EFFECT OF TOP DRESSING WITH COMPLEX FERTILIZER ON THE YIELD OF RICE

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Effect of top dressing with complex fertilizer on the yield of rice" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for award 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 "Effect of top dressing with complex fertiliser on the yield of rice" is a record of research work done independently by Sri. Sam Mathew, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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INTRODUCTION

The effectiveness of a fertilizer on crop growth depends largely on the variety grown and the time and method of its application. Among the various methods of application, the effect of split application of plant nutrients on the growth and yield of rice has been fairly well studied. However, the interpretation with regard to the behaviour of phosphorus in soils, and the beneficial effects of phosphorus application to different types of soils still remain as a problem for detailed examination.

Japanese workers put forward a theory of nutrioperiodism in rice, according to which nitrogen is needed by rice plant at early stage, phosphorus at tillering and potassium at ear formation stage (Tuneya, 1961). However, the general practice of fertilizing rice in India is to apply one half of each of nitrogen and potassium and entire phosphorus as basal dose. The other half of nitrogen and potassium are usually top dressed at a later stage viz. at tillering or panicle initiation. However, phosphorus shows a complex reaction in the soil. The moment it is applied to the soil it undergoes a chain of reactions forming various complexes in soil depending on the soil reaction. It is generally reported that cereals especially rice show only a low response to phosphatic fertilizers. The poor response to added phosphatic fertilizer even to a soil which is inherently low in phosphorus status, is largely the result of high fixation of applied phosphorus rendering it unavailable to plants. To overcome the problem and to improve the efficiency in utilization of fertiliser phosphorus by rice, various measures like mixing the phosphate fertilizer with organic matter or compost, deep placement, slurry dipping of roots, split application etc. were generally recommended.

In India the general recommendation for phosphorus fertilization is to apply the full quantity either along with last ploughing or at the time of transplanting. In Kerala the Package of Practices Recommendation by KAU (1986) is to apply basally the entire phosphorus needed for the rice crop. However, this recommendation is not seen followed by many farmers inspite of extension efforts. Several farmers have an innovative practice of applying a portion of P as basal and applying the remaining part at a later stage of growth as top dressing in the form of a complex fertilizer or any other soluble form of P fertiliser. Many others even skip the basal dressing and use full P as top dressing at late tillering stage or early panicle initiation stage, inspite of their awareness of the Package Recommendation.

Several reasons have been attributed by rice farmers for their preference to top dressing phosphorus. In view of the non-availability of phosphatic fertilizers in sufficient quantity at the time of planting, farmers are often forced to postpone the P fertilization. About two thirds of the rice cultivation in India is done under rainfed conditions and the possible flooding of the field during the Virippu Season (Kharif) renders fertilizer application difficult or ineffective. Basal application of N and P introduces an element of risk by loss of nutrients. During Mundakan (Rabi) season also the planting time creates problems, especially of water management in some locations. Moreover, some farmers in Kerala believe that top dressing with ammophos (ammonium phosphate sulphate) would bring about improved yield of paddy with bolder grain, and hence reluctant to apply the entire dose of N and P as basal.

The feasibility of top dressing phosphorus for rice has been indicated by some research workers. However, several findings have revealed that top dressing had not any added advantage over basal dressing, while some soil scientists have maintained that top dressing reduced the yield of paddy compared to basal application. Favourable trends in rice yield have also been reported. Hence the efficacy of top dressing of phosphate fertilizer for paddy still remains as a problem for more detailed investigation. Taking into consideration the importance of phosphorus management in paddy culture, it is felt necessary to enlighten the farmer community on the feasibility of top dressing of rice with phosphorus and accordingly the present field investigation was undertaken with the following objectives:

1. To find out whether top dressing of paddy with water soluble P in addition to a basal dose of P has any effect in improving the yield of grain and straw.

2. To find out a suitable combination of the sources of P for basal as well as for top dressing of paddy.

3. To study whether the constituent ammonium salt in ammophos has any role in enhancing the availability of soluble phosphate top dressed to paddy.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The role of phosphorus in plant nutrition has been well established. Applied phosphorus is known to undergo fixation which results in the temporary unavailability of the element to the plant. Though top dressing of phosphorus is not a package recommendation for rice, some farmers prefer top dressing of soluble phosphorus and claim improved yields. The knowledge on the efficacy of top dressing of phosphate fertilizer for rice will be useful for finding out how best the applied phosphorus can be made available to the plant. An attempt is made here to review some of the earlier work carried out in this aspect having relevence to the present study.

I <u>Nutritional importance of phosphorus</u>

The importance of phosphorus nutrition in crop production is recognized 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 very critical in the plant nutrition in as much as it controls several vital metabolic processes within the plant. The high crop yields by P application to soils have been attributed to stimulation of root development making the plant more resistant to drought, promotion of early tillering, flowering and ripening and better seed setting, development of more active tillers which enable the plant to recover more rapidly and more completely after any adverse situation and high food value owing to high P content of grain De Geus (1954). Moreover, it is involved in the plant metabolism, energy transformation and photosynthesis and induces disease resistance.

II <u>Influence of top dressing of phosphorus on Growth characters of rice</u>

a. Height of plants

Sethi (1943) reported that application of nitrogen and phosphorus at transplanting resulted in maximum height than that applied at two or three weeks after transplanting and before flowering.

Sahu and Sahoo (1969) could not obtain any significant difference in plant height at harvest due to different times of application of phosphate and potash.

Subramoniam (1970) found that basal application of phosphorus in the presence of nitrogen significantly increased the height of rice plants over split application.

From the field experiments conducted on rice, Gopal Rao (1972) concluded that the height of plants was not influenced by the time of application of phosphorus.

Bhardwaj et al. (1974) conducted field experiments on the rate and time of application of phosphorus for two successive years and found that in the first year no significant difference could be obtained between the control (full basal) and the treatments of 30 kg P_2O_5 applied half at planting and rest at tiller initiation. In the second year at the tiller initiation stage P treatment was found to favour the height of plant.

Vijayan et al. (1977) reported that top dressing of 20, 40, 60 and 80 kg ha^{-1} of P through soil application at 25 DAP increased the height of plants at all growth stages compared to the control.

From field trials to evaluate the effect of method of applying P on stand establishment and yield, Singh et al. (1987) concluded that basal application of P enhanced the plant height.

b. Number of tillers

Sethi (1943) found that nitrogen and phosphate applied at 30 DAP resulted in maximum number of tillers than at any other time of application.

Sahu and Sahoo (1969) and Subramoniam (1970) could not obtain any significant difference in tillering due to different times of application of phosphorus.

Terman and Allen (1970) found that in a P deficient soil, application of P at later dates decreased tillering.

Gopal Rao (1972) observed a positive trend in favour of full basal application of phosphorus and potash over split application of these elements. Similar results were obtained by Roy and Jha (1987) and Singh et al. (1987) and they concluded that early application of P enhanced early tillering and such tillers were more productive.

Bhardwaj (1974) found that tiller development was at a faster rate when P was applied at planting or tillering stage in comparison with those where P was applied at panicle initiation stage. However, Vijayan et al. (1977) observed that top dressing of 40 to 60 kg P ha^{-1} through soil at 25 DAP increased the number of tillers when compared to the control.

III <u>Influence on yield attributes</u>

a. Number of productive tillers per sq.m

Contradicting reports are traceable in literature regarding the influence of time of application of phosphatic fertilizers on the number of productive tillers per m^2 in rice.

Subramoniam (1970) reported an absence of difference in the number of productive tillers per m^2 due to different times of application of phosphorus.

Bhardwaj et al. (1974) conducted two successive field experiments on the rate and time of application of P fertilizers on paddy and reported that highest number of productive tillers per m^2 was noticed when P was applied in two splits ie. half at planting and rest at tiller initiation. However, in the succeeding year, application of entire P at tiller initiation was found to be as effective as that applied in two splits.

