278	9056
10	561	2222	3000	4343	8778
11	556	2111	2899	4556	8667
12	567	2333	3510	5333	8944
Mean	572	2153	3024	4700	8514
Treatment comparison	N.S	N.S	N.S	N.S	N.S
S.E. of mean (0.05)	16.635	28.092	298.835	561.070	500.480

B. YIELD ATTRIBUTES

1. Productive tiller count

The data on the mean number of productive tillers per square metre in both Virippu and Mundakan seasons are furnished in Table 9 and the analysis of variance in Appendix VI.

The effect of levels and methods of phosphorus application did not manifest any effect on the number of productive tillers in both Virippu and Mundakan seasons. However, treatment T_{12} and T_3 gave the highest productive tiller count for both Virippu and T_{12} for the Mundakan seasons (485 and 549 per square metre respectively). The control T_1 gave the least number of productive tillers.

2. Length of panicle

The mean values for the length of panicle for the Virippu and Mundakan seasons are presented in Table-10 and the analysis of variance in Appendix-VI.

Although the treatment effects were not significant, it could be seen from the data that the length of panicle was highest in treatment T_{12} for both Virippu and Mundakan seasons (27.6 cm and 23.6 cm respectively) and least for treatment T_1.

Table-9

Mean number of productive tillers per square metre

Treatment	Virippu season	Mundakan season	Mean
1	443	456	450
2	469	490	480
3	485	536	511
4	466	450	458
5	463	492	478
6	459	494	477
7	459	488	474
8	465	455	460
9	463	485	474
10	463	481	472
11	439	483	461
12	485	549	517
Mean	463	488	
Treatment comparison	N.S	N.S	
S.E of Mean (0.05)	4.506	5.170	

Table -10

Mean length of panicle in cm

Treatment	Virippu season	Mundakan season	Mean
1	24.4	21.2	22.8
2	26.3	21.7	24.0
3	27.3	22.5	24.9
4	24.9	21.5	23.2
5	25.6	21.3	23.5
6	27.1	21.0	24.1
7	25.5	21.4	23.5
8	25.6	22.0	23.8
9	26.0	22.3	24.2
10	24.9	22.3	23.6
11	24.4	21.5	23.0
12	27.6	23.6	25.6
Mean	25.8	21.9	
Treatment comparison	N.S	N.S	
S.E. of Mean (0.05)	2.222	1.024	

3. Weight of Panicle

The mean values for the weight of panicle for the Virippu and Mundakan seasons are presented in Table -11 and the analysis of variance in Appendix-VI.

The data revealed that there was significant difference between the treatments in this respect. The highest weight of the panicle was recorded by treatment T_{12} for the Virippu and Mundakan seasons (1.86 g and 1.52 g respectively) and the least by treatment T_1(1.12 g and 1.10 g respectively) for the Virippu and Mundakan seasons. In the Virippu season, treatments T_{12} T_3, T_{10}, T_9 and T_8 were on par. Treatments T_{12}, T_3 and T_{10} were superior to all other treatments except T_9 and T_8. Treatments T_9, T_8, T_7, T_6 and T_2 were on par. Treatments T_6, T_2, T_4, T_5, T_{11} and T_1 were on par.

In the Mundakan season, T_{12} was superior to all other treatments except T_4 and T_{11}. Treatments T_{11}, T_4, T_6, T_3, T_{10}, T_5, T_2, T_9 and T_7 were on par but T_{11} was superior to treatments T_8 and T_1 and T_4 was superior to T_1.

4. Number of grains per panicle

The data on the number of grains per panicle are presented in Table -12 and the analysis of variance in Appendix-VI.

It is evident from the results that the effects due to the levels and methods of phosphorus application on the number of grains were not significant. However, treatment

Table - 11

Mean weight of panicle in g.

Treatment	Virippu season	Mundakan season	Mean
1	1.12	1.10	1.11
2	1.36	1.22	1.29
3	1.69	1.28	1.49
4	1.21	1.33	1.27
5	1.15	1.25	1.20
6	1.39	1.29	1.34
7	1.53	1.19	1.36
8	1.56	1.16	1.36
9	1.61	1.21	1.41
10	1.67	1.27	1.47
11	1.13	1.37	1.25
12	1.86	1.52	1.69
Mean	1.44	1.27	
Treatment comparison	Sig.	Sig.	
C.D. of mean (0.05)	0.304	0.192	

Table -12

Mean number of grains per panicle.

Treatment	Virippu season	Mundakan season	Mean
1	69	63	66
2	68	66	67
3	74	63	69
4	72	68	70
5	72	67	70
6	71	69	70
7	71	64	68
8	69	63	66
9	70	64	67
10	71	73	72
11	69	69	69
12	73	71	72
Mean	71	67	
Treatment comparison	N.S	N.S	
S.E. of Mean (0.05)	7.970	3.561	

T_3 gave the highest number of grains (74) per panicle in the Virippu season followed by T_{12} (73) and in the Mundakan season, T_{10} gave the highest number of grains (73) followed by T_{12} (71).

5. Sterility percentage

The data on the mean values for sterility percentage (transformed to angles) for Virippu and Mundakan seasons are given in Table -13 and the analysis of variance in Appendix - VI.

It was observed that the sterility percentage was not influenced by the different levels of phosphorus. The different methods of application also did not exert any significant influence on this attribute. The least value was obtained for treatment T_{10} (23.01) for the Virippu season and T_2 (22.44) for the Mundakan season. The highest value was obtained for treatment T_2 (31.39) for the Virippu season and T_9 (30.83) for the Mundakan season.

6. Thousand Grain weight

The data on the mean values on the thousand grain weight for the Virippu and Mundakan seasons are given in Table -14 and the Appendix -VII provides the corresponding analysis of variance.

Table -13

Mean sterility percentage (transformed to angles)

Treatment	Virippu season	Mundakan season	Mean
1	25.35 (18.3)	25.45 (18.5)	25.40 (18.4)
2	31.39 (27.1)	22.44 (14.6)	26.92 (20.5)
3	24.57 (17.3)	23.11 (15.4)	23.84 (16.3)
4	28.23 (22.4)	24.90 (19.1)	26.57 (20.0)
5	27.47 (21.3)	26.21 (19.5)	26.84 (20.4)
6	23.92 (17.8)	26.06 (19.3)	24.99 (17.9)
7	28.56 (22.9)	25.03 (17.9)	26.80 (20.3)
8	30.35 (25.5)	24.42 (17.1)	27.39 (21.2)
9	21.80 (13.7)	30.83 (26.3)	26.32 (19.7)
10	23.01 (15.2)	24.51 (17.2)	23.76 (16.2)
11	24.72 (17.5)	22.81 (15.0)	23.77 (16.2)
12	25.90 (19.1)	22.59 (14.7)	24.25 (16.9)
Mean	26.27	22.78	
Treatment comparison	N.S	N.S	
S.E. of means (0.05)	3.211	2.763	

* Figures in the parenthesis are the mean percentages.

Table -14

Mean weight of thousand grains in g.

Treatment	Virippu Season	Mundakan Season	Mean
1	25.70	24.33	25.02
2	26.47	24.70	25.59
3	30.00	27.87	28.94
4	27.67	21.37	24.52
5	27.03	23.53	25.28
6	26.27	23.20	24.74
7	27.03	23.90	25.47
8	27.33	24.90	26.12
9	28.57	26.03	27.30
10	29.17	21.40	25.29
11	27.70	23.10	25.40
12	30.20	25.60	27.90
Mean	27.76	24.16	
Treatment comparison	N.S	N.S	
S.E. of Mean (0.05)	2.579	1.948	

There was no significant difference in the thousand grain weight with different nutrient levels and methods of application. The treatment T_{12} gave the highest value (30.20 g) for the Virippu season followed by T_3 (30.00 g) and for the Mundakan season T_3 gave the highest value (27.87 g). The lowest value was recorded by treatment T_1 (27.70 g) in the Virippu season and treatment T_{11} (23.10 g) in the Mundakan season.

7. Grain yield

The data pertaining to the grain yield of the Virippu and Mundakan seasons as influenced by the levels and methods of application of phosphorus are presented in Table-15 and the analysis of variance in Appendix-VII.

The data revealed that the levels and methods of phosphorus application had no effect on the grain yield. However, in both Virippu and Mundakan season, the highest yield of 3357 kg/ha and 3064 kg/ha respectively were recorded by treatment T_{12}. Treatment T_9 also recorded a yield of 3064 kg/ha during the Mundakan season.

The analysis of variance on the pooled analysis are presented in Appendix-VIII. The results revealed that there was no significant difference between the treatments. The S x T interaction also was not significant. However, there was significant difference between the two seasons, the Virippu season being superior to the Mundakan season.

Table -15

Mean Grain Yield in kg/ha.

Treatment	Virippu season	Mundakan season	Mean
1	3014	2897	2956
2	2995	2678	2837
3	3012	2825	2919
4	3023	2606	2815
5	3097	2772	2935
6	3018	2866	2942
7	3060	2773	2917
8	3023	2783	2903
9	3179	3064	3122
10	3127	3030	3079
11	3138	2969	3054
12	3357	3064	3211
Mean	3087	2861	
Treatment comparison	N.S	N.S	
S.E. of Means (0.05)	200.319	186.826	

8. Straw yield

Table 16 furnishes the data pertaining to the straw yield as influenced by the levels and methods of phosphorus application. The analysis of variance are presented in Appendix-VII.

The data revealed that the yield of straw was not significantly influenced by the levels and methods of phosphorus application. In the Virippu season, the highest yield (4972 kg/ha) was recorded by T_4 whereas for the Mundakan season the highest yield of 5274 kg/ha was recorded by T_9.

The data on the pooled analysis of straw yield (Appendix-VIII) revealed that the treatment effect and S x T interaction was not significant. However, there was significant difference between seasons, the Mundakan season being superior to the Virippu season.

9. Harvest Index

The data on the man values of harvest index for the Virippu and Mundakan seasons expressed as percentage are presented in Table-17 and the analysis of variance in Appendix-VII.

The levels and methods of phosphorus application did not exert any significant influence on the harvest index in both the seasons.

Table-16

Mean straw yield in kg/ha

Treatment	Virippu season	Mundakan season	Mean
1	4708	5148	4928
2	4692	5134	4913
3	4880	5002	4941
4	4972	5127	5050
5	4577	5027	4802
6	4727	5256	4992
7	4658	5044	4851
8	4801	5190	4995
9	4928	5274	5100
10	4637	5269	4953
11	4649	5148	4899
12	4949	5064	5007
Mean	4765	5140	
Treatment comparison	N.S	N.S	
S.E. of means (0.05)	287.25	213.27	

Table-17

Harvest index in percentage.

Treatment	Virippu season	Mundakan season	Mean
1	39.3	35.9	37.6
2	39.0	34.3	36.7
3	39.2	36.1	37.6
4	38.8	33.7	36.3
5	40.9	35.3	38.1
6	39.3	35.3	37.3
7	39.6	35.5	37.6
8	38.5	35.0	36.8
9	39.2	36.7	38.0
10	40.2	36.9	38.6
11	40.3	36.6	38.5
12	40.3	35.9	38.1
Mean	39.6	35.6	
Treatment comparison	N.S	N.S	
S.E of means (0.05)	1.46	1.94	

C. QUALITY CHARACTER

Protein content of grain

Data on the mean values of the protein content of the grain for the Virippu and Mundakan seasons are furnished in Table-18 and the analysis of variance in Appendix-VII.

The data showed that there was no significant difference in the protein content of the grain with different levels and methods of application of phosphorus. Both in the Virippu and Mundakan seasons treatment, T_6 gave the highest percentage (8.48 and 8.61 respectively) of protein in the grain.

D. UPTAKE OF NUTRIENTS

1. Uptake of nitrogen

The data on the uptake of nitrogen expressed in kg per hectare for the Virippu and Mundakan seasons are presented in Table 19 and the analysis of variance in Appendix-IX

The data revealed that there was no significant difference in the uptake of nitrogen as influenced by the different levels and methods of application of phosphorus. However, in the initial stages, the uptake was highest for treatment T_8 in the Virippu season and T_2 in the Mundakan season. At the final stages also the same trend was observed.

Table-18

Protein content (percentage) in grains

Treatment	Virippu season	Mundakan season	Mean
1	7.59	7.65	7.62
2	8.12	7.91	8.02
3	8.10	6.81	7.46
4	7.54	7.66	7.60
5	7.40	8.05	7.73
6	8.48	8.61	8.55
7	7.60	8.09	7.85
8	8.09	7.58	7.84
9	8.27	8.43	8.35
10	7.91	7.47	7.69
11	7.20	8.42	7.81
12	7.40	8.18	7.79
Mean	7.81	7.90	
Treatment comparison	N.S	N.S	
S.E. of Mean (0.05)	0.636	0.783	

Table-19

Uptake of Nitrogen (kg/ha)

Treat-ment	Initial			Final		
	Virippu season	Mundakan season	Mean	Virippu season	Mundakan season	Mean
1	17.53	7.78	12.66	80.23	78.83	79.53
2	18.60	13.29	15.95	84.14	89.21	86.68
3	18.02	11.38	14.70	78.55	78.81	78.68
4	17.31	9.69	13.50	81.99	83.69	82.84
5	14.02	13.41	13.72	79.38	79.29	79.34
6	18.52	10.15	14.34	87.20	73.99	80.60
7	18.43	10.56	14.50	91.30	65.36	78.33
8	19.65	11.78	15.72	91.31	79.72	85.53
9	16.45	9.31	12.88	85.77	83.35	85.56
10	16.11	9.54	12.83	83.65	84.02	83.84
11	17.57	9.89	13.73	87.65	76.51	82.08
12	18.31	10.61	14.46	87.30	78.23	82.77
Mean	17.54	10.62		84.87	79.42	
Treatment comparison	N.S	N.S		N.S	N.S.	
S.E. of mean (0.05)	1.918	1.844		5.304	7.878	

2. Uptake of Phosphorus

The mean values of phosphorus uptake at successive stages of growth for the Virippu and Mundakan seasons are presented in Table-20 and 21 and the analysis of variance in Appendix -X.

The effect of phosphorus was found not significant during the three growth stages in both Virippu and Mundakan seasons. In the Virippu season, at maximum tillering, the uptake was highest for treatment T_2 but at panicle initiation and harvest, the uptake was highest for treatment T_{12}. For the Mundakan season, at maximum tillering the uptake was highest for treatment T_1, but at panicle initiation and at harvest the uptake was highest for treatment T_{12}.

3. Uptake of Potassium

The data on the uptake of potassium in kg per hectare at the initial and final stages for the Virippu and Mundakan seasons are presented in Table-22 and the analysis of variance in Appendix- XI

Although the results did not show any significant difference in the uptake of potassium due to different levels and methods of phosphorus applications, treatment T_3 gave the highest values in the initial stages in both seasons. In the final stages, treatment T_7 gave the highest values in the Virippu season and treatment T_9 in the Mundakan season.