Vijayan et al. (1977) found that top dressing of 40, 60 and 80 kg ha^{-1} of P through soil at 25 DAP increased the number of productive tillers compared to the control. However, Gopal Rao (1972), Roy and Jha (1987) and Singh et al. (1987) observed a trend favouring the basal application of entire quantity of P towards enhanced number of productive tillers per m^2.

b. Length of panicle and panicle weight

Many research workers were of the opinion that the time of application of phosphate fertilizer has not any significant expression on the length and weight of panicle.

Sahu and Sahoo (1969) found that there was no significant difference in the length of panicle due to different times of application of phosphate and potash for rice. The non-significant influence of time of application of phosphate on length of panicle was also reported by Gopal Rao (1972), but a trend favouring the basal application of entire quantity of P was observed. However, Singh (1987) reported that application of full dose of P as basal enhanced the length of panicle and panicle weight.

c. Number of filled grains per panicle

Sahu and Sahoo (1969) reported that there was no significant difference in the number of fertile grains per panicle due to split application of phosphorus. Similar observations were also reported by Subramonian (1970) and Gopal Rao (1972). Singh et al. (1987) however, noticed that full dose of P application as basal increased the number of grains per panicle.

d. Thousand grain weight

It is generally believed that the time of application of P fail to bring about any effect on the thousand grain weight.

Sahu and Sahoo (1969) and Vijayan et al. (1977) reported that there was no significant difference in the thousand grain weight due to time of application of phosphate. Singh et al. (1987) also arrived at the same conclusion. However, Gopal Rao (1972) observed that the basal application of phosphate was superior to the late applications and showed maximum thousand grain weight.

IV Influence on yield

Several reports are available indicating the beneficial effect of split application of P on increased yield of rice grain.

Samad et al. (1956) and Vijayan et al. (1977) reported that soil application of phosphate as top dressing at 25 DAT recorded maximum yield of grain.

Fried and Breeshart (1963) found that application of P at later stages was almost (if not) equally as effective as basal application and there was little advantage in split application.

Bhumbla and Rana (1965) and Ray et al. (1966) reported that the application of N, P and K at maximum tillering stage resulted in highest yield of grain and also found that application of P at boot leaf stage gave lower yield than when applied at maximum tillering stage.

Rana and Bhumbla (1969) found that superphosphate when applied 40 DAP increased the grain yield more than that from the P which was applied later.

Eid (1973), Halappa (1978) and Mellu and Bhandari (1978) also obtained results showing the superiority of split application of P compared to basal application with respect to grain yield.

Yogeswar Rao et al. (1973) stated that application of fertilizers to IET 1991 (Sona) rice in three splits through soil alone or soil and foliage increased the yield of grain. However, Bhardwaj (1974) observed that grain yield was greatest when P was applied at planting or at tillering or was split between these two stages. But delaying the P application upto panicle initiation stage reduced the yield.

Choudhary and Virmani (1975) conducted pot experiments to study the uptake and utilization of fertilizer P in different varieties and found that the dry matter yield was increased when monocalcium phosphate was applied at 21 DAT.

According to Gupta et al. (1975), Shukla and Choudhary (1977) and Venkateswara Reddy et al. (1988), application of 50 per cent P at transplanting and 50 per cent at tillering was best for obtaining highest yield of grain.

The highest grain yield with top dressing of phosphatic fertilizers two weeks after transplanting compared to basal application was reported by Dev et al. (1976). From a series of experiments on rice Rabindra (1978) concluded that high rice yield resulted with the application of P in two splits of ½ at planting and ½ at tillering. In soils of high P content application of 60 kg P_2O_5 ha^{-1} at transplanting or 2, 4 or 6 weeks later resulted in grain yield of 3.96, 4.0, 3.94 and 3.62 t ha^{-1} respectively compared to the 3.71 t ha^{-1} without P.

The studies conducted by Jagiprapa and Takahashi (1978) on the time and rate of fertilizer application for rice revealed that single application of 25 kg P_2O_5 ha^{-1} at 40 DAP or 35 days before flowering gave the highest yield.

In a green house experiment to study the effect of different times of application of P and Mn, Nandi and Mandal (1979) obtained higher grain yield when P was applied at the initial vegetative stage.

BOJAŽIEVA (1980) from field trials on rice with added NPK observed higher paddy yields than in the unfertilised control when NPK at 120, 110 and 110 kg ha^{-1} respectively were applied in two splits of 67 per cent before planting and 33 per cent as a top dressing.

Choudhary and Uppal (1981) reported that application of 60 kg P_2O_5 ha^{-1} applied in one dose at puddling was best for cv. IR-8 and Jaya while cv. J-351 responded best to P, half applied at puddling and half at tillering.

According to Chakravorti et al. (1982) the application of P could be delayed by 40 days in both dry and wet seasons except in Hyderabad soils where 30 days and in CRRI Cuttack soil upto 10 days delay were permissible in dry seasons to get optimum yield.

Chandrasekharappa (1985) reported that NPK fertiliser in three splits (50 per cent at planting, 25 per cent at 25 DAT and 25 per cent at 50 DAT) or in two equal splits viz. at planting and at 25 DAT could yield highest grain than full basal application.

Lee et al. (1986) stated that split dressing of FYM, N, P or Si applied alone or in combinations increased grain yields by 6 to 11 per cent.

Field investigations at Rice Research Station (RRS), Monkompu, Kerala during 1981 Puncha season indicated maximum grain yield with 30 kg P_2O_5 ha^{-1} applied half as basal and half at AT stage. Maximum grain yield could also be recorded in 1983 Puncha season with 45 kg P_2O_5 ha^{-1} applied in three splits viz. ¼ basal, 3/8 at AT stage and 1/8 at PI stage, but none of these results was statistically significant. Trials at RRS, Monkompu (1984) with three complex fertilizers viz. 16:20, 20:20 and 17:17:17 revealed maximum grain yield in plots top dressed with 20:20 complex fertiliser compared to basally dressed plots. The pooled analysis of data relating to another field study conducted during 1984-86 indicated maximum grain yield when the complex fertilizers were applied 50 DAS though the result was again not significant. Further studies during 1986 using P^{32} revealed top dressing with 20:20 ammophos split at 20 and 40 DAP, top dressing of ammonium sulphate and superphosphate at 10 DAP and top dressing of urea + superphosphate at splits of 10 and 30 DAP gave maximum grain yield though not significant. (Kerala Agricultural University, Research Report, 1983, 1984, 1986, 1987; Annual Report, 1987).

Studies conducted in different countries have revealed that top dressing of P was as good as basal dressing in relation to grain yield.

Consistent increase in yield of grain by P applied at sowing or as top dressing 30 to 70 DAS in Texas have been reported by Jones (1952). Gunes (1953) and Ramankutty and Vijayan (1987) reported the absence of any significant difference in yield whether phosphorus was applied before or after transplanting the crop.

Mikkelsen and Patrick (1968) suggested top dressing of P fertilizers approximately 2-3 weeks after seeding and immediately prior to flooding the crop for maximum grain yield in South United States.

Broeshart et al. (1964) from radio tracer studies on methods and time of application of phosphate fertilizers to rice recommended single application of P at transplanting but not later than at the AT stage.

According to Sahu and Sahoo (1969) the time of application of phosphate depends on the varietal response. In tall indica rice varieties and he could not obtain any significant difference between the yields of grain due to different times of P application.

In a soil having moderate P supplying capacity, Ferman and Allen (1970) obtained similar rice yields due to different dates of P application.

The desirability of applying phosphate fertilizer as basal during dry season for maximum grain yield and top dressing in wet season upto one month after transplanting without affecting yield has been indicated by Katyal (1978) who also found that application 90 kg P_2O_5 ha^{-1} in two splits equalled the grain yield to that of single application as basal. Agarwal (1980) observed that yields were similar with P and K applied as a single dressing at transplanting or in two equal splits at transplanting and as top dressing.

Diamond (1985) reported that surface application of P from transplanting upto four weeks of transplanting showed similar response as mixing fertilizer with soil before transplanting.

Research findings are also available indicating reduction in grain yield resulting from top dressing of P fertilizer. Studies conducted by Mitsui (1964) in Japan revealed that basal application of P gave better grain yield than the split application. Similar findings are also available from the works of Davide (1965).

According to Mahapatra (1969) the timing of P depend on two factors, viz., requirement of the plant and the availability of soil P and recommended the desirability of basal application. The superiority of basal application of P fertilizers for maximum grain yield was also reported by Khin Win et al. (1970) and Subramoniam (1970).

From field experiments conducted on rice on the feasibility of top dressing of P and K in sandy clay loam soils of Kerala, George and Sreedharan (1971) suggested that highest yield of grain was obtained when full quantity of P was applied at planting than as top dressing. Similar findings have been recorded also by Gopal Rao (1972), Subramonian and Morachan (1975) and Shirval et al. (1978). Patrick et al. (1974) found that application of P at sowing resulted in higher grain yields than when P was applied four and six weeks after sowing. Katyal and Sreemannarayan (1975) concluded that basal application gave the highest yield and it declined when P application was delayed.

According to Choudhary and Uppal (1981), application of P fertilizer depends on the variety used and found that 60 kg P_2O_5 ha^{-1} applied in one dose at puddling was best for cv. IR-8 and Jaya. Raju (1985) noticed that split application of phosphate as single superphosphate reduced the yield of grain over full basal application.

From field experiments to find out the time and method of application of P in rice, Singh et al. (1987) reported that application of 17.5 kg P ha^{-1} as basal resulted in higher grain yield than other methods of P application.

V <u>Influence on straw yield</u>

The usefulness of top dressing of P in increasing the straw yield has been reported by many workers.

In Texas, Jones (1952) observed that phosphorus applied at sowing or as top dress 30-70 DAS gave consistant increase in the yield of straw.

Samad et al. (1956), and Vijayan et al. (1977) obtained maximum yield of straw from soil application of 60 kg P_2O_5 ha^{-1} as top dressing at 25 DAP.

The need of an adequate supply of phosphorus from transplanting upto booting stage for rice was indicated by Reyes et al. (1962).

Bhumbla and Rana (1965) reported that application of N, P and K at maximum tillering stage resulted in highest yield of straw.

The superiority of split application of P as compared to its basal application was reported by Eid (1970) and Halappa et al. (1970). However, Yogeswar Rao et al. (1973) stated that application of fertilizer to IET-1991 (Sona) rice in three splits through soil or soil and foliage increased the straw yield.

Chaudhary and Virmani (1975) conducted field experiments to study the uptake and utilization of fertilizers and found that the dry matter yield was increased when the whole P was applied at 21 DAT.

According to Gupta et al. (1975) and Rabindra (1978), 50 per cent P applied at transplanting and 50 per cent at tillering or at three weeks after transplanting resulted in maximum straw yield.

From green house experiments to find out the optimum time of application of P and Mn, Nandi and Mandal (1979) found that, highest yield of straw was obtained when P was applied at the beginning of vegetative phase and Mn at reproductive phase.

Chandrasekharappa (1985) reported that application of fertilizers in three splits (½ at planting, ¼ at 25 DAT and ¼ at 50 DAT) or in two equal splits viz. at planting and at 25 DAT recorded highest straw yield.

Trials conducted at RRS, Moncompu, Kerala during 1984-86 indicated maximum straw yield with factomphos (20:20) application at 40 DAS, but was not significant.

Many workers have obtained similar yields of straw from top dressing of phosphorus when compared to basal applications.

Venkateswarlu (1968) reported that there was practically no significance in yield difference in straw between the applications of phosphorus basally, before transplanting and immediately after transplanting. The absence of any significant difference between the yields obtained due to different times of application of phosphate was also reported by Sahu and Sahoo (1969), Ahamed (1970) and Subramonian (1970). However, Katyal (1978) reported that, in wet season the phosphate fertilizer can be delayed upto 30 DAT without affecting the yield. The field trials conducted at RRS, Moncompu during 1981-83 indicated no significant difference in the straw yields between the basal and top dressed P treatments.

However, reports are also available indicating reduction in straw yield from top dressing of phosphorus. Davide (1963), Patrick and Gaikwad (1969) and KhinWin et al. (1970) reported that basal application increased the yield of paddy straw. The highest yield of paddy straw obtained by the application of entire quantity of P fertilizer at planting rather than as top dressing was reported by George and Sreedharan (1971) and Gopal Rao (1972).

Subramonian and Morachan (1975) obtained the highest yield of straw from P and K treatments as basal dressing and N as three way splits.

According to Katyal (1978) and Raju (1983) the split application of phosphate as single superphosphate reduced the yield of straw significantly over full basal application.

Shirval et al. (1978) stated that application of full P and K as basal gave higher yields of straw and also found that when basal dose of 50 per cent NPK was skipped but top dressed through soil the straw yield decreased significantly. Trials conducted at RRS, Moncompu during 1981-83 indicated maximum straw yield with 45 kg P_2O_5 ha^{-1} applied full basal.

VI <u>Uptake of phosphorus by rice in relation to time of application of phosphorus</u>

According to Dastur and Pizarda (1934) and Jacob (1958) P was useful not only in the early stages of development but may also be utilized at later stages of growth of rice plant.

Mitsui (1955) found that during initial growth stages, the P uptake by plant was more from basally applied phosphate as compared to its later application. However, when P was applied at later stages of growth, the uptake was more than that from basal treatment but no influence on grain yield was noticed. Nishigaki et al. (1958) and Maung Mya-Thaung (1960) reported that the young rice plant after transplanting depends largely on easily available P or water soluble P.

Kasai and Asada (1959 a,b) noticed that rice plant continues to take up P from the soil even after boot stage but P absorbed after flowering accumulate in roots. Mitsui (1960), Seetharama Rao and Krishna Rao (1961) and Reyes (1952) also reached at the same conclusion and stressed the need for an adequate supply of P from transplanting to booting stage. However, Patil et al. (1959) revealed that single application of P upset the balanced nutrition of nitrogen and phosphorus and recommended split application of P in small quantity at various growth stages.

Mahapatra (1969) and Mohamed Ali and Morachan (1973) stated that due to higher uptake of P during the early stages of growth of rice plant, basal application of P has to be preferred.

According to Ishizuka (1960) phosphorus is absorbed from the beginning of early tillering, beyond which the absorption is slight or absent.

Tuneya (1961) put forward the theory of nutrio-periodism in rice, and accordingly, nitrogen is needed at early stage, P at tillering and K at ear formation stage.

From the results of the field experiments using radioactive phosphorus, Broeshart et al. (1964) recommended the application of phosphorus as a single dose at transplanting and its application should not be delayed beyond the period of tillering.

Bhumbla and Rana (1965) reported that application of P at maximum tillering stage resulted in higher P content in grain than the later period of application, which showed higher P content in straw.

Patnaik et al. (1965) recommended a single application of entire P at final puddling due to the fact that the later applied P even though increased the uptake is not very effective in increasing the grain yield.

The highest grain phosphorus content recorded by single application of P as basal was reported by Chandrasekaran and Raj (1969). Patnaik and Nanda (1969) found that the absorption of nitrogen, phosphorus and potassium by HYV of rice became vigorous immediately after transplanting and continued almost upto flowering.