Table-20

Uptake of phosphorus (kg/ha) at different stages of growth

Virippu season

Treatment	Maximum tillering	Panicle initiation	Harvest
1	2.16	4.02	29.47
2	2.48	4.45	34.11
3	2.44	5.16	35.03
4	2.12	4.82	31.65
5	2.46	4.28	34.64
6	1.98	4.44	29.47
7	2.13	5.12	32.99
8	2.28	3.95	28.58
9	2.03	5.08	33.44
10	2.34	4.26	28.81
11	2.21	4.73	27.27
12	2.21	5.51	39.48
Mean	2.24	4.65	32.15
Treatment comparison	N.S	N.S	N.S.
S.E. of means (0.05)	0.2855	0.788	4.404

Table-21

Uptake of phosphorus (kg/ha) at different stages of growth

Mundakan season

Treatment	Maximum tillering	Panicle initiation	Harvest
1	2.64	8.18	24.26
2	2.46	9.63	26.10
3	1.48	9.44	29.24
4	1.65	10.08	23.76
5	1.49	10.59	25.58
6	1.97	9.84	25.81
7	1.87	8.39	23.13
8	1.67	9.49	26.63
9	1.69	9.24	27.01
10	1.77	9.40	27.11
11	2.00	9.23	24.94
12	1.68	10.73	29.28
Mean	1.86	9.52	26.07
Treatment comparison	N.S	N.S	N.S.
S.E. of mean (0.05)	0.4736	1.395	3.309

Table-22

Uptake of potash (kg/ha)

Treatment	Initial			Final		
	Virippu season	Mundakan season	Mean	Virippu season	Mundakan season	Mean
1	10.21	5.44	7.83	126.42	126.82	126.62
2	11.56	9.12	10.34	137.39	128.46	132.93
3	12.01	9.69	10.85	135.39	134.42	134.91
4	11.15	5.80	8.19	136.95	118.90	127.65
5	10.57	9.09	9.83	129.09	119.61	124.35
6	10.81	7.72	9.27	133.74	126.79	130.27
7	11.25	5.94	8.60	146.16	118.37	132.27
8	10.42	7.71	9.07	128.24	117.32	122.78
9	10.17	6.80	8.49	139.84	138.61	139.23
10	10.25	7.16	8.71	142.85	127.32	135.09
11	10.88	6.83	8.86	125.23	122.76	124.00
12	10.91	7.12	9.02	130.22	129.54	129.88
Mean	10.85	7.37		134.29	125.74	
Treatment comparison	N.S	N.S		N.S.	N.S.	
S.E. of mean (0.05)	0.576	0.095		2.977	9.579	

E. SOIL ANALYSIS

1. Total nitrogen content of the soil

The data on the mean values of the nitrogen content of the soil before and after the experiment are presented in Table -23 and the analysis of variance in Appendix-XII

There was no significant difference in the nitrogen status of the soil before and after the experiment. The data revealed that the nitrogen status of the soil was not significantly influenced by the levels and methods of phosphorus application.

2. Available phosphorus in the soil during successive stages of growth

The data on the mean values of the phosphorus content of the soil at successive stages of growth for the Virippu and Mundakan seasons are presented in Tables-24 and 25 and the analysis of variance in Appendix- XIII.

The results show that the average available phosphorus before the experiment was 49.03 kg P_2O_5/ha. In the Virippu season, the average available P_2O_5 increased to 84.57 kg P_2O_5/ha at maximum tillering stage. Thereafter it showed a slight decrease to 78.04 kg P_2O_5/ha at panicle initiation stage and decreased to 58.4 kg/ha at harvest.

Table-23

Total nitrogen content of the soil (%)

Treatment	Before the experiment	After the experiment		Mean
		Virippu season	Mundakan season	
1	0.107	0.121	0.135	0.128
2	0.126	0.131	0.138	0.135
3	0.103	0.121	0.131	0.126
4	0.103	0.121	0.131	0.126
5	0.131	0.140	0.149	0.145
6	0.117	0.126	0.139	0.133
7	0.121	0.131	0.145	0.138
8	0.126	0.140	0.149	0.145
9	0.126	0.136	0.140	0.138
10	0.121	0.126	0.131	0.129
11	0.112	0.121	0.126	0.124
12	0.121	0.131	0.145	0.138
Mean	0.118	0.129	0.138	
Treatment comparison	N.S	N.S	N.S	
S.E. of mean (0.05)	0.017	0.0188	0.0153	

Table-24

Available phosphorus content of the soil (kg/ha) at different stages of growth.

Virippu season

Treat-ment	Before the experiment	Maximum tiller-ing	Panicle initia-tion	Harvest
1	49.2	83.9	77.1	56.9
2	50.2	85.8	79.7	59.8
3	49.0	85.2	78.9	59.1
4	47.7	85.0	78.8	59.1
5	49.2	84.9	77.6	58.7
6	48.4	83.9	77.4	57.3
7	49.3	85.2	77.5	58.4
8	48.9	84.7	78.3	59.3
9	48.7	84.4	77.8	58.2
10	49.1	84.1	79.4	59.0
11	49.2	83.8	76.9	57.6
12	49.4	83.9	77.1	57.4
Mean	49.03	84.57	78.04	58.4
Treatment Comparison	N.S	N.S	N.S	N.S.
S.E. of mean (0.05)	1.759	1.087	3.945	1.385

Table-25

Available phosphorus content of the soil (kg/ha) at different stages of growth

Mundakan season

Treat-ment	Maximum tillering	Panicle initiation	Harvest
1	84.1	75.3	50.7
2	88.0	79.9	57.4
3	89.8	77.3	55.0
4	87.8	76.8	54.8
5	87.9	76.3	52.4
6	84.1	75.4	52.4
7	87.4	76.4	53.4
8	86.8	76.8	54.9
9	86.3	75.2	53.1
10	87.5	75.9	53.3
11	87.8	76.6	54.8
12	85.4	75.2	51.4
Mean	86.91	76.43	53.63
Treatment comparison	N.S	N.S	N.S
S.E. of mean (0.05)	2.692	1.951	3.202

In the *Mundakan* season, at maximum tillering the average available P_2O_5 in the soil was 86.91 kg P_2O_5/ha at maximum tillering stage which slightly decreased to 76.43 kg P_2O_5/ha at panicle initiation and 53.63 kg P_2O_5/ha at harvest.

The data revealed that the levels and methods of phosphorus application had no significant influence on the phosphorus status of the soil at any of the growth stages.

However, the available phosphorus in the soil was highest when the entire dose of phosphorus was applied as a basal dose at all growth stages in both seasons.

3. Available potassium content of the soil

Data on the available potassium content of the soil before and after the experiment are furnished in Table-26 and the analysis of variance in Appendix- XIV.

There was no significant difference in the available potassium status of the soil before and after the experiment. The data revealed that the levels and methods of phosphorus application had no significant influence on the potassium status of the soil.

F. Economics of Production

The economics of production are given in Table-27. The maximum profit of Rs.3199.30 was obtained in the treat-

Table-26

Available potassium content of the soil (kg/ha)

Treat-ment	Before the experiment	After the experiment		Mean
		Virippu season	Mundakan season	
1	79.52	84.71	94.64	89.68
2	79.77	83.74	94.08	88.91
3	84.88	94.19	96.37	95.28
4	73.00	74.00	86.61	80.31
5	88.63	94.80	97.11	95.96
6	81.20	88.50	95.68	92.09
7	84.86	101.65	100.96	101.31
8	81.39	87.75	95.23	91.49
9	77.69	81.30	92.00	86.65
10	84.92	105.33	99.05	102.19
11	80.00	92.59	96.90	94.75
12	76.80	77.81	89.89	83.85
Mean	80.64	88.86	94.88	
Treatment comparison	N.S	N.S	N.S	
S.E. of Mean (0.05)	7.668	13.194	12.580	

Table-27

Economics of Rice production per hectare per season

Treatment	Total income from yield of grain and straw	Cost of fertilizer (Urea + muriate of potash + superphosphate/ KH_2PO_4/ D A P	Labour charges	Total expenses for fertilizers and labour	Net profit
	Rs. ps	Rs. ps	Rs. ps	Rs. ps	Rs. ps
1	8,129.60	418.20	5,074.00	5,492.20	2,637.40
2	7,968.40	615.10	5,074.00	5,689.10	2,279.30
3	8,266.00	615.10	5,124.00	5,714.10	2,526.90
4	7,944.40	565.90	5,074.00	5,639.90	2,304.50
5	8,270.00	565.90	5,124.00	5,664.00	2,580.10
6	8,188.80	516.60	5,124.00	5,615.60	2,548.20
7	7,974.80	516.60	5,074.00	5,590.60	2,384.20
8	8,270.80	1,000.00	5,074.00	6,074.00	2,196.80
9	8,724.80	529.80	5,099.00	5,628.80	3,096.00
10	8,520.40	480.45	5,099.00	5,579.45	2,940.95
11	8,427.20	516.60	5,099.00	5,615.60	2,811.60
12	8,888.40	615.10	5,074.00	5,689.10	3,199.30

Price of 1 kg grain = Rs. 2.00
Price of 1 kg straw = Rs. 0.80
Price of 1 kg urea = Rs. 2.25
Price of 1 kg superphosphate = Rs. 0.90
Price of 1 kg MOP = Rs. 1.30
Price of 1 kg KH_2PO_4 = Rs.148.85
Price of 1 kg D A P = Rs. 93.00
Labour charges per day for men = Rs.25.00
Labour charges per day for women = Rs.22.00

ment T_{12}. The treatment T_8 gave the least profit of Rs.2196.80. Among the different levels of phosphorus application, the control plot without phosphorus gave the highest profit of Rs.2637.40.

DISCUSSION

DISCUSSION

The present investigation is an attempt to evaluate the relative efficiency of different levels and methods of phosphorus application to rice variety, Triveni. It has been reported that phosphate fertilizers did not show any significant response to rice in almost all the research stations in Kerala. Therefore, an attempt has been made to study the effect of different levels and methods of phosphorus application on rice yield and quality, uptake of phosphorus by the plant and availability of phosphorus in the soil. The results obtained are discussed hereunder.

A. GROWTH CHARACTERS

1. Height of plants

The results (Tables-1 & 2, and Appendix) revealed that phosphorus had no significant influence on the height of the plant at any of the growth stages. This is in agreement with results of Place et al.(1970), Alexander et al.(1973), Kalyanikutty and Morachan (1974) and Bharadwaj et al.(1974). Since phosphorus is involved more on the reproductive development of the plant, it is quite natural that the vegetative development of the plant was not affected by the application of phosphorus.

The different methods of phosphorus application also did not show any significant effect on the height of the plants. Abdulgalil et al.(1979) also reported that plant height was not affected by foliar application of phosphorus compared to soil fertilizer application. Nair et al.(1977) reported that phosphorus applied as early in the nursery, had no effect on the plant height.

2. Tiller number

It is seen that phosphorus did not significantly influence the number of tillers at any stages of the growth (Table 2 & 3). This means that the different levels of phosphorus application had no effect on the number of tillers. Similar results were reported by Sreenivasalu and Pawar (1965), Kalyanikutty and Morachan (1974), Rao et al.(1974) and Suseelan et al.(1979). As in the case of height of plant, the different methods of phosphorus application also had no significant effect on the number of tillers per hill. This is in agreement with results of Krishnamoorthy et al.(1973) that under certain soil conditions, soil application of phosphorus is as good as foliar application.

3. Leaf Area Index

In the case of leaf area index also the effect of phosphorus was not significant. There was no significant difference between the different levels and methods of phosphorus application on the leaf area index. The leaf area index is the expression of vegetative development of the plant in relation to land area utilized, to harvest maximum solar radiation for photosynthesis. The major role in this respect is being played by nitrogen and as such phosphorus could not exert any influence on this character.

4. Dry Matter production

Eventhough there was a slight significant difference in the dry matter production in the initial stages for the Virippu crop, no significant influence of either levels or methods of phosphorus application could be seen in the subsequent observations. Boatwright and Viets (1966) found that supply of phosphorus for the first five weeks was adequate to produce maximum drymatter. The increasing trend in dry matter production was from tillering to flowering and thereafter a negligible increase was observed by Thandapani and Rao (1976). Gupta and Singh (1977) reported poor response of rice to applied phosphorus, Singlachar and Chandrasekhar (1978) could not find any effect of seed treatment on the growth of paddy compared with untreated seed.

Phosphorus did not reveal any positive effect on the vegetative characters at any of the growth phases studied. Several workers have reported that plants could show response to added phosphorus only when the available phosphorus status of the soil was low (Davide, 1960; Terman and Allen, 1970; Alexander et al. (1973). It is seen from Tables-24 and 25 that the average available phosphorus contents of the soils were 49.03, 85.74, 77.23 and 56.01 kg P_2O_5/ha, before sowing, at maximum tillering, panicle initiation and harvest stages, respectively. This high status of available phosphorus contents of the soil during the various growth stages, satisfactorily explains the reason for the lack of response to applied phosphorus.

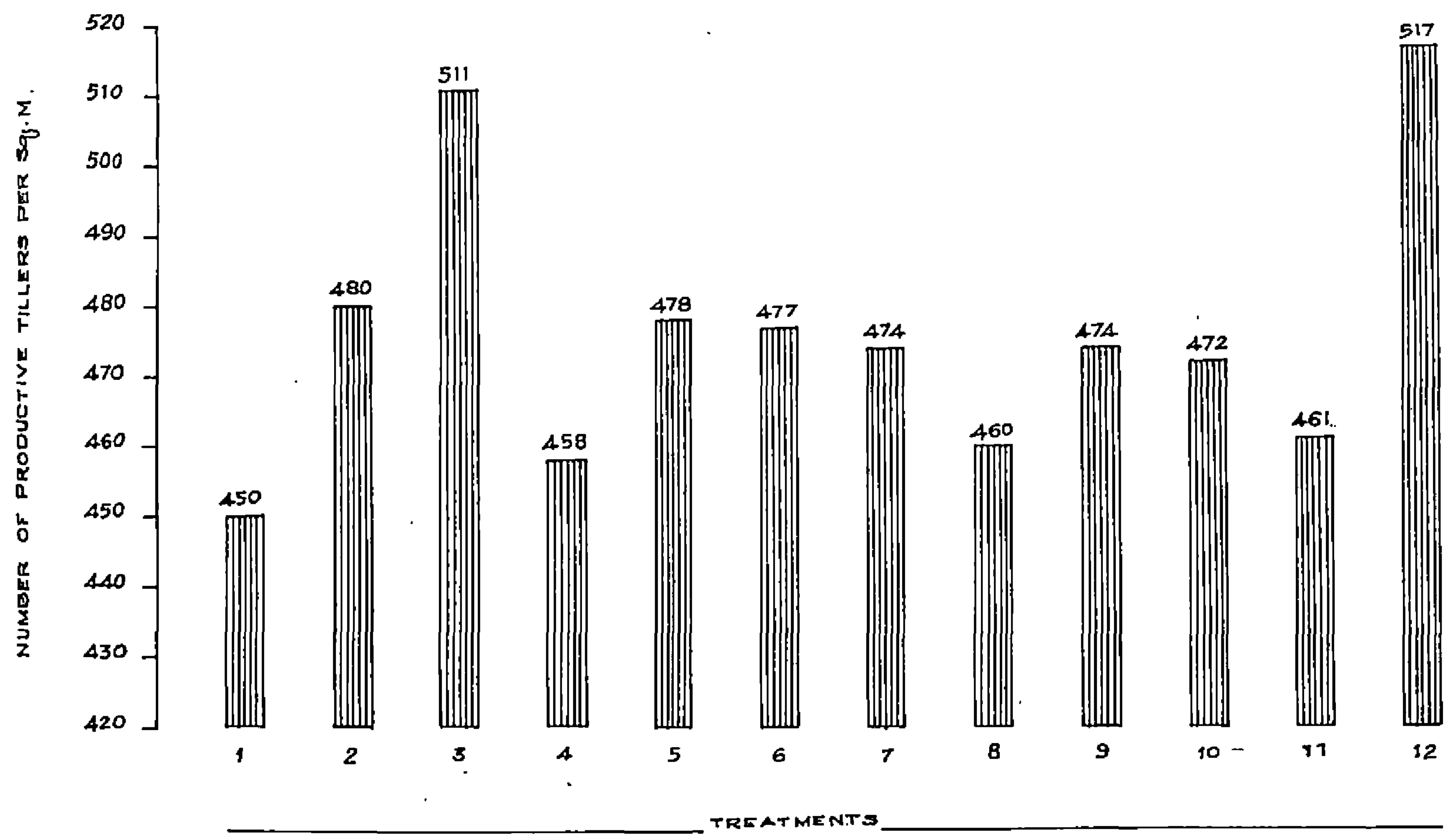
B. YIELD COMPONENTS AND YIELD

1. Number of productive Tillers and Panicles

The results presented in Tables 9 and 10 and Fig.3 showed that the number of productive tillers was not significantly influenced by the levels of phosphorus application. Similar results were reported by Aaron et al. (1971), Alexander et al.(1973), Rao et al.(1974) and Sadanandan and Sasidhar (1976).