According to Sahu and Sahoo (1969) top dressing of phosphate resulted in a lower uptake of nutrient. He concluded that phosphorus absorbed during the critical growth stages of crop is adequate for producing optimal grain yield.

Dev et al. (1970) found that, dwarf varieties of rice absorbed more P from the applied fertilizer at maximum tillering stage.

Subramonian (1970) and Gopal Rao (1972) obtained highest P content in grain from basal application of phosphorus.

Terman and Allen (1970) concluded that the late applied P was readily absorbed by rice but not effective in increasing the yields. However, Badanur and Venkata Rao (1973) observed that while the application of P increased the available P content of soil, it decreased the P saturation percentage.

According to Muthuswamy et al. (1973 a), half of the total requirement of P was absorbed between PI and flowering stages and about 3/4th of P was translocated to grain.

Bhardwaj (1974) reported that the delay in P application upto PI stage would result in insufficient requirement of rice for the element. However, Gupta et al. (1975) noted that when P was applied in two splits (½ at transplanting and ½ at tillering) the uptake was maximum.

Choudhari and Virmani (1975) observed a better utilization of fertilizer P when applied as monocalcium phosphate at 21 DAT.

Dev et al. (1976) from P^{32} experiments reported high uptake of phosphorus by rice plant (13.91 kg ha^{-1}) when P was top dressed at 14 DAT compared to its basal application (13.61 kg ha^{-1}).

Rai and Murty (1976) noticed increased P content from 14 to 42 DAP and slow P absorption in the early stages and retarded during lag phase.

De Datta (1978) recommended late application of P, but not later than at the time of AT. According to him early application of P is essential for root elongation, while P applied during the tillering stage is most efficiently utilized for grain production.

Hamissa et al. (1978) from isotopic studies on the fertilizer efficiency on rice, noted that P uptake was not affected by time of application of fertilizer.

Katyal (1978) reported that P in the plant was higher if the fertilizer was applied 30 DAP. However, late absorbed P increased yield but less than the early absorbed P.

Rabindra (1978) applied phosphate @ 50 kg ha^{-1} to rice crop and found that the P content of leaves in the split application (½ basal + ½ tillering) treatment was higher when compared to single application treatment (full basal) and no P control. He also noted that the P content of soil and P saturation percentage were lowest in the control and were highest in the two split treatments. The P-fixing capacity was highest in the control and lowest in the two split treatment. Nandi and Mandal (1979) also noted highest level of P content in plant when P was applied at the beginning of vegetative phase.

Chakravorti et al. (1982) conducted trials on split application of superphosphate in dry season as well as wet season and concluded that recovery from soil of applied P generally decreased with increasing delay in its application after transplanting. He recommended that top dressing of P may be done within 10-30 DAT in a P deficient soil for maximum recovery of applied P, and in soils having moderate P supplying capacity, top dressing may be delayed upto 30-40 DAT.

Raju (1983) found that, split application of P fertilizer did not increase the P uptake compared to basal application. The percentage of P derived from the fertilizer and the percentage of P utilization were highest when phosphate was applied as di ammonium phosphate (DAP) in splits which also resulted in significant reduction in soil P uptake. From pot culture studies he also found that P absorption took place even at later stages when applied as top dressing and that, less P was absorbed from basal dose than from top dressing.

Raju (1985) using labelled P applied in two splits viz. half as basal and half at 60 DAT found increased P uptake in grain and straw compared to its application at transplanting only. The fertilizer P and soil P uptake values were higher in grains than in straw. Through the alternate tagging technique he also revealed that, greater portion of basally applied P was retained in the straw than from the top dressed P. Venkateswara Reddy (1988) recommended that for rice, split application (½ at transplanting + ½ at tillering) of P @ 60 kg P_2O_5 ha^{-1} as DAP resulted in its higher utilization.

VII Effect of combined application of N and P on rice growth and yield

Several scientists have reported that application of nitrogen along with phosphorus would enhance the plant uptake of phosphorus. Mitsui et al. (1961), Basak (1962) and Manu and Purnapragnachar (1963) reported higher utilisation of P when applied along with N and K. Similar results was reported by Singh and Bhardwaj (1973) and Alexander et al. (1974).

The better recovery of phosphate from ammophos than from superphosphate by rice was attributed to lesser reaction of phosphate ion with soil colloidal complex was reported by Panse and Khanna (1964) and Engelstad and Terman (1967).

According to Roychoudhari (1965) ammonium phosphate was better among complex fertilisers in its response to rice crop. Vachhani and Rao (1965) were also of the same view. Sahu and Lenka (1966), Mahapatra (1969) and Ittyavirah et al. (1979) have revealed that the response of rice to P was low without N and it increased in conjunction with nitrogen.

Datta and Venkateswarlu (1968) remarked that ammonium sulphate was found to increase the P availability when the P fertilizers were mixed with it.

Riley et al. (1971) proposed evidences for the presence of ammonium ions around the root surface, which could increase the uptake of phosphate anion by root cell, probably due to the involvement of exchange of ammonium ion for hydrogen ions, which could make the soil acidic near the root and raise the concentration of phosphate ion in the root vicinity.

Gupta et al. (1972) reported the higher uptake of DAP by the crop compared to other phosphatic fertilizers. He believed that the efficiency of these fertilizers are influenced by soil pH. In alkaline soils of pH = 8.2 single superphosphate (SSP) was superior while in neutral soils of pH = 7.2, DAP was better.

The low efficiency of single superphosphate compared to ammonium phosphate or DAP was reported by Sahu et al. (1972).

Mohamed Ali and Morachan (1973) noted that P uptake increased from the ammonium sulphate treated plots.

According to Bhattacharya and Chatterjee (1978) application of P + N aided early tillering, and early tillers gave more panicle bearing tillers, more filled spikelet per panicle and higher test weight than late ones.

BOJADŽIEVA (1980) from field experiments with NPK complex fertilizers found that, maximum grain yield was obtained by applied NPK @ 120 kg N + 110 kg P_2O_5 + 110 kg K_2O ha^{-1} in two splits of 67 per cent before ploughing and 33 per cent as top dressing.

Shinde and Patil (1980) conducted pot trials with rice with N alone and with P and K in different forms and found that application of ammophos gave the highest yields and highest uptake of nitrogen followed by ammonium sulphate + superphosphate. He also noticed that ammophos (20:20) was superior over straight and mixed fertilizers which might be due to its granular nature, water soluble form of P and ammoniacal form of nitrogen utilized by rice.

Raju (1983, 1985) found that split application of phosphate as DAP produced more dry matter yield and uptake over the basal application while, split application of SSP reduced the dry matter production and yield over its full basal application which was attributed to more intimate association of NH_4^+ ion.

Khatua and Sahu (1984) studied the response of high yielding dwarf indica rice to different sources and levels of P fertilizers and reported that ammonium phosphate induced more vegetative growth and grain yield in rabi season, than superphosphate and nitrophosphate.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present field study was undertaken to find out whether top dressing of paddy with two sources of water soluble phosphatic fertilizers viz. superphosphate, ammophos and their time of application have any favourable effect on the yield of grain and straw and also to obtain a suitable combination of forms of P for basal as well as for top dressing of paddy. The materials used and methods followed for the experiment are presented below:

MATERIALS

a. Experimental site

A field experiment was conducted in the wetlands at Palappore area situated on the western side of Instructional Farm, College of Agriculture, Vellayani.

b. Cropping history of the field

The experimental site was under a bulk crop of rice during the previous two seasons.

c. Soil

The soil of the experimental site was sandy clay loam in texture and analysed to medium P content. The representative soil sample was collected prior to the application of fertilizers and analysed for physico-chemical characteristics. The data are furnished in Table 1.