The different methods of phosphorus application also did not have any significant effect on the number of productive tillers. This is in accordance with the results of Ramakrishnan (1974) who reported that neither

FIG. 3. AVERAGE NUMBER OF PRODUCTIVE TILLERS PER SQUARE METRE.



foliar nor soil application expressed superiority over each other in increasing the productive tillers. Mehrotra et al.(1968) reported that seed treatment with KH_2PO_4 had little effect on the number of ears per plant. Findings of Celton and Velly (1966) and Nair et al.(1977) also confirmed that application of phosphorus to the nursery had no appreciable influence on the number of ear bearing tillers per hill. The results of Subramanian and Subramanian (1980) also showed that dipping the roots in superphosphate slurry had no effect on the number of productive tillers per hill.

2. Length of Panicle

Application of phosphorus has not significantly influenced the length of panicle too (Table-10). Similar results were reported by Singh and Varma (1971), Alexander et al.(1973) and Rao et al.(1974). Length of panicle therefore seems to be a varietal character which can seldom be influenced by the application of fertilizers.

The length of panicle was not influenced either by the foliar application or by other special methods of application. This is in conformity with the findings of Abdulgalil et al.(1979).

3. Weight of Panicle

The results presented in Table-11 showed that the weight of panicle was significantly influenced by the treatments. The highest panicle weight was obtained with the application of the entire dose of phosphorus in the nursery. The beneficial role of phosphorus in increasing panicle weight has already been reported by Place et al. (1970). Unlike the length of panicle, which may be a varietal character, the weight of panicle is more decided by the grains contained in the panicle. Phosphorus could have contributed more to this property of the grains and as such could favourably influence the weight of panicles.

4. Number of grains per Panicle and Sterility percentage.

It is revealed from the results presented in Tables 12 and 13 that there was no significant difference between treatments in this respect. Ahammad (1970), Alexander et al. (1973), Rao et al. (1974), Sadanandan and Sasidhar (1976), Bhattacharyya and Chatterjee (1978) and Suseelan et al. (1978) also could not find any influence of phosphorus on the number of grains.

It may be observed that at the time setting of grains took place, the full requirement of phosphorus might have been satisfied by the native soil phosphorus solubilised under the reduced conditions and this can be attributed to the lack of response to added phosphorus on this yield attribute.

The different methods of phosphorus application also did not have any positive influence on the number of grains. This is in conformity with the findings of several research workers. Ramakrishnan (1974) reported that there was no response for the number of grains per panicle by foliar and soil application. Phosphorus at 34 kg/ha alone increased the number of filled grains in the panicle over the control. Mehrotra et al.(1975) also reported that treatment of seeds with KH_2PO_4 had little effect on the number of grains per ear.

5. <u>Thousand Grain Weight</u>

The results presented in Table-14 showed that the thousand grain weight was not influenced by the levels and methods of phosphorus application. Several rice workers have reported that thousand grain weight was unaffected by phosphorus application (Reddy, 1967; Ahammad, 1970; Place et al. 1970; Alexander et al.1973; Rao et al.1974, Kalyanikutty and Morachan, 1974). Bhattacharyya and Chatterjee (1978) also reported that thousand grain weight was not influenced by phosphorus application.

According to Ramakrishnan (1974) foliar application of phosphorus was on par with soil application in its influence on thousand grain weight. Kargbo (1978) reported that foliar fertilization had a significant effect on ear weight only in some of the experiments. Merhotra et al. (1978) also confirmed that the seed treatment with KH_2PO_4 had no effect on the thousand grain weight.

Application of phosphorus did not have any positive influence on any of the yield attributes. As has been discussed earlier, this lack of response to added phosphorus can be traced to the relatively higher content of available phosphorus in the soil, which showed a constant increase due to flooding during crop growth. Similar results were reported by Basak and Bhattacharyya (1962), Raghupathy and Raj (1973), Mosi et al. (1973) and Gupta and Singh (1977). The submerged conditions favour the reduction of iron and aluminium phosphate resulting in increased availability of native and fixed phosphate which go to meet the phosphate needs of the crop (Bedrna, 1974).

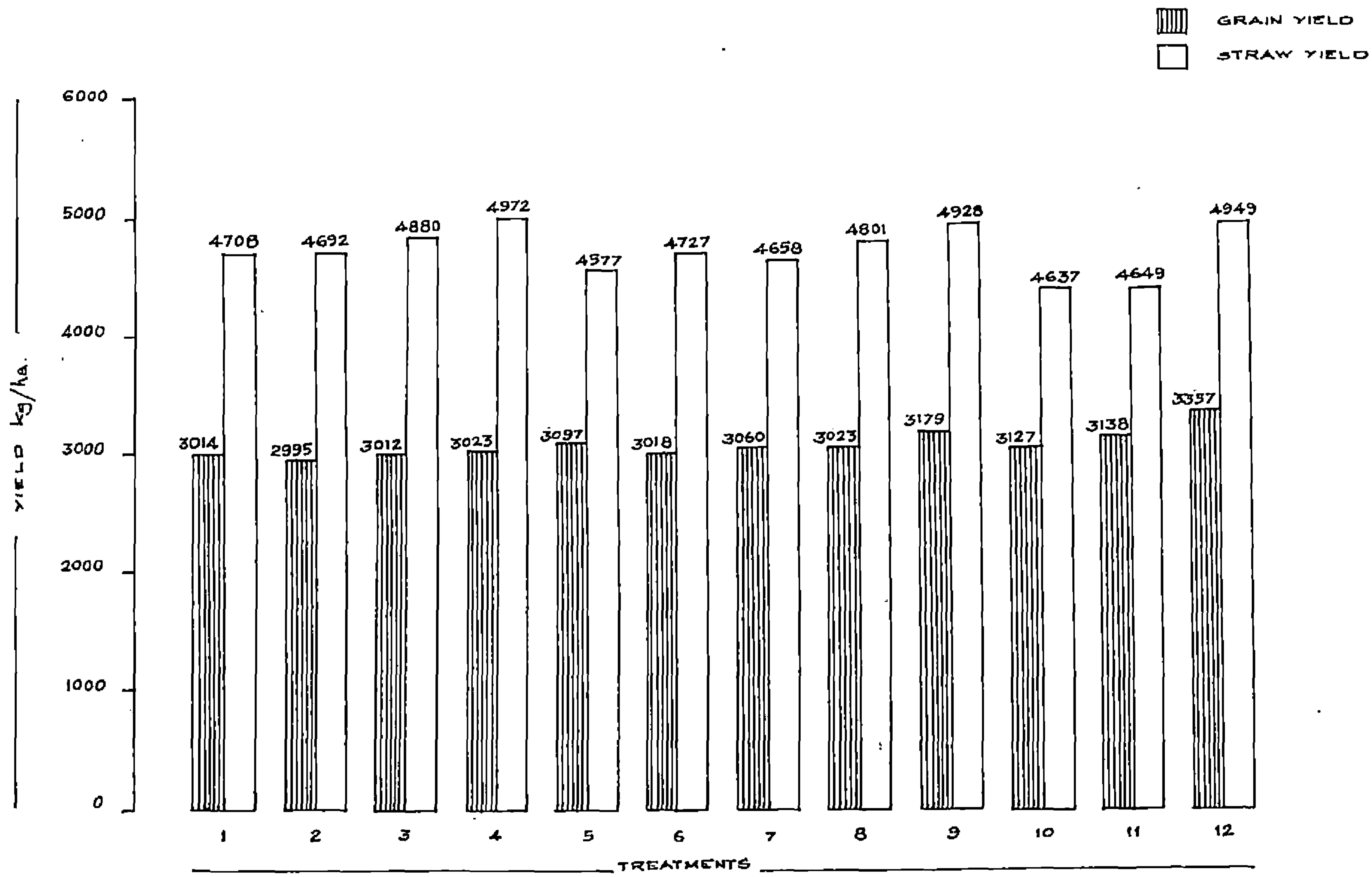
C. YIELD

1. <u>Grain Yield</u>

The data presented in Table-15 and Fig.4 and 5 on grain yield revealed that the application of phosphorus did not show any significant response in the yield of grains. Similar results have been reported by Boerema (1965), Kalam et al.(1966) and Sood et al. (1969). The lack of response to phosphorus application was also reported by Place et al.(1970) and Loganathan and Raj (1971). Rajendran et al.(1971) showed that there is lack of significant response at all centres with medium to high available phosphorus status. No significant effect on grain yield was noted by the application of different levels of phosphorus by Lal et al. (1973). Mosi et al.(1973) and Alexander et al.(1973). The results of Kolandaiswamy et al.(1974) showed that phosphorus levels and time of application did not significantly influence the grain yield. Similar results were also reported by Sasidhar (1976), Mandal and Sahu (1978), Bhuiya et al.(1979), Krishnamoorthy et al.(1979), Chhabra and Abrol (1981) and Rojas and Alvarado (1982).

The different methods of phosphorus application also did not have any significant influence on the grain yield. The work of Krishnamoorthy et al.(1973) revealed that under certain soil conditions soil application of phosphorus is as good as foliar application and equally efficient. Trials conducted by Ramakrishnan (1974), Gupta and Seth (1978), Kargbo (1978), Shirval et al. (1978), Thom et al.(1981) also confirmed that there was no significant difference between soil and foliar application of phosphorus.

FIG. 4. YIELD OF GRAIN AND STRAW - VIRIPPU SEASON.



Singlachar and Chandrasekhar (1978) reported that treatment of rice seed with KH_2PO_4 had no effect on the paddy yields compared with untreated seeds. Application of phosphorus in nursery also had no significant effect on the grain yield as reported by Celton and Velly (1966), Padalia and Mahapatra (1970) and Nair et al. (1977). Experiments by IRRI (1961) and Mariakulandai and Chamy (1967) showed that dipping in superphosphate slurry was on par with broadcast application. But the slurry treatment will help in economising the dose of superphosphate. Similar results were reported by Katyal and Ramavataram (1973), Katyal et al.(1975), Mirza et al. (1979), Reddy et al.(1979), Mirza et al.(1980) and Rao et al.(1982). In general, the grain yields tend to be higher with other methods of phosphorus application compared to foliar application of phosphorus.

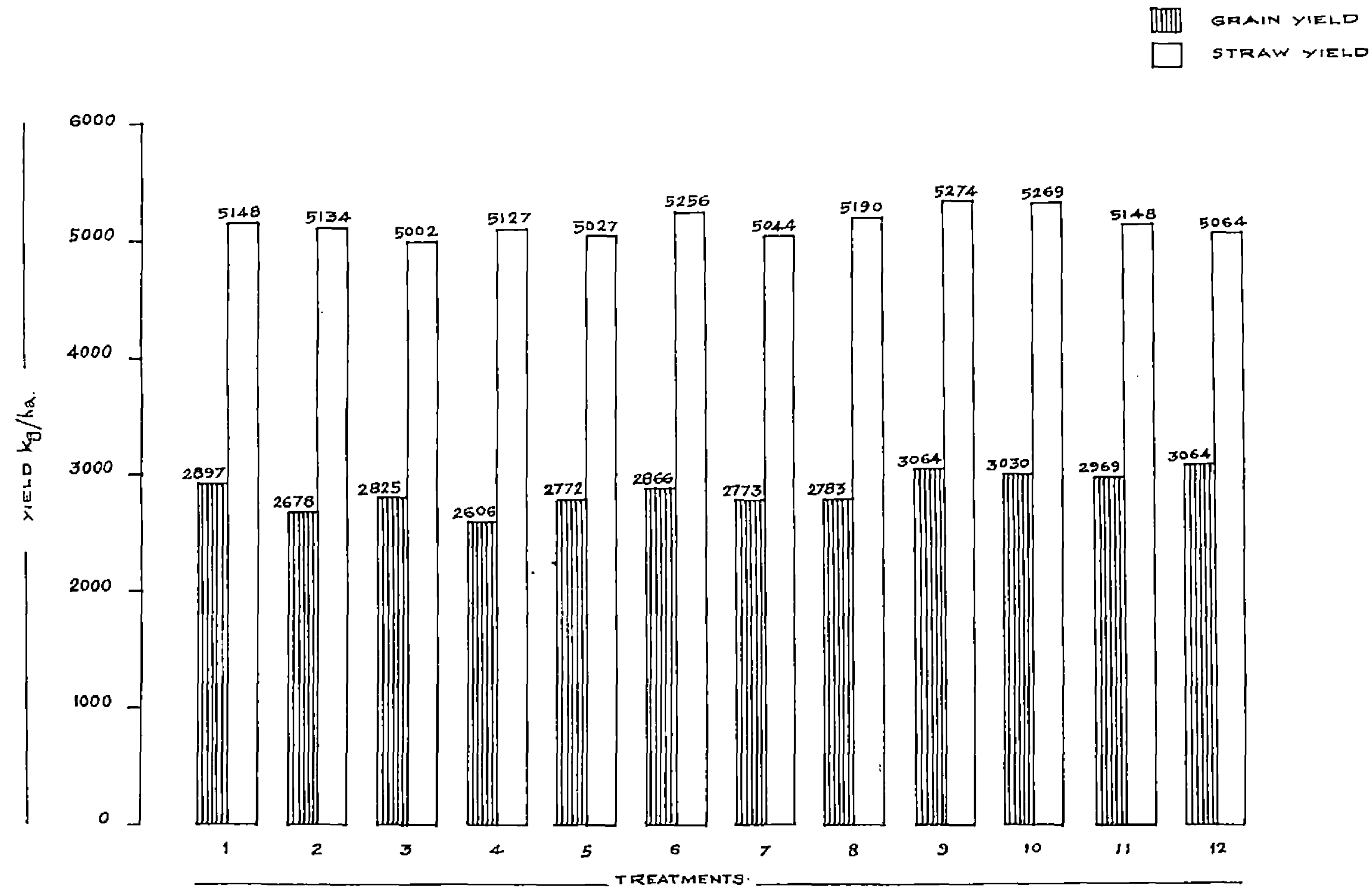
The results of trials by Ramaswamy et al.(1974) showed that dipping the seedlings in superphosphate slurry was on par with broadcast application. The inference is that plants can extract soil phosphorus under submerged conditions if soil phosphorus is not too low provided a starter effect is given by dipping the seedlings in phosphate slurry; Potassium dihydrogen phosphate, Diamonium phosphate or when the entire phosphorus is applied to the nursery and then planted in the main field.

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 could not be detected. Thus the lack of response in grain yield in the present investigation can be attributed to the relatively high status of available phosphorus in the soil, compared to the phosphorus requirement of the crop.

Increased availability of phosphorus under flooded conditions reported by Datta and Datta (1963), Broeshart et al.(1965) Mosi et al.(1973) and Gupta and Singh (1977) can be taken as indirect evidence for the lack of response to added phosphate recorded in the present investigation.

The reason for the lack of response to phosphorus can be further explained by the findings of Velley (1959) who reported that response to added phosphorus can be obtained only if the percentage of phosphorus as shown by the leaf analysis is 0.28 per cent P_2O_5 or less. Data on the phosphorus uptake at different stages of growth (Table 20 and 21) show that average phosphorus uptake of two seasons even in the control plot during maximum tillering and panicle initiation stages were 2.40 and 6.10 kg P_2O_5/ha respectively. The respective percentages of

FIG. 5. YIELD OF GRAIN AND STRAW - MUNDAKAN SEASON.



phosphorus in the plant were 0.26 per cent and 0.394 per cent which were well above the critical limit and hence the lack of response for phosphorus application.

2. Straw Yield

The results of straw yield presented in Table-16 and Fig.4 and 5 revealed the absence of any significant effect of phosphorus. The number of tillers and height of plants are the two contributing factors which determine the yield of straw. Since these factors, as has been discussed earlier, are unaffected by the treatments it is quite reasonable to expect the same trend with respect to straw yield also. Long term experiments conducted by Digar and Mandal (1957) and Kampath (1967) to study the effect of application of phosphorus on grain and straw yields of paddy showed that response to phosphorus will be obtained only in those plots where phosphorus had not been applied for 2 or 3 years. This response for phosphorus application after 2 or 3 years cropping may be due to the fact that either the equilibrium between the available and unavailable form is not maintained by natural means or the native phosphorus might have been depleted to the extent that it is not adequate to meet the requirements of the crop.

Lack of response in the case of straw yield were also reported by Loganathan and Raj (1971), Sasidhar and Sadanandan (1971), Alexander et al.(1973), Rao et al. (1974) and Suseelan et al. (1977). Ramiah et al.(1970) and Ramakrishnan (1974) reported that there was no significant difference in straw yield due to soil and foliar application of phosphorus.

These findings indicate that the object to be achieved by the application of phosphatic fertilizers is to maintain the status of nutrient in the soil as well as to tilt the equilibrium between available and unavailable forms of phosphorus to the advantage of the growing crop. This rather changes the concept of fertilizer application from 'fertilizer for crop' to 'fertilizer for soil'.

C. QUALITY CHARACTER

1. Protein content of grain

The protein content of grain provided in Table-18 showed that there was no significant difference in the protein content of grain with different levels and methods of phosphorus application. This is in conformity with the findings of Taira (1970) and Bhuiya et al.(1979) who reported that phosphorus had no significant effect on the grain crude protein content. Karim et al.(1968), Verkhotin

(1974) and Ageeb and Yousif (1978) reported a decrease in protein content with applied phosphorus.

E. UPTAKE OF NUTRIENTS

1. Uptake of Nitrogen

Results presented in Table-19 revealed that phosphorus application had no significant influence on the uptake of nitrogen by the plants. Williams (1948) found that phosphorus deficiency greatly depressed the nitrogen uptake in the early stages of growth of roots and shoots. Kimuara and Okajima (1951) and Okajima and Kimuara (1962) also observed that a low phosphorus supply suppresses early nitrogen uptake. The results presented in Table-24 show that the average available phosphorus status of the soil before sowing is 49.03 kg P_2O_5/ha. This high status of available phosphorus content of soil may be the reason for lack of significant influence of phosphorus on the uptake of nitrogen. Kalyanikutty and Morachan (1974) also reported that increased application of P_2O_5 did not have any influence on the nitrogen content in the plants. This along with lack of significant response in dry matter production might be the reason for the lack of significant influence of phosphorus on nitrogen uptake.

2. Phosphorus uptake by the plant during successive stages of growth

It is seen that the pattern of phosphorus uptake (Table 20 and 21 and Fig.6) showed a gradual increase from maximum tillering to panicle initiation and then a rapid increase from panicle initiation to harvest. This is in agreement with the findings of Patnaik et al.(1965). It was also found that the rate of absorption of phosphorus continued to increase throughout the growth period of the crop. Similar results were reported by Gargantini and Blanco (1965) and Mehrotra et al.(1968). 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. Mohanty and Patnaik (1974) and Suseelan et al.(1978) found that the pattern of phosphorus absorption showed an increasing trend upto primordia initiation stage, followed by a gradual depression thereafter.

The effect of phosphorus was not significant in increasing the phosphorus uptake by the plant at any of the growth stages. Similar results were reported by Alexander et al.(1974). However, Rastogi et al. (1981) revealed that increasing levels of applied phosphorus decreased the available phosphorus uptake. This can be traced to the adequacy of available phosphorus in the

FIG. 6. AVERAGE UPTAKE OF PHOSPHORUS BY THE VIRIPPU AND MUNDAKAN SEASON CROP AT DIFFERENT STAGES OF GROWTH.

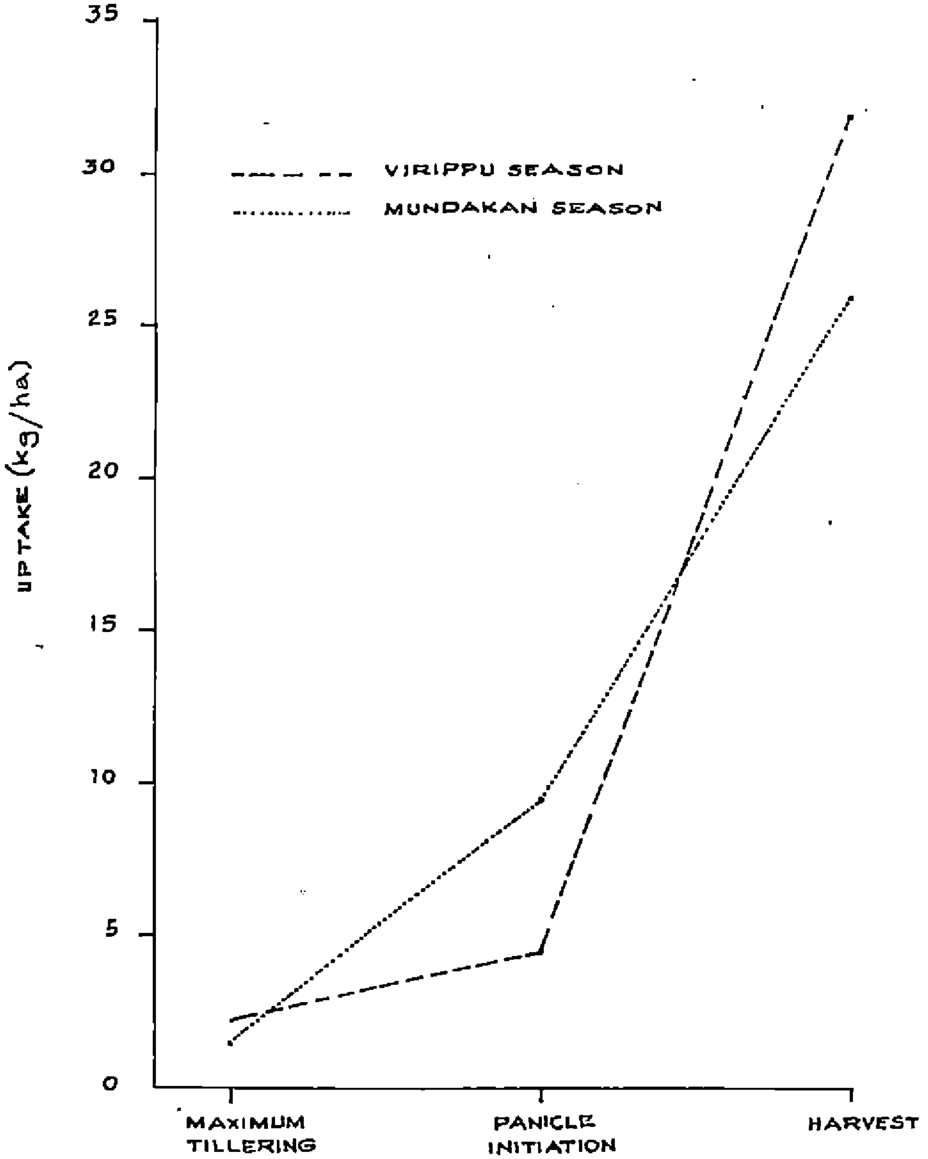
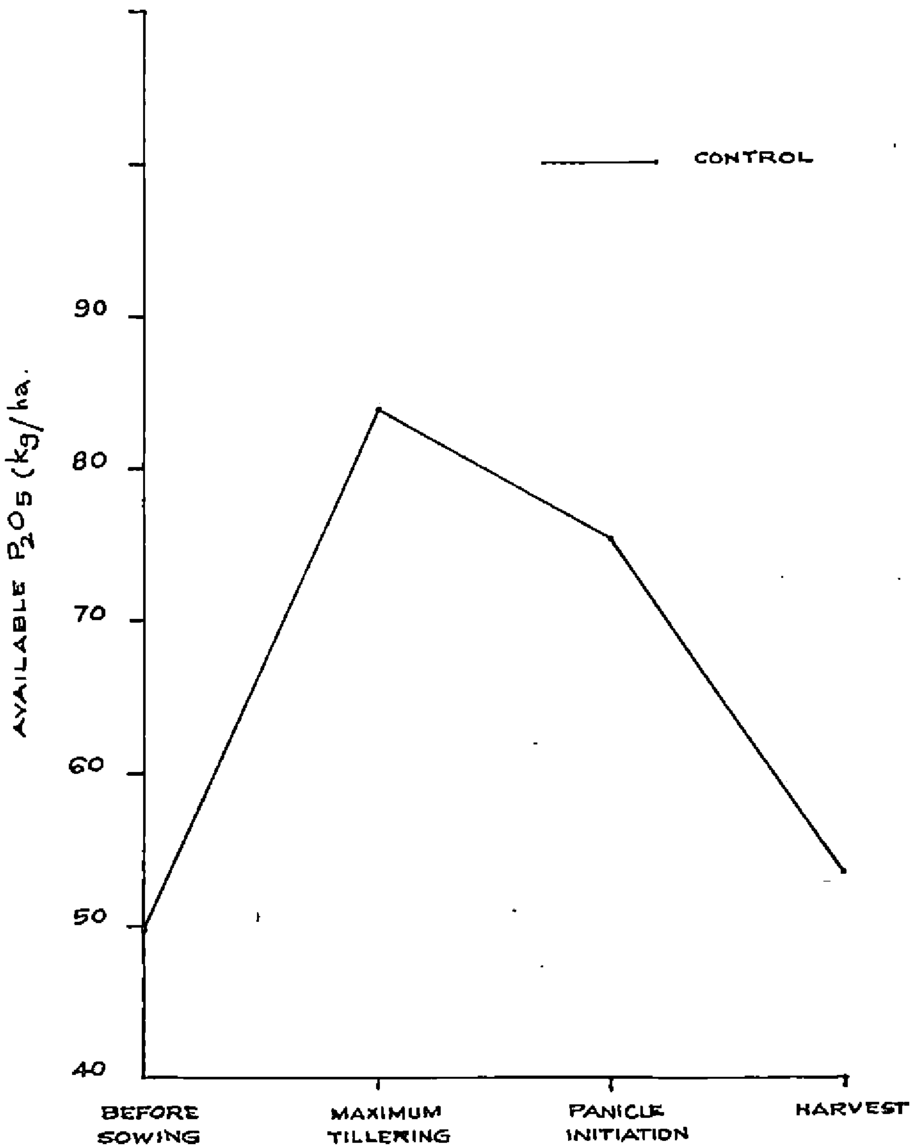


FIG. 7. AVERAGE AVAILABLE P_2O_5 AT DIFFERENT STAGES OF GROWTH - EFFECT DUE TO FLOODING.



soil, even in the control plots.

3. <u>Uptake of Potash</u>

The Table 22 on the uptake of potassium showed no significant difference due to phosphorus application. Kalyanikutty and Morachan (1974) reported that application of P_2O_5 did not influence the potassium content of plants. Thandapani and Rao (1974) also reported similar results. In the present study though the application of phosphorus has slightly increased the potassium uptake, the effect was not significant.

E. SOIL ANALYSIS

1. <u>Nitrogen content of soil before and after the experiment.</u>

The Table-23 on the total nitrogen content of the soil before and after the experiment showed that there was no significant difference in the nitrogen content of the soil between the different treatments. This can be explained by the fact that a uniform dose of nitrogen was applied to all the treatments.

2. <u>Available phosphorus status of the soil during different stages of Plant growth.</u>

The data on the available phosphorus status of the soil (Tables-24 and 25) revealed that the available phosphorus in the soil was relatively high at the time of sowing. The average available phosphorus was 49.03 kg P_2O_5/ha before sowing, which gradually increased by maximum tillering stage to 85.74 kg P_2O_5/ha, then showed a slight decrease by panicle initiation to 77.23 kg P_2O_5/ha and this decreasing trend was continued till harvest at which time it was 56.01 kg P_2O_5/ha (Fig.7). The increase in the available phosphorus status of the soil can be attributed to the flooded condition of the soil. Datta and Datta (1963), Broeshart et al.(1965), Mahapatra (1968), Mosi et al.(1973) and Gupta and Singh (1977) reported that waterlogging generally resulted in an increase in the water soluble phosphate. Bedrna (1974) attributed the increase in the availability of phosphate to the reduction of ferric to ferrous phosphate under flooded conditions.

Jose and Raj (1971) reported that hydrated oxides of iron, the most important form of iron in soil are insoluble or very difficultly soluble in water and have a higher capacity for fixing soluble phosphates added to soil through fertilizers. On submergence, the reduction of these compounds result in the production of more soluble compounds of iron in their ferrous state. Since large amounts of iron are brought into solution the phosphate fixing capacity of the soil is markedly decreased, consequent on waterlogging. They further reported that presence of decomposing organic matter has been found to influence the rate of release of iron as noted by higher amounts of soluble iron in submerged soils containing appreciable amounts of organic matter.

It may look paradoxical that after a steep rise in the available phosphorus content of the soil from sowing to tillering time, a reduction is noticed from tillering to panicle initiation, eventhough the soil was submerged throughout from sowing to flowering stage (Fig.7). This decrease noticed may be due to the greater removal of available phosphorus by the growing crop from tillering to panicle initiation compared to the period from sowing to tillering. It can substantiated by the fact that even from the control plot the crop removed 6.10 kg P_2O_5/ha during the period from tillering to panicle initiation as compared to 2.4 kg P_2O_5/ha during the period from sowing to tillering.

However, the available phosphorus status of the soil showed a steep decrease from panicle initiation to harvest. This again may be due to the fact that a good amount of available phosphorus might have been taken up by the plant. The average decrease noticed was 21.22 kg P_2O_5/ha and this decrease is in agreement with the corresponding increase in the uptake, being 20.76 kg P_2O_5/ha during this period. The fact that oxidised conditions prevailed in the field, as the entire field was completely drained two weeks prior to harvest also might have contributed to the reduction in the available phosphorus content of the soil from panicle initiation to harvest. Savant and Ellis (1964) observed that soil moisture, definitely influenced the availability of both native and applied phosphorus. Patrick and Mahapatra (1968) have reported that drying of soil decreased the available phosphorus content in the soil.

3. Available Potassium status of the soil

The data on the available potassium status of the soil presented in Table-26 indicated that the different treatments could not make any significant difference in the potassium status of the soil. As in the case of nitrogen this can be explained by the fact that a uniform dose of potassium was applied to all the treatments and there was no significant difference in the uptake of potassium by the different treatments.

4. Economics of Phosphorus application

The economics of production given in Table-27 revealed that the maximum profit of Rs.3199.30 was obtained in treatment T_{12} (application of the entire dose of superphosphate in the nursery). This may be due to the starter dose of phosphorus given to the rice seedlings in the nursery thereby enabling the seedlings to give higher yield in the main field resulting in a higher profit. The treatment T_8 has given the least profit of Rs.2196.80. The high cost of the chemical KH_2PO_4 stands in the way of getting a higher net profit. In general, the net profit per hectare was higher with different methods of phosphorus application as compared to soil application and among the different methods, foliar application gave the least profit compared to other methods of application.