Table 1 Physico-chemical characteristics of the soil

A. Physical characteristics

1. Particle size distribution		
a) Coarse sand (per cent)	:	31.40
b) Fine sand (per cent)	:	20.10
c) Silt (per cent)	:	20.90
d) Clay (per cent)	:	25.50
Textural class	:	Sandy clay loam
2. Bulk density (g cc^{-1})	:	1.62
3. Particle density (g cc^{-1})	:	2.80
4. Pore space (per cent)	:	52.47
5. Volume expansion on wetting (per cent)	:	4.23
6. Water holding capacity (per cent)	:	30.53

B. Chemical characteristics

1. pH	:	5.50
2. Electrical conductivity (dSm^{-1})	:	0.08
3. Organic matter (per cent)	:	0.95
4. Total nitrogen (per cent)	:	0.07
5. Total phosphorus (per cent)	:	0.08
6. Total potassium (per cent)	:	0.12
7. Available nitrogen (kg ha^{-1})	:	165.50
8. Available phosphorus (kg ha^{-1})	:	25.50
9. Available potassium (kg ha^{-1})	:	60.50
10. Exchangeable calcium (me/100g)	:	2.10
11. Exchangeable magnesium (me/100g)	:	0.35
12. Cation exchange capacity (c mol(+)kg^{-1} of soil)	:	6.20

d. Season

The experiment was conducted during the Mundakan (second crop) season of 1988 from September 1988 to January, 1989.

e. Variety

The rice variety used for the study was Jyothi, which is a HYV having a duration of 110-125 days. The kernel has red colour and being an acceptable variety to farmers. It is widely cultivated in Kerala. The seeds for the experiment were procured from the Agricultural Development Office at Trivandrum.

f. Fertilizers used

The fertilizers used for the experiment were ammonium sulphate analysing to 20.5 per cent N, factomphos (Ammonium phosphate sulphate complex manufactured by FACT) analysing to 20.0 per cent N and 20.0 per cent P_2O_5, superphosphate analysing to 16.0 per cent P_2O_5 and Muriate of potash 60.0 per cent K_2O.

METHODS

a. Treatments

All the treatments except T_1 (control) received a uniform dose of N, P and K at 90:45:45 kg ha^{-1} as per the Package Recommendation of the Kerala Agricultural University.

The treatment T_1 received only N and K at 90 and 45 kg ha^{-1} respectively. Nitrogen was applied to all plots as ammonium sulphate. The P treatments were given as factomphos (which also served as an additional source of nitrogen) and single superphosphate. The nitrogen requirement in the factomphos treated plots was met from factomphos as well as from ammonium sulphate. Factomphos (20% N and 20% P_2O_5) used in this study is chemically ammonium phosphate sulphate. Nitrogen and potassium were applied in two splits, ½ dose as basal and ½ at panicle initiation (PI) stage. Phosphorus was applied in plots at different stages as per the following schedules

- T_1 - Control (no phosphorus)
- T_2 - Full P in the form of superphosphate as basal
- T_3 - Full P in the form of 20:20 complex (factomphos) as basal
- T_4 - Full P in the form of factomphos top dressed at active tillering (AT) stage (25 DAT)
- T_5 - Full P in the form of superphosphate top dressed at AT
- T_6 - ⅓ P basal as superphosphate + ⅓ P at AT as superphosphate + ⅓ P at panicle initiation (PI) as superphosphate
- T_7 - ⅓ P basal as factomphos + ⅓ P at AT as factomphos + ⅓ P at PI as factomphos

T_8 - ¼ P basal as superphosphate + ¼ P at AT as factomphos + ½ P at PI as factomphos

T_9 - ¼ P basal as factomphos + ½ P at AT as superphosphate + ¼ P at PI as superphosphate

T_{10} - ½ P basal as superphosphate + ½ P at AT as factomphos

T_{11} - ½ P basal as superphosphate + ½ P at AT as superphosphate

T_{12} - ½ P basal as factomphos + ½ P at AT as superphosphate

T_{13} - ½ P basal as factomphos + ½ P at AT as factomphos

b. Design and layout

The experiment was laid out in a Randomised Block Design with 13 treatments with three replications. The layout plan is presented in fig. 1. The gross plot size was 5 x 4.5 m (net size 4 x 4.1 m) and there were a total of 39 plots. The spacing followed for planting rice seedlings was 20 x 10 cm. Two rows all around each plot were provided as border rows. Leaving the border row, the next row of plants was considered as destructive row to enable the collection of plant sample at intervals to find out the dry weight of plant and for chemical analysis. Thus the net plot size was 4 x 4.1 m.

N

FIG. 1 LAYOUT PLAN

R_2	T_3	T_{13}	T_4	T_5	T_9	T_7	T_2	T_{10}	T_{12}	T_1	T_6	T_8	T_{11}
R_1	T_5	T_1	T_9	T_{12}	T_3	T_6	T_8	T_{13}	T_2	T_4	T_{10}	T_7	T_{11}
R_3	T_1	T_4	T_9	T_6	T_{13}	T_8	T_7	T_{12}	T_5	T_{10}	T_2	T_{11}	T_3

PLOT SIZE: 5X4.5 M

c. Details of cultivation

i) Land preparation

Nursery: The nursery area of 80 m^2 was ploughed well and raised beds of 1.5m width and 15cm height were prepared with drainage channels in between. Sprouted seeds were broadcasted uniformly and irrigation was commenced on the fifth day after sowing (DAS) and there after a uniform depth of 5cm water level was maintained.

Main field: The main field was ploughed twice, levelled and individual plots were laid out, with bunds of 30cm width around each plot. Main and sub irrigation-drainage channels were provided for each plot. Individual plots were again puddled and perfectly levelled. Cowdung was applied at the rate of 5 t ha^{-1} and well incorporated into soil.

ii) Application of fertilizer

A quantity of 45 kg N ha^{-1} and 22.5 kg K_2O ha^{-1} were applied as basal dose to all plots as per Package Recommendation. Phosphorus was applied in the form of superphosphate and factomphos as per the treatments programmed. First top dressing was given at 20 DAT corresponding to AT stage and second top dressing was at 40 DAT corresponding to PI stage.

iii) Transplanting and maintenance

Twenty days old healthy seedlings were uprooted from the nursery and transplanted in the main field at a spacing of 20 x10 cm with two seedlings per hill. Gap filling was done within five days wherever necessary. A water level of 1.5cm was maintained initially and later increased to 5cm.

iv) Plant protection

All plots were hand weeded twice viz., at 20 DAT and 35 DAT. Ekalux, Dimecron and Hinosan were sprayed against leaf roller, stem borer, gall midge and sheath blight respectively during the tillering stage of the plant. Metacid was sprayed against rice bug at milky stage.

v) Harvest

The crop was harvested after 120 days of duration. About 20 days before harvest, the field was drained. The border rows and the remaining hills of destructive row were harvested first from each plot and removed. The net plot area was then separately harvested, threshed, cleaned, sun dried, winnowed and grain yield at 14 per cent moisture was recorded. The weight of sun dried straw was also recorded.

Biometric observations

Biometric observations were recorded as suggested by Gomez and Gomez (1984). One square metre area of plants was marked out in each plot and set apart for taking the following observations.

A. Growth characters

Growth characters such as height of the plant and number of tillers per square metre were recorded at three stages viz. on 20th DAT, corresponding to active tillering stage, at 35 DAT, and at harvest.

1. Height of plant

Except at harvest the height was measured from the base to the tip of the longest leaf. At harvest the height from base to tip of longest panicle was taken and mean height of 5 or 10 plants expressed in centimetre.

2. Number of tillers per m^2

The tillers from the one square metre area in each plot were counted at different stages and recorded.