Between the different levels of phosphorus application the highest profit of Rs.2637.40 was given where fertilizer phosphorus was not applied showing that where the available phosphorus status of soil is reasonably high, cultivation of rice without application of phosphorus is more economical.

SUMMARY AND CONCLUSIONS

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A field experiment was laid out in the wetlands of the Instructional farm attached to the College of Agriculture, Vellayani, during the Virippu and Mundakan seasons of 1983- '84 to study the relative efficiency of various levels and methods of phosphorus application to rice variety, Triveni. The experiment was laid out in randomised block design with three replications. The effect of phosphorus application on the yield and quality of rice was studied. The uptake and availability of phosphorus at different growth stages were also studied. The results of the investigation are summarised below:

1. The different levels and methods of phosphorus application did not have any effect on plant height.
2. The total number of tillers was not affected by the levels and methods of phosphorus application.
3. Phosphorus had no effect on the number of productive tillers per square metre. There was no significant difference between the levels and methods of phosphorus application.
4. Length of panicle, number of grains per panicle, sterility percentage and thousand grain weight were not influenced by the levels and methods of phosphorus application.

5. The only productive attribute which was significantly influenced by phosphorus application was the weight of panicle. In this, application of phosphorus to the nursery recorded the highest weight of panicle.

6. The levels and methods of phosphorus application had no influence on the grain yield, straw yield and harvest index.

7. There was no significant difference in the protein content of the grain as influenced by the levels and methods of phosphorus application.

8. The uptake of nitrogen, phosphorus and potassium was not influenced by the levels and methods of phosphorus application.

9. The pattern of phosphorus uptake showed a gradual increase from maximum tillering to panicle initiation followed by rapid increase upto harvest.

10. The total nitrogen, available phosphorus and exchangeable potassium status of the soil was not influenced by the levels and methods of phosphorus application.

11. The available phosphorus status of the soil increased gradually upto maximum tillering stage, showed a slight decrease by panicle initiation

and this decreasing trend was continued till harvest.

12. Considering the yield and the economics of different levels and methods of application of phosphorus in two seasons, application of the entire dose of phosphorus to the nursery appears to be a more desirable method of phosphorus application.

The lack of response to applied phosphorus in the present investigation cannot be taken as an indication that phosphorus is of lesser importance in stepping up crop yields. Since the present investigation was conducted under conditions where the available phosphorus status of the soil was relatively high and submergence would lead to an increase in the availability of native phosphorus. It will be desirable to conduct further investigations on a long-term basis to study the response of rice to phosphorus under varying soil and climatic conditions. A better response to the application of phosphorus to the nursery, evident from this investigation, suggest that it will be desirable to conduct further studies in this line.

REFERENCES

REFERENCES

Aaron, D.S., Morachan, Y.B. and Murugesan, M. (1971) Response of IR-8 paddy strain to fertilizers in Coimbatore District, Madras Agri.J. 58(5): 379-384.

*Abdulgalil, A.A., Ibrahim, A.A., Zerdan, E.M. and Aarsan, M.A. (1979). Response of rice to foliar application of N and P under saline conditions. II. Rice Yield and some contributing characters Egyptian J. Agron. 4(1): 105-124.

Abraham, A. and Koshy, M.M. (1978). The comparative efficiency of foliar and soil application of complex fertilizers on paddy. Agric. Res. J. Kerala. 16(2): 249-250.

Agarwal, M.M. (1978). Effect of Nitrogen, Phosphorus and Potash on the yield, uptake and quality of rice. Indian J. Agric. Res. 12(1): 35-38.

Agarwal, M.M. (1980). Phosphorus and Potassium requirement of rice in relation to time of application. Indian J. Agric. Res. 14(1): 53-56.

*Ageeb, O.A.A. and Yousif, Y.H. (1978). P and K Nutrition of rice (Oryza sativa) in the Sudan Kenana. Experimental Agriculture. 14(1): 33-39.

Ahammad, P. (1970). Studies on the NPK requirements of Annapurna rice (Oryza sativa L.) under Vellayani conditions. M.Sc.(Ag.) thesis submitted to the University of Kerala.

*Akhundov, F.G. (1968). Application to rice in the Lenkoran region of Azerbaidzhan, SSR. Khimiya sel'. khoz. 11: 5-6.

Alexander, K.M., Sadanandan, N. and Sasidhar, V.K. (1973). Effect of various levels of Nitrogen and Phosphorus on the yield and other agronomic characters of rice variety Triveni. Agric. Res. J. Kerala. 1(2): 109-113.

Alexander, K.M., Sadanandan, N. and Sasidhar, V.K. (1974). Effect of different levels of nitrogen and phosphorus on the uptake of phosphorus by rice variety - Triveni. Agric. Res. J. Kerala 12(2):140-144.

Alexander, K.M., Sadanandan, N. and Sasidhar, V.K.(1974). Effect of graded doses of nitrogen and phosphorus on the available phosphorus status of soil during various growth stages of rice. Agric. Res. J. Kerala. 12(1): 11-13.

Ali, A.M. and Morachan, Y.B. (1973). Uptake and Quality studies in Rice (Oryza sativa L.). Madras Agric. J. 60(8): 755-59.

Ali, A.M. and Morachan, Y.B. (1980). Note on the effect of season, stages, Water management and nitrogen levels on the uptake of phosphorus in two swamp rice varieties. Indian J. Agric. Res. 14(4): 254-258.

Anonymous. (1961). Eighth meeting of the IRC working party on rice soils, water and fertilizer practices. Int. Rice. Comm. Newsl. 11(2): 17-19.

Anonymous (1964). Annual Report. Int. Rice Res. Inst. Manila. pp. 78-79.

Anonymous. (1965). Annual Report. Int. Rice Res. Inst. Manila. pp. 53-56.

Anonymous. (1976). Soil fertility and fertilizer management. Long term fertility experiments. Int. Rice Res. Inst. Annual Report. pp. 257-258.

Anonymous. (1979). Soil and crop management. Soil fertility and fertilizer management, Long-term fertility experiments. Int. Rice Res. Inst. Annual Report. 257-258.

Anonymous. (1983). Package of Practices Recommendations. Kerala Agricultural University. pp. 1-26.

*Axenova, I., Albescu, I. and Mainu, A. (1969). Dynamics of available nitrogen and phosphorus in paddy soils as determined by split application of fertilizer. Analele Institutului de cercetari pentru Imbunatatiri Funciare Si Pedologie, Pedologie. 3: 39-50.

*Bacha, R.E. and Scherer, C.H. (undated). Efficiency of foliar fertilizers in irrigated rice. In Anais, VII reuniao da cultura do arroz. Rio Grande do Sul Brazil. Empresa Brasileira de Pesquisa Agropecuariae. pp. 60-63.

Bapat, M.V., Kamat, V.N. and Umale, S.R. (1978). Effect of fortification of seeds with nutrients on the yield and quality of wheat. Seeds and Farms. 4 (1/2): 21-25.

*Bartholomew, R.P. (1931). Quoted by Mandal, L.N. Transformation of phosphorus in waterlogged soils 'Phosphorus in Soils, Crops and Fertilizers' Bulletin No.12. Indian Soc. Soil Sci. pp.73-79.

Basak, M.N. and Bhattacharyya, R. (1962). Phosphate transformation in rice soils. Soil Sci. 94 (4): 258-262.

Basak, M.N., Chowdhari, S.B. and Romabhattacharya. (1961). Effect of fertilizers on the nutritive value of rice grain. Indian J. Agric. Sci. 31 (2): 113.

*Basu, R.N. and Prativa Pal. (1978). Seed treatment for Vigour, viability and productivity of Rice. Rice in West Bengal. 1: 163-170.

Bear, F.E. (1949). Utilization of phosphorus from various fertilizer minerals. Soil Sci. 68:113

Bedrna, Z. (1974). The transformation of P and K fertilizers in the soil. Transactions of 10th International Congress of Soil Science. IV. 327-333

Bharadwaj, R.B.L., Rao, Y.V. and Gautam, R.C. (1974). Response of upland rice to rate and time of application of phosphorus. Indian J. Agron. 19(2): 113-118.

Bhattacharyya, K.K. and Chatterjee, B.N. (1978). Growth of rice as influenced by phosphorus. Indian J. Agri. Sci. 48(10): 589-597.

*Bhuiya, Z.H., Islam, S.M.N., Haque, M.S. and Mian, M.M.H. (1979). Effect of N, P. and K fertilizers on the performance of Dharial rice. Yield and Protein content. Bangladesh J. Scientific and Industrial Res. 14(3/4): 311-315.

*Bhuiya, Z.H., Zattar, M.A. and Torafder, S. (1975). Foliar and ground applications of N, P and K fertilizers on the growth, yield and quantity of rice. Bangladesh Journal of Biological Sciences. 4(1): 20-22.

Biswal, K.C. and Mishra, A. (1970). Response of winter paddy varieties to nitrogen and phosphorus. Oryza. 7(1): 27-30.

Black, C.A. (1967). Soil-Plant relationships. John Wiley and Sons. Inc. New York. 2nd Ed. pp.792.

Boatwright, G.O. and Viets, F.G. (1966). Phosphorus absorption during various growth stages of spring wheat and intermediate wheat grass. Agron. J. 58: 185-88.

Bodade, V.N. (1966). Effect of foliar application of nitrogen and phosphorus on the yield of jowar. Indian J. Agron. 11(3): 267-269.

Bora, P.K. and Goswami, N.N. (1983). Effect of phosphorus fertilization and soil moisture regimes on P content of rice crop. IRRN. 8(1): 19-20.

Bora, P.K. and Goswami, N.N. (1980). Effect of Phosphorus fertilization on priming of native P by rice in acid soils of Assam. I R R N. 5(5): 23.

Bora, P.K. and Goswami, N.N. (1983). Effect of phosphorus fertilization on the nitrogen, phosphorus, potassium and calcium content of ADT-27 rice (Oryza sativa L.) Madras Agric. J. 61(6): 135-40.

Bradley O.B. and Sieling, D.H. (1953). Quoted by Wm. H. Patrick, Jr. and Mahapatra, I.C. Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. 'Adv. in Agron'. 20(1): 339-55.

Bredero, T.J. (1965). Nitrogen, Phosphorus and Potash uptake by lowland rice to yields of some Nigerian alluvial soils. Agron. J. 57(5): 421-25.

Broeshart, H., Hannold, E. and Fried, M. (1965). The effect of water conditions and redox status of rice soils on the availability of soil and fertilizer phosphate. Plant and Soil. 13: 305-313.

*Celton, J. and Velly, J. (1966). Effect of fertilizers applied to the nursery and the rice field on rice yield. Agron. trop. Paris. 21(10: 1111-17.

Chandrasekharan, M. and Durairaj, D. (1969). Influence of modes of fertilizer application on the uptake of Nitrogen, phosphorus and potassium by Co-29 paddy during different stages of growth. Madras Agric. J. 56(10): 636-641.

*Chang, S.C. and Jackson, M.L.(1958). Quoted by Wm.H. Patrick, Jr. and Mahapatra, I.C. Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. 'Adv. in Agron'. 20(1):339-55.

Chavan, A.R. and Magar, N.G.(1971). Effect of fertilizer on the protein content of rice. Current Science. 40(23): 642.

Chaudhary, M.L. and Uppal, A.K. (1981). Accumulation of phosphorus by three varieties of rice and its relationship to phosphate fertilization. Indian J. Agric. Res. 15(3): 145-148.

Chhabra, R. and Abrol, I.P. (1981). Fertilizer phosphorus requirement of rice and wheat grown on sodic soils. Int. Rice Res. Newsl. 6(4): 22.

Chiang, S.C.(1963). Quoted by Patrick, Wm.H., Jr. and Reddy C.N. Changes in phosphorus in Rice soils. 'Soils and Rice'. I R R I, Philippines. pp. 373-375.

Chowdhury, M.Y., Ali, S., Zaman, W. and Altamas, S.U. (1978). Effect of phosphorus and Zinc Sulphate on the yield and protein contents in rice grains. Indian J. Agric. Chem. 11(2): 69-76.

*Chowdhury, S.U., and Mian, M.H. (1978). Effect of phosphatic fertilizers on rice yield. Thai. J. Agric. Sci. 2(2): 111-119.

Dargan, K.S. and Chhillar, R.K. (1978). Studies on the effect of nitrogen and missing application of P and K in rice-wheat sequence in alkali soils. Indian J. Agron. 23(1): 14-18.

Dargan, K.S., Chhillar, R.K. and Bhumbla, D.R. (1980). Effect of levels of phosphorus and zinc on rice and their residual effect on wheat in sodic soils. Indian J.Agron. 25(3): 514-515.

Datta, N.R. and Datta, N.P. (1963). Response to phosphate of rice and wheat in different soils. J. Indian Soc. Soil Sci. 11(2): 117-128.

*Davide, J.G. (1960). Phosphorus fixation in waterlogged soils. Ph.D. dissertation, North Carolina State College, North Carolina.

*Dean, L.A. and Fried, M. (1953). Soil-plant relationships in the phosphorus nutrition of plants. Soils and Fert. Phosphorus in crop nutrition. IV: 43.

*De Datta, S.K., Moomaw, J.C., Racho, V.V. and Simsiman, G.V. (1966). Phosphorus supplying capacity of lowland rice soils. Proc. Soil Sci. Soc. Am. 30(5): 613-17.

*De Geus, J.G. (1954). Means of increasing rice production Quoted by Chatterjee, B.N. and Maiti.S. 'Principles and Practices of rice growing. Oxford and I.B.H. Publishing Co. pp.186.

De Rege, F. and Leonzio, M. (1969). Influence of increasing rates of fertilizing elements on the growth of fertile tillers in rice, Riso. 18(4): 263-78.

Dhillon, N.S., Sidhu, A.S. and Dev, G. (1979). Prediction of responses to phosphorus application by rice and wheat in soils of north-western Punjab. J. Indian Soil Sci. 27(1): 88-89.

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

Dixit, R.S. and Singh, M.M. (1977). Levels of NPK for rainfed paddy. Int. Rice Comm. Newsl. 26(2): 26.

*Dobrunov, L.G., Gostenko, G.P. and Tsvetkova, B.M. (1968). Response of rice plants to N and P fertilizers at different stages of growth. Turdy Inst. Bot. Alma-Ata. 26: 36-48.

*Enyi, B.A.C. (1964). Effect of varying phosphorus and water supply on growth and yield of upland rice varieties. Trop. Agric. Trin. 41: 147-53.

*Enyi, B.A.C. (1966). The effect of nursery and field fertilization on the growth and yield of rice variety BG-79. Ghana Jnl. Sci. 6(1-2): 41-51.

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

*Fujiwara, A. (1950). Chemical constitution and availability of iron and aluminium phosphates. Part I. Tohaku J. Agric. Res. 1: 129-41.

*Fujiwara, A. (1964). Specific role of N, P and K in the metabolism of rice Plant. Mineral nutrition of the rice plant. I.R.R.I., Manila. Oxford and IBH Publishing Co., Calcutta. pp.318-320.

* Gargantini, H. and Blanco, H.G. (1965). Absorption of nutrients by rice crops. Bragantia. 24(38): 515-28.

*Gasser, J.K.R. (1956). Quoted by Wm. H. Patrick, Jr. and Mahapatra, I.C. Transformation and availability to rice of Nitrogen and phosphorus in waterlogged soils. 'Adv. in Agron'. 20(1): 339-55.

Gately, (1968). The effect of different levels of N, P and K on the yield and nitrogen content of plants. J. Agric. Sci. 70: 361.

George, C.M. and Sreedharan, C. (1970). Response of rice to top-dressing with phosphate and Potash in Kerala. Agric. Res. J. Kerala. 8(2): 110-113.

Gill, K.S., Saini, S.S. and Sehgal, K.L. (1971). Studies on the protein content in improved rice varieties of Punjab. Oryza. 8(1): 35-42.

Gomez, A.K. (1972). Techniques for field experiments with Rice. Layout/sampling/sources of error. IRRI Los Banos, Philippines.

Gopalakrishnan, V., Gururajan, B. and Rajagopalan, K. (1975). Response of Co-36 rice variety to N, P and K levels under different dates of sowing. Madras Agric J. 62(9): 582-583.

Gowda, M.K.M., Raju, S. Sadashivaiah, T., Varadaraju and Kulkarni, K.R. (1978). Response of paddy to nitrogen, phosphorus, potash and zinc on farmer's field in Shimoga district. Mysore J. Agri. Sci. 12(1): 55-62.

Gupta, A.P., Kaishtha, B.P., Manchanda, M.L. and Agarwal, S.C.(1975). Effect of split application of phosphorus on the yield and P uptake of paddy. Riso. 24(4): 329-33.

Gupta, J.P. and Seth, J. (1978). Effect of different rates and methods of N and P application on dry matter accumulation and uptake of plant nutrients by wheat under saline conditions. Indian J. Agron. 23(3): 275-77.

*Gupta, R.K. and Singh, T.A. (1977). Inter-relationships among labile phosphorus, Kinetics, Phosphatic potentials and fertilizer response of rice in sub-himalayan soil. Agrochemica. 21(1/2): 123-133.

Halappa, G., Sangiah, M., Rao, B.V.V. and Vijayamma, R. (1970). Studies on the influence of fertilizer application on the yield, tillering and grain formation in IR-8 paddy. Mysore J. Agric.Sci. 4(3): 306-12.

Iruthayaraj, M.R. and Morachan, Y.B. (1980). Note on the effect of seasons, stages, water management and nitrogen levels on the uptake of phosphorus in two swamp rice varieties. Indian J. Agric. Res. 14(4): 254-58.

Ishizuka, Y. (1964). Absorption and Utilization of phosphoric acid by wheat and rice plants at various growth stages. Transactions of 8th Internat. Cong. of Soil Science. 4: 459-70.

Islam, M.A. and Elahi, M.A. (1954). Reversion of ferric iron to ferrous iron under waterlogged conditions and its relation to available phosphorus. J. Agric. Sci. 45: 1-2.

Ittyavirah, P.J., Nair, S.S., Panicker, K.S. and John, P.S. (1979). Phosphate and potash fertilization of rice in the clay loam soils of Kuttanad. Agric. Res. J. Kerala. 17(2): 236-239.

Jackson, M.L.(1962). Soil Chemical Analysis. Prentice Hall, Inc. Englewood cliffs, N.J. pp.452.

Jha, K.P., Mahapatra, I.C. and Dastane, N.G.(1973). Uptake of Phosphorus by rice varieties Sabarmati and Jamuna as influenced by moisture regime and nutrient sprays. Indian J. Agron. 18(1): 51-57.

Jose A.I. and Raj, D. (1971). The chemistry of submerged soils. Indian Agric News Digest 2: 290-95.

*Kadrekar, S.B. and Mehta, V.B. (1975). Effect of graded levels of nitrogen and phosphate on protein content of rice. Res. J. Mahatma Phule Agric. Univ. 6(2): 99-103.

Kalam, M.A., Thampi, P.S. and George, C.M. (1966). Direct and Cumulative effects of Nitrogen, Phosphorus and Potassium on rice. Agric. Res. J. Kerala 4(1): 11-15.

Kalyanikutty, T.K. and Morachan, Y.B. (1974). Influence of NPK on the growth, yield and composition of rice varieties differing in inherent yield potentials. Madras Agric. J. 61(8): 239-244.

*Kampath, E.J. (1967). Residual effect of large applications of phosphorus in high phosphorus fixing soils. J. American Soc. Agron. 59: 25-27.

Karim, A., Chowdhury, M.Y. and Islam, T. (1968). A study on the effects of NPK fertilizers on the quality of rice grains. Sci. Res. 4(4): 198-206.

*Kasai, Z. and Azada, K. (1960). Translocation of mineral nutrients in higher green plants. Part 10. Behaviour of phosphorus absorbed at each growth stage in ripening rice plant. J. Sci. Soil Manure Japan. 30: 479-482.

Katyal, J.C. (1978). Management of phosphorus in lowland rice. Phosphorus in Agriculture. 73: 21-34.

Katyal, J.C. and Ramavataram, N. (1973). A root dipping technique to economise fertilizer phosphorus. AICRIP. CRRI Annual Report. ICAR. pp. 151.

Katyal, J.C., Ramavataram, N., Freeman, W.H. and Shastry, S.V.S. (1975). Maximising the efficiency of phosphatic fertilizers. Int. Rice Comm. Newsl. 24(1): 35-39.

Katyal, J.C., Seshu, D.V., Shastry, S.V.S. and Freeman, W.H. (1975). Varietal tolerance to low phosphorus condition. Current Science. 44(7): 238-240.

*Kawaguchi, K. (1965). Quoted by Wm. H.Patrick, Jr. and Mahapatra I.C. Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. 'Adv. in Agron'. 20(1): 339-55.

Khatua, K.B. and Sahu, B.N. (1970). Response of high yielding dwarf-indica rice to different sources and levels of phosphate fertilizers. Oryza. 7(1): 17-20.

*Kimuara and Okajima, H. (1951).Quoted by Fujiwara, A. Specific roles of nitrogen, phosphorus and potassium in the metabolism of the rice plant. 'The mineral nutrition of the rice plant' Oxford and IBH publishing Co. Calcutta. pp. 94.

Kolandaiswamy, S., Theetharappan, T.S. and Ramamoorthy,R. (1974). Effect of top-dressing of P and K on rice. Madras Agric. J. 61(9): 651-652.

Korableva, L.I. (1974). The composition of mineral phosphates and the transformation of phosphorus fertilizers in bottomland soils. Transactions, 10th International Congress of Soil Science. IV. 273-280.

Kothandaraman, G.V., Krishnaswamy, R. and Krishnamoorthy, K.K. (1975). Studies on the quality of IR-20 rice as influenced by fertilization. Madras Agric. J. 62(6): 346-48.

Krishnamoorthy, K.K., Kothandaraman, G.V., Subbiah, S. and Vadivelu, S. (1979). Effect of N, P and K application on the yield of rice under continuous cropping system. Mysore J. Agric. Sci. 13(2): 171-178.

Krishnamoorthy, K.K., Vadivelu, S.I., Rajasubramaniam, S. Helkiah, J. and Shetty, K.S. (1973). Efficacy of soil and foliar application of N and P to IR-8 rice. Madras Agric. J. 61(8): 286-287.

Krishnaswamy, R., Kothandaraman, G.V., Jayaraj, G. and Krishnamoorthy, K.K. (1974). Yield and quality of IR-8 rice as influenced by fertilization. Madras Agric. J. 61(8): 262-267.

*Kuo, K.E. (1973). Split application of phosphatic fertilizer for rice. Taiwan, Agric. Quarterly. 9(4): 83-119.

Lal, M. and Mahapatra, I.C. (1975). Effect of phosphate carriers varying in water soluble and citrate soluble-P content on uptake of major nutrients NPK by rice. Riso. 24(1): 49-58.

Lal, M. and Mahapatra, I.C. (1977). Relative efficiency of different phosphate carriers varying in water and citrate soluble P in wetland rice. Indian J. Agron. 22(1): 1-6

*Lal, R., Verma, B.S. and Singh, R.R. (1973). Performance of tall and dwarf varieties of rice in relation to N, P and K fertilization. Balwant Vidyapeeth Journal of Agricultural and Scientific Research. 15(1/2): 11-14.

Loganathan, S. and Raj, D. (1971). Influence of different levels and combination of N, P and K on the yield of grain and straw in certain high yielding paddy strains. Madras Agric. J. 58(5):354-358.

Loganathan, S. and Raj. D. (1972). Characterisation of the pattern of uptake of different nutrients by certain high yielding paddy strains. Madras Agric. J. 59(4): 215-218.

Mahapatra, I.C. and Gupta, S.K. (1978). Foliar application of Macro and Micro nutrients on Rice. Indian J. Agron. 23(4): 369-371.

Mahatim Singh, Singh, K., Srivastava, J.P. and Singh, R.P. (1979). Influence on nitrogen, phosphorus and potassium nutrition on the uptake and yield of drilled rice. Oryza. 16(2): 91-98.

Majumdar, D.K. (1971). Effect of sowing time and fertilizers on yield attributes and yield of rice (Oryza sativa L.) Indian J.Agron. 16(1): 6-9.

Majumdar, D.K. (1973). Uptake of nitrogen and phosphate as influenced by sowing time and fertilization and recoveries of nitrogen and phosphate from the added fertilizers by rice (Oryza sativa L.). Indian Agriculturist. 17(1): 69-74.

Mandal, A.B. and Sahu, B.N. (1978). Effect of source of nitrogen, phosphorus and their methods of application on the yield of rice and net income. Indian J. Agron. 23(3): 255-266.

Mandal, L.N. and Mandal, K.C. (1973). Quoted by Mandal, L.N., Transformation of phosphorus in waterlogged soils 'Phosphorus in soils, crops and fertilizers' Bulletin No.12. Indian Soc. Soil Sci. pp.73-79.

Mariakulandai, A. and Chamy, A. (1967). Rice and Phosphates. Fert. News. 12(2): 20-21.

*Matzel, W. (1974). A survey of problems associated with the utilization of fertilizer and soil phosphorus. Archiv fur Acker-und Pflanzenbau und Bodenkunde. 18(7): 471-87.

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

Mehrotra, O.N., Sinha, N.S. and Srivastava, R.O.L. (1968).
1. Studies on the nutrition of Indian Cereals.
2. Uptake of nitrogen and phosphorus at different stages of growth by early paddy (unhulled rice) under varying fertilizer management. Pl. Soil. 28(3): 422-30.

Mehrotra, O.N., Srivastava, J.P. and Nath, S. (1967). Effect of soaking paddy seeds in nutrient solution of phosphate on germination, growth and yield. Indian J. Agron. 12(4): 351-352.

Mehrotra, O.N., Srivastava, J.P. and Nath, S. (1968). Germination, growth and yield of wheat as influenced by presowing seed treatment in phosphate solution. Indian J. Agron. 13(1): 52-56.

Mirza, W.A., Reddy, C.S., Khan, F., Rao, Y.Y and Naidu, N.G. (1980). Response of Telia Hamsa rice to different levels and methods of phosphate application. Indian J. Agron. 25(3): 329-331.

Mirza, W.A., Reddy, T.M.M., Audinarayana, M. and Venkatachari, A. (1979). Phosphate levels and methods of application to rice crop. Indian J. Agric. Res. 13(1): 13-17.

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

Mohanty, S.K. and Patnaik, S. (1974). Uptake of nutrients in relation to growth of rice as influenced by varying nutrient environments in different soil types. Riso 23(4): 351-63.

Mosi, A.P., Venkataraman, A., Periasamy, M. and Natarajan, K. (1973). A preliminary study on the response to nitrogen, phosphorus and potassium of some high yielding varieties of rice in Thanjavur District. Madras Agric. J. 60(5): 302-307.

Mujumdar, A.S. and Somawanshi, R.B. (1979). Effect of presowing seed soaking on emergence, dry matter production and uptake of phosphorus by wheat (Triticum aestivum). J. Maharashtra Agriculture Universities. 4(3): 259-61.

Mujumdar, A.J. (1978). Effect of seed soaking in solution of KH_2PO_4 and NaH_2PO_4 on germination, root growth and chemical composition of seedlings of Bengal gram and wheat. Thesis abstracts. Mahatma Phule Krishi Vidyapeeth, Maharashtra 4(1): 68-69.

Muthuswamy, P., Raj, D. and Krishnamoorthy, K.K. (1973 b) Mineral nutrition of high yielding rice (Oryza sativa L.) varieties. Madras Agric. J. 60(8): 764-767.

Nair, M. (1968). Effect of different forms and levels of phosphorus on the growth, yield and composition of three high yielding varieties of rice (IR-8, TN-1 and Culture-28). M.Sc.(Ag.) thesis submitted to the University of Kerala.

Nair, R.R., Pillai, G.R., Pisharody, P.N. and Gopalakrishnan, R.(1972). Response of rice to graded doses of phosphorus in connection with magnesium and spartin. Indian J. Agron. 17(4): 317-20.

Nair, R.R., Pillai, G.R., Pisharody, P.N. and Gopalakrishnan R.(1977). Investigations on the effect of heavy manuring of rice seed beds. Agric. Res. J. Kerala 15(2): 154-159.

Nair, R.R., Pisharody, P.N. (1970). Response of rice to phosphate manuring in a waterlogged lateritic sandy loam of Kerala. Agric. Res. J. Kerala 8(1): 6-13.

Naphade, J.D.(1969). Influence of phosphate application to various soils on the response of rice and phosphorus uptake at different stages of plant growth. Riso. 18(1): 37-42.

Narayanan, T.R. and Vasudevan, K.V. (1957). Foliar verus soil fertilizer application in crops. 7th Scientific Workers' Conference. Madras Agric. J. 44: 663.

*Oh, W.K. and Lee, T.K. (1968). Studies on the cause of several low yield of paddy soils. Res. Rep. Office rur. Dev. Suwon. 11 (3) : 1-8.

*Okajima, H. (1965). Quoted by Wm. H.Patrick, Jr. and Mahapatra, I.C. Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. 'Adv. in Agron'. 20 (1) : 339-55.

*Okajima H. and Kimuara. (1952, 1962). Quoted by Fujiwara, A. Specific roles of nitrogen, phosphorus and potassium in the metabolism of the rice plant 'The Mineral Nutrition of the Rice Plant' Oxford and IBH Publishing Co., Calcutta. pp.94.

Oomen, P.K., Oza, A.M. and Subbiah, B.V. (1972). Varietal difference in the relative uptake of soil and fertilizer phosphorus by high yielding varieties of wheat and rice as revealed by studies with P^{32}. Indian J. Agric. Sci. 42 (5) : 370-74.

Padalia, C.R. and Mahapatra, I.C. (1970). Effect of nursery treatments on the yield and growth of rice crops. Indian J. Agron. 15 (1) : 49-51.

Padmakumari, C., Nair, N.C. and Koshy, M.M. (1969). The response of two high yielding varieties of rice to NPK applications, in an acid peat soil of Kerala. Agric. Res. J. Kerala. 7 (1) : 10-13.

*Padole, V.R. (1979). Effect of pre-soaking seed treatment of wheat with chemicals and hormones on the yield and uptake of NPK. J. Maharashtra Agricultural Universities. 4 (1) : 85-88.

Pande, H.K. and Tilak, K.V.B.R. (1970). Effect of varying levels of nitrogen and phosphate fertilization and different dates of seeding on growth and yield of upland rice. Riso. 19 (1) : 87-94.

Patel, J.P. (1967). Interrelationship of different proportions of N-P fertilizer application and planting patterns in rice in the Jabalpur dt. Indian J. Agron. 12 (2): 46-48.

Patnaik, S. and Gaikwad, S.T. (1969). Efficiency of phosphorus and potassium absorbed during the various growth stages of IR-8 for grain production. Indian J. Agric. Sci. 39 (1): 117-21.

Patnaik, S., Misra, C.S. and Bhadrachalam. (1965). Studies on the nutrition of rice plant (Oryza sativa L.) Part VIII. Productive efficiency of phosphorus absorbed at various growth stages of indica rice. Proc. of the Indian Acad of Sci. LXI (6): 309-315.