3. Dry matter yield and uptake

The total P uptake at different stages were obtained as a product of the content of this nutrient in the plant and weight of dry matter and expressed kg ha^{-1}, at 20, 35, 45 DAT and at harvest. The first three stages corresponded to, prior to top dressing at AT, 15 days after top dressing at AT and 10 days after top dressing at PI stage. For the estimation of dry matter yield (DMY) at the specified periods, five sample hills were uprooted from the destructive row, washed and sun dried, the samples were oven dried at a temperature of $80 \pm 5^{\circ}C$ to constant weight and dry matter production was calculated and expressed in kg ha^{-1}.

B. Yield attributes and yield

The plants set apart for taking biometric observations were cut and the following observations were recorded as suggested by Gomez and Gomez (1984).

1. Number of panicles/m^2
2. Number of filled grains per panicle
3. Number of unfilled grains per panicle
4. Thousand grain weight
5. Grain yield: The grain yield was recorded from the net area at 14 per cent moisture and expressed in kg ha^{-1}.
6. Straw yield: The straw obtained from the net plot was uniformly sun dried, weighed and expressed in kg ha^{-1}.

C. Chemical analysis

1. Plant analysis

The plant samples collected at various stages as well as grain and straw were dried at $80\pm5^{\circ}C$, ground in a porcelain mortar and used for chemical analysis.

a. Nitrogen content and uptake

The nitrogen content of samples was determined by modified micro-kjeldahl digestion method as suggested by Jackson (1967).

b. Phosphorus content and uptake

Phosphorus content of the plant sample was determined from triple acid extract (9:2:1 = HNO_3:H_2SO_4:$HClO_4$). In an aliquote of the extract, phosphorus was estimated colorimetrically by the vanado molybdate phosphoric yellow colour method in nitric acid system. The yellow colour was read in Spectronic 2000 at a wave length of 470 nm (Jackson, 1967).

The phosphorus concentration thus obtained was multiplied with the DMY at the respective stages and uptake of phosphorus computed and expressed as kg ha^{-1}.

c. Content and uptake of potassium

Potassium content of plant sample was determined from triple acid extract of plant using Perkin-Elmer Atomic Absorption Spectrophotometer, Model 3030.

2. Soil analysis

Representative soil samples were collected from the individual plots prior to planting, air dried, powdered with a wooden mallet, sieved through a 2mm sieve and stored for chemical analysis.

1. Mechanical analysis

The mechanical composition of soil was determined by International Pipette Method after oxidation of organic matter with hydrogen peroxide (Piper, 1967).

2. Soil reaction

The soil pH was measured in a 1:2.5 soil-water suspension using Perkin-Elmer photo volt pH meter with a combined glass-reference electrode.

3. Electrical conductivity

The specific conductivity was determined in 1:2 soil water extract using Elico Soil Bridge and the value expressed in dS m^{-1}.

4. Cation Exchange Capacity

The Cation Exchange Capacity (CEC) was determined using neutral normal ammonium acetate (Jackson, 1973) and expressed in Cmol($\pm$)kg^{-1}.

5. Physical constants

These were determined by the method of Keen-Raczkowski (Wright, 1938).

6. Organic carbon

Organic carbon was estimated by the Walkley and Black's rapid titration method using diphenyl amine as indicator (Jackson, 1973) and expressed as percentage.

7. Total nitrogen

Total nitrogen status of the soil was evaluated by the Micro-Kjeldahl digestion and distillation method (Jackson, 1973).

8. Total phosphorus

Total phosphorus was determined by Vanadomolybdo-phosphoric yellow colour method (Hesse, 1971).

9. Available nitrogen

Available nitrogen content of soil was determined by alkaline permanganate method (Subbiah and Asija, 1956).

10. Available phosphorus

Available phosphorus was estimated by extracting the soil with Bray No.1 extract (0.03 N NH_4F and 0.025 N HCl) and there after developing chloromolybdic acid blue colour and read in Spectronic 2000 Spectrophotometer at a wave length of 660 nm (Jackson, 1973).

11. Extractable bases

a) Available potassium

Available potassium was estimated by neutral normal ammonium acetate extraction method using Perkin-Elmer Model 3030 Atomic Absorption Spectrophotometer (AAS) and the spectrum of absorption was determined at a wave length of 422.7 nm (Jackson, 1973).

b) Available calcium

Available calcium was determined by neutral normal ammonium acetate method using PE 3030 Atomic Absorption Spectrophotometer at a wave length of 422.7 nm (Jackson, 1973).

c) **Available magnesium**

Available magnesium was estimated by neutral normal ammonium acetate extract method using PE 3030 AAS at a wave length of 285.2 nm (Jackson, 1973).

Periodical analysis of soil samples

Soil samples were collected from each plot, at different stages, viz. prior to basal dressing, prior to top dressing, 10 days after top dressing and at harvest. These samples were analysed for available P as per the method described earlier.

Statistical analysis

The data generated from the field experiment and laboratory studies were analysed statistically by ANOVA technique and the results were interpreted to arrive at conclusions.

The correlations between the soil properties, grain yield, straw yield and plant phosphorus content were worked out to find out their relationship.

RESULTS

RESULTS

The observations recorded at different stages during the field experiment to study the effect of top dressing on the growth and yield of rice using two water soluble forms of phosphorus, viz. superphosphate and factomphos, after statistical treatment are presented in this Chapter.

Biometric observations

The biometric observations on crop growth recorded during the three sampling periods viz. prior to and after top dressing at AT stage and at harvest were statistically analysed and the results are presented below.

1. Plant height

The mean height of plants was recorded just prior to top dressing at active tillering (AT), 15 days after top dressing at AT stage and at harvest. The results are presented in Table 2.

Results on mean plant height recorded just prior to top dressing at active tillering (AT) stage indicated no significant difference among the various treatments. The plant height varied between 34.90 cm in T_2 and 37.27 cm in T_6.

The mean table pertaining to plant height measured at 15 days after top dressing of phosphorus at AT stage indicated significant difference. While the height varied between

Table 2. Mean plant height (cm) as influenced by basal and top dressed P treatments

Treatments	Before top dressing at AT	15 days after top dressing at AT	At harvest
T_1	35.23	43.50	68.10
T_2	34.90	48.60	68.77
T_3	37.10	49.07	70.93
T_4	35.77	59.23	69.73
T_5	36.70	50.50	71.07
T_6	37.27	49.60	69.23
T_7	37.17	56.30	69.20
T_8	45.80	57.27	71.77
T_9	36.30	53.20	71.47
T_{10}	35.40	57.77	71.97
T_{11}	35.40	48.50	68.03
T_{12}	36.03	49.10	69.30
T_{13}	37.13	59.60	72.40
F	1.22 NS	9.55**	1.39 NS
CD	-	4.83	-

** Significant at 1% level
NS Not significant

43.5 cm in T_1 (control) and 59.6 cm in T_{13} (½ basal factomphos and ½ top dress factomphos), the treatments T_{13}, T_4, T_8 and T_7 which received top dressing of factomphos either the entire dose or in split dose were found to be similar and superior to the remaining treatments. The top dressed treatments of superphosphate and full P basal treatments of superphosphate as well as factomphos were on par and were superior to the control.

At harvest the influence of the various treatments on plant height was not significant. The plant height varied between 68.10 cm in the control and 72.40 cm in T_{13}. It can be seen in the Table that the treatment T_{13} has influenced the plant height at all the three sampling stages studied though significant difference could be observed only in the second stage.

2. Number of tillers

The data on the mean number of tillers per square metre observed at active tillering, at 15 days after top dressing at AP and at harvest stage are presented in Table 3.

The mean tiller count per square metre recorded just prior to the top dressing at AP stage was found to vary between 323.83 in the control plot and 360.00 in the treatment T_{13}, followed by T_{10} with 355.33 and T_{12} with 355.00 tillers.