Patnaik, W.H. Jr., Peterson, F.J. and Wilson, F.E. (1974). Response of lowland rice to time and method of application of phosphate. Agron. J. 66 (3): 459-60.

Patrick, Wm, H., Jr. and Mahapatra I.C. (1968). Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. 'Adv. in Agron.' 20 (1): 339-55.

* Paul, H and Delong, W.H. (1949). Quoted by Wm.H.Patrick, Jr. and Mahapatra, I.C. Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. 'Adv. in Agron'. 20 (1): 339-55.

Place, G.A., Sims, J.L., Hall, V.L. (1970). Effect of nitrogen and phosphorus fertilization on growth, yield and cooking characteristics of rice. Agron. J. 62 (2): 239-43.

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

Prabha, R., Aiyer, R.S. and Money, N.S. (1975). Response of rice (variety IR-8) to zinc as affected by levels of phosphatic fertilizers. Agric. Res. J. Kerala. 13 (2): 117-122.

Rabindra, B. (1978). Effect of split application of phosphorus on rice yield. Mysore J. Agric. Sci. 12(3): 385-387.

Rabindra, B. and Deshpande, P.B. (1980). Slurry technique in phosphatic fertilization of transplanted rice. Mysore J. Agric. Sci. 14(1): 41-44.

Raghupathy, B. and Raj, D. (1973). Availability fluctuations of soil phosphorus fractions during paddy growth under flooded conditions. Madras Agric. J. 60(1): 17-22.

Rai, R.S.V. and Murty, K.S. (1975). Tillering in relation to N, P and K contents in long duration rice varieties. Indian J. Pl. Physiology. 18(2): 173-176.

Rajagopalan, S., Palaniyandi, V.G. and Muthusankaranarayanan, S. (1979). Effect of seed, seedbed and mainfield treatments on the yield of ADT-31 and IR-20. Int. Rice Res. Newsl. 4(6): 17-18.

Rajappa, M.G. and Krishnamoorthy, K. (1969). Preliminary studies on yield components of drill sown rice in response to nitrogen and phosphorus. Mysore J. Agric. Sci. 3(3): 360-365.

Rajat, De. (1971). A review of foliar fertilization of crops in India. Fert. News. 16: 77-84.

Rajendran, K., Jayaraj, G., Sivappah, A.N., Muthiah, N.E. and Loganathan, S. (1971). Trends in Yield response of CO-25 paddy as influenced by soil series and manuring. Madras Agric. J. 58(6): 435-441.

Raju, A.S., Rao, G.V.M.M., Sathe, A. and Rao, C.V.S. (1980). Root dipping- a technique to supply phosphorus to lowland rice. J. Nuclear Agric. and Biology 9(4): 141-143.

Ramakrishnan, M.S. (1974). Response of rice to foliar and soil application of nitrogen and phosphorus. Madras Agric. J. 61(8): 253-57.

Ramaswamy, C., Palaniappan, S.P and Morachan, Y.B. (1974) A note on the effect of seedling treatment with superphosphate slurry on the yield of rice - Ponni. Madras Agric. J. 61(10-12): 1011-12.

Ramiah, S., Morachan, Y.B. and Kaliappa, R. (1970). Response of ragi varieties to different levels and methods of phosphorus application. Madras Agric. J. 57(11): 556-63.

Ramsingh and Dubey (1975). Response of rice to P and K in relation to time of application. Indian J. Agron. 20(2): 198-199.

*Rao, I.V.S. and Rao, D.V.K. (1965). Ionic effects and interactions of phosphorus and molybdenum in rice. 1. On P and N contents. Andhra agric. J. 12(6): 187-200.

Rao, T.K.G., Kolandaiswamy, S., Seshadri, P. and Sankaran, S. (1974). Studies on levels and times of application of phosphorus and potassium on rice. Madras Agric. J. 61(8): 258-261.

Rao, V.S. and Rao, D.V.K. (1961). 8th meeting of Int. Rice Comm. working party. Rice Soils Working paper. 5: 15.

Rao, Y.Y., Reddy, T.V.R., Reddi, G.H.S. and Venketeswarlum, M.S. (1973). Studies on split and foliar application of complex fertilizers on IET-1991 rice. Indian J. Agric. Res. 7(3-4): 204-6.

Rao, Y.Y., Ikramullah, M. and Rao, L.G.G. (1982). Effect of dipping rice roots in phosphate nutrient solution on grain yield. Rice Res. Newsl. 7(2): 18.

Rastogi, A.K., Mahajan, J.P. and Sinha, S.B. (1981). Phosphorus utilization by three rice varieties at different stages of growth in a vertisol. J. Nuclear Agric. and Biology 10 (2) : 48-50.

*Reddy, R.K. (1967). Influence of nitrogen, phosphorus and plant population on the yield and other growth characters of Co-33 rice. Dissertation submitted to the Madras University.

Reddy, R.K., Yogeswara Rao, Y and Sankara Reddy, G.M. (1978). Nitrogen uptake of high yielding rice varieties in relation to seedling rates and fertility levels. Indian J. Agric. Res. 12 (4) : 266-268.

Reddy, T.M.M., Reddy, M.R., Audinarayana, M. and Chari, A.V. (1979). Rice production under limited use of fertilizer nitrogen and phosphorus. Indian J. Agron. 24 (3) : 276-81.

*Reyes, E.D., Davide, J.G. and Orara, L. (1962). Nitrogen, Phosphorus and Potassium uptake by a lowland rice variety at different stages of growth. Phillipp. Agricst. 46 : 7-19.

Robinson, J.G. and Rajagopalan, K. (1977). Response of high yielding varieties of rice to graded levels of phosphorus and potassium. Madras Agric. J. 64 (2) : 138-139.

Rojas, W.C. and Alvarado, A.R. (1982). Nitrogenous and phosphatic fertilizer applications to rice in the Central-South Zone of Chile. Effect on grain yield. Agricultura Tecnica. 42 (1) : 15-21.

Russel, E.W. (1962). Soil Conditions and Plant growth, Longman Green and Co., New York. 10th edition.

Sadanandan, A.K., Mohanty, S.K., Patnaik, S. and Mistry, K.B. (1980). ^{32}P tracer studies on the efficiency of amonium nitrate phosphates and polyphosphates for growing rice on different soil types. J. Nuclear Agric. and Biology. 9 (4) : 135-138.

Sadanandan, N. and Sasidhar, V.K. (1976). Studies on the response of rice variety - Triveni to phosphorus application. Agric. Res. J. Kerala. 14(2): 175-177.

Sahu, B.N. (1955). Effect of farmyard manure, amonium sulphate and superphosphate on tho yield of paddy. Indian J. Agron. 10(2): 155-64.

Sanyasi raju. (1954). Preliminary report on laterite soil. Effect of manuring on the composition of paddy grains. Madras Agric. J. XLVI (1): 17-19.

*Sasaki, K. and Wada, S. (1975). Effects of nitrogen, phosphoric acid and potash on the percentage of sterile grains in rice plants. Proceedings of the crop science Society of Japan. 44(3): 250-254.

Sasidhar, V.K. and Sadanandan, N. (1971). Effect of different levels of phosphorus on the yield of rice variety - Rohini in Vellayani. Agric. Res. J. Kerala. 9(2): 14-21.

Savant and Ellis. (1964). Quoted by Mandal, L.N. Transformation of phosphorus in waterlogged soils. 'Phosphorus in soils, Crops and Fertilizers' Bulletin No.12. Indian Soc. Soil Sci. pp.73-79.

Shapiro, R.E.(1958a). Effect of flooding on availability of phosphorus and Nitrogen. Soil Sci. 85(4): 190-7

Shapiro, R.E.(1958 b). Quoted by Mandal, L.N. Transformation of phosphorus in waterlogged soils. 'Phosphorus in Soils, Crops and Fertilizers'. Bulletin No. 12. Indian Soc. Soil Sci. pp. 73-79.

Sharma, J.P. and Singh, M. (1967).Response of paddy to increasing rates and different methods of nitrophosphate application. Indian J. Agron. 12(1): 46-50.

*Shiga, H. (1976). Effect of phosphorus fertility of soils and phosphate application on lowland rice. Japan Agric. Res. 10(1): 12-16.

*Shiga, H., Yamaguchi, Y and Awazaki, H. (1976). Effect of phosphorus fertility of soils and phosphate application on rice culture in cool regions. 2. Response of rice plant growth to the amounts of extractable phosphorus in flooded soils under field conditions. Research Bulletin of the Hokkaido National Agricultural Experiment Station. 113: 95-107.

*Shiota, Y., Inagaki, A., Hasegawa, T. and Okimura, I. (1980). Effects of long-term fertilization on growth and yield of rice plants, their uptake of nutrients and soil properties. Res. Bull.of the Aichi-Ken Agric. Res. Centre. 12: 52-60.

Shirval, A.S., Desphande, P.B. and Kulkarni, K.R. (1978). A comparison of soil and foliar application of fertilizer elements on the yield of paddy (Var. Madhu). Mysore J. Agri. Sci. 12(3): 381-384.

Simpson, J.E., Adair, C.R., Kohler, G.O., Dabald, H.A., Kester, F.B. and Hlick, J.T. (1965). Quality evaluation studies of foriegn and domestic rice. Tech. Bull. Service. No.331. USDA. pp.1-86.

Singh, A.I. and Chatterjee, B.N. (1980). Effect of seed treatment and fertilization on the upland rice production. Indian J. Agron. 25(3): 479-486.

Singh, M. and Varma, S.C. (1971). Effect of different rates of nitrogen and phosphorus application on the yield and yield attributing characters of T(N)1 rice. Indian J. Agron. 16(3): 257-260.

Singh, S. and Ram, P. (1977). Changes in solubility of phosphorus and its availability to rice plant in the waterlogged soils. J. Ind. Soc. of Soil Sci. 25(2): 129-133.

Singh, V. and Prakash, J. (1979). Effect of nitrogen, phosphorus and potassium application on the availability of nutrients to rice. Madras Agric. J. 66 (12) : 794-798.

Singlachar, M.A. and Chandrasekhar, N.V. (1978). Effect of seed fortification on the growth and yield of rice. Science and culture. 44 (7) : 313-314.

Singh, M. and Pandey, R.K. (1969). Spray fertilization with phosphate boosts yield of berseem seed. Indian Fmg. 19 (4) : 2-22.

Sinha, S.B., Rastogi, A.K. and Mahajan, J.P. (1980). Uptake of fertilizer phosphorus by three rice varieties in a vertisol. J. Nuclear Agric. and Biology. 9 (4) : 139-140.

Sinha, R.N. (1969). A note on the effect of pre-soaking with plant growth regulators and nutrient solution on panicle length of rice. Madras Agric. J. 56 (4) : 201-203.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical methods. Oxford and IBH Publishing Co. Calcutta. 6th Edn. pp. 1-593.

Sood, P.R., Gupta, T.R. and Moolani, M.K. (1969). Response of Taichung (Native (-1 to various levels of nitrogen and phosphorus. Riso. 18 (3) : 241-245.

* Sperber, J.I. (1958). Quoted by Wm.H. Patrick, Jr. and Mahapatra, I.C. Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. 'Adv. in Agron'. 20 (1) : 339-55.

Sreenivasalu, K. and Pawar, M.S. (1965). Studies on the influence of N, P and K on some quantitative characteristics in two indica and Japonica varieties. Rice News Teller. 13 (3) : 81-83.

Suramanian, A. and Subramanian, P. (1980). Influence of phosphorus and methods of its application on rice. Madras Agric. J. 7(6): 411-12.

Sundaram, K., Subbiah, V., Murugesan, M. and Seshu, K.A. (1969). Response of rice to fertilizer application in cultivator's field in Tamil Nadu. Madras Agric. J. 56(12): 803-811.

Suseelan, P. (1969). Studies on the effect of graded doses of phosphorus in conjunction with lime on growth, yield and phosphorus uptake in rice. M.Sc.(Ag) thesis, University of Kerala.

Suseelan, P., George, C.M. and Sreedharan, C. (1977). Effect of phosphorus and lime application on rice variety IR-8. Agric. Res. J. Kerala. 16(2): 240-41.

Suseelan, P., George, C.M. and Sreedharan, C. (1978). Studies on the uptake pattern of phosphorus by rice under graded dose of phosphorus in conjunction with lime. Agri.Res. J.Kerala. 16(1): 5-8.

*Taira, H. (1970). Effect of fertilization on protein content in high yielding rice. Proc. Crop Sci. Soc. Japan. 39(2): 200-203.

Tamhane, R.V., Motiramani, D.P., Bali, Y.P. and Donahue. (1964). Soils- Their Chemistry and fertility in Tropical Asia. Prentice Hall of India. Pvt. Ltd., New Delhi.

*Tanaka, A. (1962). Quoted by Wm. H.Patrick, Jr. and Mahapatra, I.C. Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. 'Adv.in Agron' 20(1): 339-55.

Tanaka, A., Patnaik, S. and Abichandani, C.T. (1960). Influence of increasing levels of phosphorus and potash on the yield and other nutrients uptake by rice. Proc. Ind. Acad.Sci. 49: 158-68.

*Terman, G.L. and Allen, S.E. (1970). Fertilizer and soil P uptake by paddy rice as affected by soil P level, source and date of application. J. agric. Sci. Camb. 75(3): 547-52.

Terman, G.L., Allen, S.E. and Engelstad, O.P. (1970). Response by paddy rice to rates and sources of applied phosphorus. Agron. J. 62(3): 390-94.

Thandapani, V. and Rao, J.S. (1974). Effect of phosphorus fertilization on the nitrogen, phosphorus, potassium and calcium content of ADT-27 Rice (Oryza sativa L.). Madras Agric. J. 61(6): 135-140.

Thandapani, V. and Sakharam Rao, J. (1976). Effect of Phosphorus fertilization on the physiology of rice. Madras Agric. J. 63(3): 148-150.

Thom, W.O., Miller, T.C. and Bowman, D.H. (1981). Foliar fertilization of rice after midseason. Agron. J. 73(3): 411-414.

Tisdale, S.L. and Nelson, W.L. (1975). Soil fertility and Fertilizers. Macmillan Company Ltd., Galt, Ontario.

*Vahl, L.C. and Gomes, A.S. (undated). Comparison of traditional and foliar fertilizers on irrigated rice. In Anias VII reuniao da cultura do arroz, Rio Grande do sul. Pelotas, Brazil; Empresa Brasileira de Pesquisa Agropecuaria. pp.64-68.

*Varma, S.C. (1971). Effect of nitrogen and phosphorus application on the dry matter accumulation and uptake, translocation and recovery of nutrient by Taichung (Native)-1. J. Scientific Res. of the Banaras Hindu University. 22(1): 11-19.

Veeraju, P.C., Morachan, Y.B. and Ali, Y.M. (1975). Studies on the methods of nitrogen application and pre-soaking seed in rainfed Sorghum (Co-20). Madras Agric. J. 62(8): 513-517.

*Velley, J. (1959). Quoted by Angladette, A. 'The mineral nutrition of the rice plant' Oxford and IBH Publishing Co., Calcutta. pp.366.

*Verkhotin, I.I. (1974). Effect of rates and proportions of mineral fertilizers on grain yield and quality of rice grown on dark chestnut soils in the Sivash region. Byelletin Vsesoyuznogo Instituta Udobrenii i Agropochvo-vedeniya. 19: 58-61.

Vijayan, K.P. and Rao, J.S. (1975). Uptake pattern of phosphorus in rice related to modes of application. Madras Agric. J. 62(1): 23-25.

Vijayan, K.P. and Rao, J.S. (1977). Soil and Foliar application of phosphorus on rice. Madras Agric. J. 64(8): 527-532.