Table 3. Mean tiller count per square metre as influenced by basal and top dressed P treatments

Treatments	Before top dressing at AT	15 days after top dressing at AT	At harvest
T_1	323.33	316.67	336.67
T_2	346.67	368.33	398.33
T_3	328.33	368.33	398.33
T_4	338.33	333.33	368.33
T_5	340.00	326.67	355.00
T_6	340.00	348.33	371.67
T_7	343.33	363.33	393.33
T_8	345.00	351.67	386.67
T_9	353.33	343.33	373.33
T_{10}	355.33	411.67	501.67
T_{11}	345.00	383.33	470.00
T_{12}	355.00	388.33	483.33
T_{13}	360.00	413.33	514.17
F	1 NS	2.67*	10.16**
CD	--	54.38	55.24

* Significant at 5% level
** Significant at 1% level
NS Not significant

However, no significant difference among treatments could be noticed at this stage.

With regard to the number of tillers at 15 days after top dressing at AT, the data revealed significant difference. While there was no significant difference between the two-split treatments and the full basal treatments of P, the two-split treatments performed better. The treatment T_{13} which received factomphos for basal as well as for top dressing at AT was found to produce the highest tiller count of 413.33 per square metre followed by T_{10} with 411.67. The lowest value (316.67) was recorded by the control. The treatments T_{13}, T_{10}, T_{12}, T_{11}, T_3, T_2 and T_7 were on par and were superior to T_8, T_6, T_9, T_4, T_5 and T_1 which are also similar. The three-split treatments produced lesser tiller count compared to full basal P treatments and the performance of full P top dressed treatments were still lower.

At harvest stage it was noticed that the two-split treatments irrespective of the combination of P sources recorded similar number of tillers per square metre and were superior to the rest of the treatments. All the remaining treatments except control were on par and significantly superior to the rest of the treatments. All the remaining treatments except control were on par and significantly superior to the control. The highest value was recorded by T_{13} (514.17) and the lowest by the control (336.67). The performance of basally applied P was better when compared to the control and was significant.

Yield Attributes

1. Number of productive tillers per square metre

The mean values of the number of productive tillers per square metre are presented in Table 4.

From the Table it is clear that, in general, top dressing of phosphate fertilizer at various growth stages of rice given in different combinations significantly influenced the productive tiller counts. The treatments T_{10} to T_{13}, which received top dressing of phosphate fertilizer in two splits viz. half basal and half at AT were superior to the rest of the treatments and were on par. The treatment T_{13} produced the maximum number of productive tillers per square metre (491.66) followed by T_{10} (476.66) and the least value was recorded by the control (271.66). The full basal treatments T_2 and T_3 were on par with the three split treatments of ¼ basal + ½ at AT + ¼ at PI, viz. T_6, T_7, T_8 and T_9 and also with the single top dressed P treatments.

2. Length of panicle

The data on length of panicles as influenced by P application are presented in Table 4.

It was observed that the length of panicle was not significantly affected by any of the treatments. The maximum length was recorded by T_{13} (18.41 cm) followed by T_{10} (18.33 cm). Panicle length ranged between 18.41 cm and 17.07 cm among the treatments.

3. Number of filled grains per panicle

The data on the mean number of filled grains per panicle are given in Table 4.

Significant difference in the number of filled grains per panicle could be noticed. The two-split P treatments showed better performance over the full basal treatments and three-split treatments and were similar. The control and full top dressed P treatments which gave significantly lesser filled grains per panicle were all on par. The number of filled grains per panicle ranged between 46.00 and 67.37. The highest mean number of filled grains per panicle was recorded by T_{13} (67.37) followed by T_{10} (63.27) and T_{12} (63.03), while the fully top dressed P treatments, T_5 and T_4 recorded mean values of 54.00 and 52.40 respectively. The control treatment produced the lowest number of filled grains per panicle (46.00) and was significant.

4. Number of chaff per panicle

The data on the mean chaff content per panicle as influenced by phosphate application are presented in Table 4.

Table 4. Effect of treatments on yield attributes

Treatments	Mean values				
	Number of productive tiller per m^2	Length of panicle (cm)	Number of filled grains per panicle	Number of chaff per panicle	Thousand grain weight (g)
T_1	271.66	17.07	46.00	26.66	25.00
T_2	358.33	17.74	61.17	19.46	25.40
T_3	360.00	17.46	62.00	17.90	29.46
T_4	305.00	17.61	52.40	23.90	25.40
T_5	308.33	18.11	54.00	24.67	25.00
T_6	326.66	18.26	57.70	23.20	24.30
T_7	343.33	17.96	57.10	21.13	24.30
T_8	348.33	17.35	56.37	22.56	25.10
T_9	343.33	18.26	59.97	22.70	25.46
T_{10}	476.65	18.31	63.27	16.00	25.36
T_{11}	466.66	17.21	61.47	15.96	25.36
T_{12}	468.33	18.10	63.03	15.33	25.43
T_{13}	491.66	18.41	67.47	14.67	25.76
F	13.66**	1.83	1.47*	3.09**	1.29
CD	58.53	NS	13.33	5.66	NS

* Significant at 5% level
** Significant at 1% level
NS Not significant

The data revealed no significant difference in the chaff content between the two-split P treatments and full basal treatments. However, these treatments were significantly superior compared to the rest of the treatments. The chaff content varied between 14.67 for the treatment T_{13} which received factomphos for basal as well as top dressing at AT and 26.66 for the control. The three-split treatments recorded lesser number of chaff per panicle compared to full top dressed treatments and the control even though they were similar.

5. Thousand grain weight

The mean values on the thousand grain weight in the different treatments are presented in Table 4.

The data clearly revealed that there was no significant difference in the thousand grain weight among the different treatments. Neither the time of application nor the form of P fertilizer influenced this yield parameter.

6. Yield of grain

The data relating to the mean grain yield in rice as influenced by time and method of phosphorus application are presented in Table 5.

Results revealed significant difference in grain yield among the treatments. The source of P and the growth stage of rice at which P was applied have influenced the grain yield over the no P control. The highest grain yield of 3363 kg ha^{-1}

Table 5. Yield of grain and straw (kg ha^{-1}) in rice as influenced by basal and top dressed P treatments

Treatments	Grain yield	Straw yield
T_1	2553	3659
T_2	3267	3988
T_3	3275	4002
T_4	3041	3761
T_5	3027	3802
T_6	3087	3920
T_7	3126	3960
T_8	3158	3951
T_9	3161	3930
T_{10}	3342	4150
T_{11}	3337	4147
T_{12}	3344	4164
T_{13}	3363	4241
F	23.03**	8.77**
CD	133	168

** Significant at 1% level

resulted from the split application of factomphos as half P basal and half P top dress (T_{13}). The grain yield was found to decrease in the order $T_{13} \geq T_{12} > T_{10} > T_{11} > T_3 > T_2$ which were on par. Though the treatment T_{13} was significantly superior over the three-split P treatments, (T_6 to T_9), full P top dressing (T_4 and T_5) and the control (T_1), it was found similar to the other two-split P treatments (T_{10}, T_{12} and T_{11}) and the full P basal treatments (T_3 and T_2). The treatments T_3 and T_2 which received full basal application in the form of factomphos and superphosphate respectively, recorded grain yields of 3275 kg ha^{-1} and 3267 kg ha^{-1}. These two basal treatments were significantly superior over the single top dressed treatments and the control. The three-split treatments (T_9, T_8, T_7 and T_6) were on par and found superior when compared to the control. Between the single top dressed treatments, the factomphos treatment T_4 performed better compared to superphosphate treatment T_5. The lowest yield of grain (2553 kg ha^{-1}) was recorded by the control.

The grain yield obtained from the various treatments are graphically illustrated in Fig. 2.