Weeraratna, C.S. (1976). Phosphorus, iron and manganese uptake of some low and high yielding rice varieties. Int. Rice Comm. Newsl. 25(1/2): 45.

*Williams, R.F. (1948). The effect of phosphorus supply on the rate of intake of P and N upon certain aspects of P metabolism in graminaceous plants. Australian J. Sci. Res. Sci. pp. 333-361.

*Yang, P.L., Wang, Y.P. and Chiang, M.H. (1968). Effect of split fertilization on rice production. J. Agric. Forest. 16 and 17.

Yatazawa, M. (1954). Utilization of ^{22}P in investigation of foliar application of phosphates. Soil Fert. 18: 270.

* Original not seen.

APPENDICES

Appendix-Ia

Meteorological data during the crop season, 1983-84

Standard weeks	Period From	To	Total rain fall. (mm)	Temperature (°C) Maximum	Minimum	Relative Humidity (%)
23	June 5	June 11	16.0	31.6	23.8	79.1
24	June 12	June 18	102.0	31.1	22.9	82.5
25	June 19	June 25	12.6	31.1	22.9	79.8
26	June 26	July 2	25.4	31.0	23.0	80.5
27	July 3	July 9	-	31.6	23.9	78.7
28	July 10	July 16	69.0	32.6	23.1	81.0
29	July 17	July 23	50.5	29.8	22.4	84.6
30	July 24	July 30	1.5	30.3	22.4	83.7
31	July 31	Aug 6	22.6	30.6	22.0	82.4
32	Aug 7	Aug 13	78.9	29.9	23.0	85.3
33	Aug 14	Aug 20	85.7	28.7	22.4	89.0
34	Aug 21	Aug 27	-	29.9	23.0	82.0
35	Aug 28	Sept 3	3.4	30.5	23.5	82.1
36	Sept 4	Sept 10	36.0	30.1	23.2	81.8
37	Sept 11	Sept 17	53.8	29.6	22.9	84.7
38	Sept 18	Sept 24	65.3	30.1	22.8	83.4
39	Sept 25	Oct 1	6.2	30.1	22.9	82.6
40	Oct 2	Oct 8	3.0	30.5	23.7	81.3
41	Oct 9	Oct 15	-	31.7	23.4	75.8
42	Oct 16	Oct 22	14.1	31.6	23.2	77.1
43	Oct 23	Oct 29	18.0	31.2	23.5	81.8
44	Oct 30	Nov 5	33.8	31.5	23.3	90.7
45	Nov 6	Nov 12	16.6	30.6	21.2	75.5
46	Nov 13	Nov 19	38.7	31.0	21.4	78.9
47	Nov 20	Nov 26	28.8	30.7	21.9	79.6
48	Nov 27	Dec 3	46.5	30.8	22.0	78.6
49	Dec 4	Dec 10	3.9	31.7	22.4	70.5
50	Dec 11	Dec 17	16.4	31.5	23.7	70.1

(contd...)

Appendix- Ia contd.

Stand-ard weeks	Period From		To	Total rain fall (mm)	Temperature (^oC) maxi-mum	Mini-mum	Rela-tive Humidity (%)
51	Dec. 18	-	Dec.24	19.2	31.1	24.1	89.8
52	Dec. 25	-	Dec.31	68.7	30.4	22.0	80.6
1	Jan 1	-	Jan 7	2.2	30.8	23.6	76.6
2	Jan 8	-	Jan 14	-	31.3	24.2	72.0
3	Jan 15	-	Jan 21	31	30.8	24.1	79.5
4	Jan 22	-	Jan 28	-	31.1	23.1	54.6

Appendix- I b

Weather Data: Average values for the past 24 years (1958-1982)

	Rainfall (mm)	Temperature (°C)		Humidity (per cent)
		Maximum	Minimum	
January	34.62	30.93	22.46	79.88
February	36.00	31.34	22.87	82.05
March	35.06	32.17	24.00	81.36
April	89.16	32.27	25.02	83.29
May	197.70	31.75	24.92	85.07
June	292.20	30.42	23.95	85.13
July	220.90	29.72	23.46	87.18
August	138.63	29.77	23.22	86.02
September	150.28	30.12	23.36	85.77
October	264.14	29.70	23.76	87.41
November	208.05	29.91	23.81	86.97
December	71.85	30.66	23.26	84.78

Appendix- II

Abstract of analysis of variance table for height of plants at fortnightly intervals

Viríppu Season

Source	df	1st fornight M.S	2nd fortnight M.S	3rd fortnight M.S	4th fortnight M.S	5th fortnight M.S.
Block	2	68.09	42.07	81.16	21.48	86.83
Treat	11	22.88	6.59	23.22	9.33	7.08
Error	22	14.78	5.84	14.05	6.94	6.99
Total	35					

Mundakan Season

Source	df	1st fortnight M.S	2nd fortnight M.S	3rd fortnight M.S	4th fortnight M.S	5th fortnight M.S
Block	2	65.37	52.09	203.19	147.64	131.02
Treat	11	10.40	34.46	17.53	29.16	40.04
Error	22	4.90	38.03	19.49	31.25	23.27
Total	35					

Appendix-III

Abstract of analysis of variance table for number of tillers per square metre at fortnightly intervals

Viri<u>ppu Season</u>

Source	df	1st fort-night M.S	2nd fort-night M.S	3rd fort-night M.S	4th fort-night M.S	5th fort-night M.S
Block	2	21358	10973.5	15979.5	14713	4301
Treat	11	2030.64	5201.45	1838.82	2093	2262.36
Error	22	2501.18	2513.86	2408.5	2204.91	1773.18
Total	35					

Mundakan Season

Source	df	1st fort-night M.S	2nd fort-night M.S	3rd fort-night M.S	4th fort-night M.S	5th fort-night M.S
Block	2	38.11	274.53	1275.11	9952.44	3944.78
Treat	11	730.21	2040.26	1178.45	1492.05	1714.21
Error	22	862.47	3412.44	2202.44	1654.35	1490.20
Total	35					

Appendix IV

Abstract of analysis of variance table for leaf area index at fortnightly intervals

Virippu season

Source	df	1st fort-night M.S	2nd fort-night M.S	3rd fort-night M.S	4th fort-night M.S	5th fort-night M.S
Block	2	0.410	0.309	0.671	0.364	0.773
Treat	11	0.147	0.210	0.092	0.112	0.183
Error	22	0.174	0.372	0.184	0.126	0.186
Total	35					

Mundakan season

Source	df	1st fort-night M.S	2nd fort-night M.S	3rd fort-night M.S	4th fort-night M.S	5th fort-night M.S
Block	2	0.418	0.162	0.085	1.361	0.141
Treat	11	0.075	0.146	0.169	0.432	0.176
Error	22	0.155	0.139	0.285	0.336	0.202
Total	35					

Appendix V

Abstract of analysis of variance table for dry matter production at fortnightly intervals

Virippu season

Source	df	1st fort-night M.S*	2nd fort-night M.S*	3rd fort-night M.S	4th fort-night M.S	5th fort night M.S
Block	2	4428.69	18431.03	83842.75	347198.03	391407.45
Treat	11	10511.36	26726.15	35996.86	1002042.93	321542.20
Error	22	2136.15	10619.69	77801.72	488887.21	508181.90
Total	35					

Mundakan season

Source	df	1st fort-night M.S	2nd fort-night M.S	3rd fort-night M.S	4th fort-night M.S	5th fort-night M.S
Block	2	17425.86	58942.33	546560.78	1565227.02	1016143.53
Treat	11	28366.57	58858.52	115228.57	359189.85	433058.99
Error	22	13895.59	39627.39	133953.66	472200.30	376389.38
Total	35					

* Significant at 0.05 level

Appendix VI

Abstract of analysis of variance table for number of productive tillers per square metre, length of panicle, weight of panicle, number of grains per panicle and sterility percentage

Virippu Season

Source	df	Number of productive tillers per square metre M.S	Length of panicle M.S	Weight of panicle * M.S	Number of grains per panicle M.S	Sterility percentage M.S
Block	2	1511.3	0.563	0.0672	356.03	27.43
Treat	11	567	3.69	0.189	9.17	26.14
Error	22	1019.34	7.41	0.0321	95.30	15.46
Total	35					

Mundakan Season

Source	df	Number of productive tillers per square metre M.S	Length of panicle M.S	Weight of panicle * M.S	Number of grains per panicle M.S	Sterility percentage M.S
Block	2	430.11	8.92	0.0106	73.45	0.869
Treat	11	2653.24	1.59	0.0346	36.20	15.76
Error	22	1342.02	1.57	0.0129	19.02	11.45
Total	35					

* Significant at 0.05 level

Abstract VII

Abstract of analysis of variance table for thousand grain weight, grain yield, straw yield, harvest index and protein content of grains.

Virippu season

Source	df	Thousand grain weight M.S	Grain yield M.S	Straw yield M.S	Harvest index M.S	Protein content of grains M.S
Block	2	14.48	42992.86	150989.05	5.62	1.03
Treat	11	6.14	32272.69	57801.66	1.54	0.491
Error	22	9.98	60191.62	123767.11	3.21	0.608
Total	35					

Mundakan season

Source	df	Thousand grain weight M.S	Grain yield M.S	Straw yield M.S	Harvest index M.S	Protein content of grains M.S
Block	2	8.40	67428.69	40055.3	1.96	1.03
Treat	11	10.39	67044.35	26640.7	2.93	0.757
Error	22	5.69	52355.91	68225.3	5.63	0.919
Total	35					

Appendix VIII

Abstract of analysis of variance table for pooled analysis of grain and straw yield

Source	df	Grain yield M.S	Straw yield M.S
Season	1	922081.99	2534626.12
Treat	11	83797.5	41403.13
Season x Treat	11	15553.18	40975.40
Pooled Error	44	56273.76	95996.21

Appendix IX

Abstract of analysis of variance table for uptake of nitrogen at initial and final stages.

Source	df	Virippu		Mundakan	
		Initial M.S	Final M.S	Initial M.S	Final M.S.
Block	2	0.219	145.56	15.97	249.76
Treat	11	6.49	55.81	8.01	111.32
Error	22	5.52	42.21	5.10	93.15
Total	35				

APPENDIX- XI

Abstract of analysis of variance table for uptake of Potash

Source	df	Virippu Season		Mundakan season	
		Initial M.S.	Final M.S.	Initial M.S.	Final M.S
Block	2	0.512	73.06	1.72	294.54
Treat	11	1.009	132.69	5.62	132.54
Error	22	0.495	135.85	3.44	137.62
Total	35				

APPENDIX- XII

Abstract of analysis of variance table for nitrogen status of the soil before and after the experiment

Source	df	Before the experiment. M.S.	After the experiment	
			Virippu season M.S	Mundakan season M.S.
Block	2	0.0000092	0.000689	0.000036
Treat	11	0.00027	0.000152	0.00018
Error	22	0.00046	0.000527	0.00035
Total	35			

APPENDIX -X

Abstract of analysis of variance table for uptake of phosphorus at different stages of growth.

Virippu season

Source	df	Maximum tillering M.S	Panicle initiation M.S	Harvest M.S.
Block	2	0.0363	1.922	43.32
Treat	11	0.0835	0.736	36.28
Error	22	0.1223	0.932	29.10
Total	35			

Mundakan season

Source	df	Maximum tillering M.S.	Panicle initiation M.S.	Harvest M.S.
Block	2	0.8523	1.942	56.197
Treat	11	0.3906	1.717	11.307
Error	22	0.3364	2.919	16.423
Total	35			

APPENDIX- XI

Abstract of analysis of variance table for uptake of Potash

Source	df	Virippu Season		Mundakan season	
		Initial M.S.	Final M.S.	Initial M.S.	Final M.S
Block	2	0.512	73.06	1.72	294.54
Treat	11	1.009	132.69	5.62	132.54
Error	22	0.495	135.85	3.44	137.62
Total	35				

APPENDIX- XII

Abstract of analysis of variance table for nitrogen status of the soil before and after the experiment

Source	df	Before the experiment. M.S.	After the experiment	
			Virippu season M.S	Mundakan season M.S.
Block	2	0.0000092	0.000689	0.000036
Treat	11	0.00027	0.000152	0.00018
Error	22	0.00046	0.000527	0.00035
Total	35			

Appendix XIII

Abstract of analysis of variance table for the available P_2O_5 status of the soil at different stages of growth

Virippu season

Source	df	Before the experiment M.S.	Maximum tillering M.S.	Panicle initiation M.S.	Harvest M.S.
Block	2	0.645	5.14	42.41	3.68
Treat	11	1.022	1.28	2.69	2.46
Error	22	4.64	1.77	23.35	2.88
Total	35				

Mundakan season

Source	df	Maximum tillering M.S.	Panicle initiation M.S.	Harvest M.S.
Block	2	20.02	11.25	25.64
Treat	11	8.46	5.26	10.26
Error	22	10.87	5.71	15.38
Total	35			

Appendix XIV

Abstract of analysis of variance table for the exchangeable potassium status of the soil before and after the experiment

Source	df	Before the experiment M.S.	After the experiment: Virippu season M.S	After the experiment: Mundakan season M.S.
Block	2	2.099	212.18	14.29
Treat	11	40.41	261.13	47.72
Error	22	88.20	132.05	237.39
Total	35			

PHOSPHORUS NUTRITION OF RICE

BY

USHA, L.

ABSTRACT OF THE THESIS

SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENT FOR THE DEGREE

OF

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COLLEGE OF AGRICULTURE

VELLAYANI, TRIVANDRUM

1985

ABSTRACT

With a view to study the relative efficiency of various levels and methods of phosphorus application to rice variety, Triveni, an experiment was conducted in the wetlands of the Instructional Farm attached to the College of Agriculture, Vellayani, during the first and second crop seasons of 1983-'84. The various treatments tried were

1. Control (No phosphorus)
2. Full basal (35 kg P_2O_5/ha)
3. 3/4 basal + 1/4 foliar
4. 3/4 basal
5. 1/2 basal + 1/4 foliar
6. 1/4 basal + 1/4 foliar
7. 1/2 basal.
8. Soaking seeds in KH_2PO_4 (Potassium dihydrogen phosphate)- 20 per cent solution and no phosphorus in the main field
9. Dipping seedling roots in KH_2PO_4- 1.5 per cent solution and no phosphorus in the main field.
10. Dipping seedling roots in 2.0 per cent Diamonium phosphate and no phosphorus in the main field.
11. Dipping seedling roots in superphosphate slurry and no phosphorus in the main field.
12. Application of 35 kg P_2O_5 in the nursery and no phosphorus in the main field.

The experiment was laid out in a randomised block design with three replications.

The study revealed that the different levels and methods of phosphorus application had no effect on the various growth characters such as plant height, number of tillers, leaf area index and dry matter production.

The yield and yield attributes also were not influenced by the levels and methods of phosphorus application except the weight of panicle . Phosphorus had no effect on the number of productive tillers per square metre, length of panicle, number of grains per panicle, sterility percentage and thousand grain weight.

The grain and straw yield also were not influenced by phosphorus application. However, the highest grain yield was given by treatment number 12 in both seasons.

Studies on chemical composition and uptake of nutrients showed that the uptake of nutrients was not influenced by the levels and methods of phosphorus application. The pattern of phosphorus uptake showed a gradual increase from maximum tillering to panicle initiation followed by a rapid increase upto harvest.

The total nitrogen, available phosphorus and exchangeable potassium status of the soil were not influenced by phosphorus application. The available phosphorus status of the soil increased gradually upto maximum tillering stage, showed a slight decrease by panicle initiation and this decreasing trend was continued till harvest.

The maximum net profit of Rs.3199.30 was obtained by the application of the full dose of phosphorus to the nursery (T_{12}).