7. Yield of straw

Table 5 provides the data pertaining to straw yield as influenced by the time and sources of application of P fertilisers.

FIG. 3 STRAW YIELD (Kg ha^{-1})

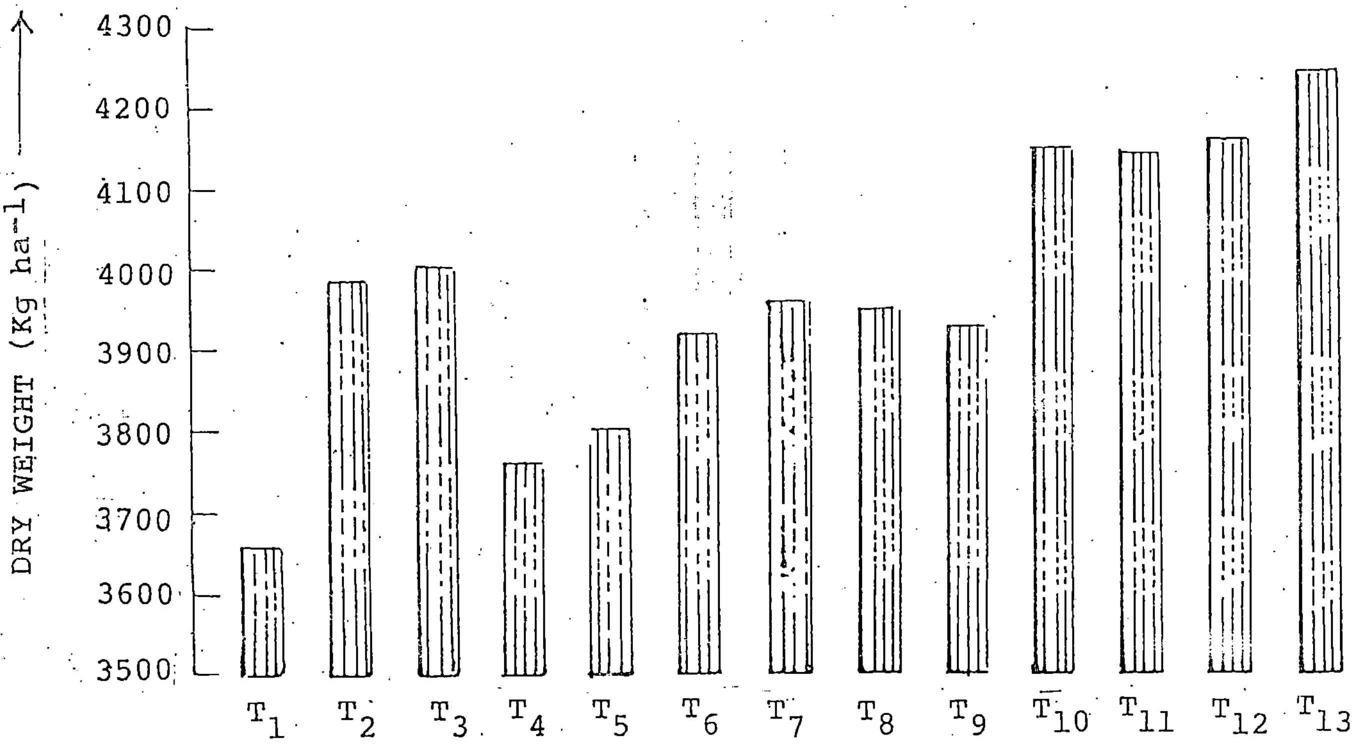
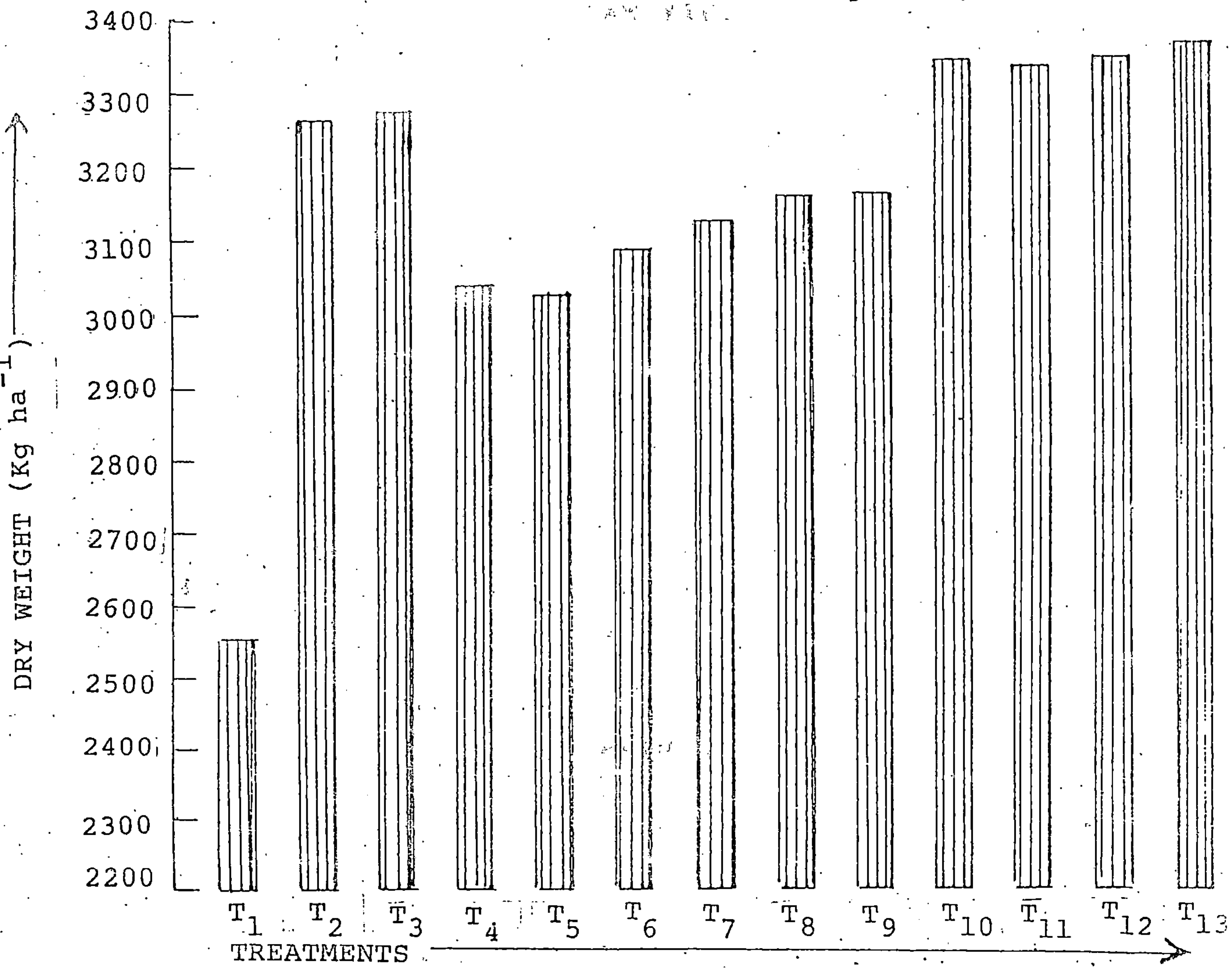


FIG. 2 GRAIN YIELD (Kg ha^{-1})



In general, the two-split treatments performed better compared to the others with regard to straw yield. The straw yield decreased in the order two splits > full basal > three splits > full top dress > control. All the two-split treatments (T_{13}, T_{12}, T_{10} and T_{11}) were similar among themselves. However, the straw yield in the treatment T_{13} viz., ½ basal and ½ top dress, both given as factomphos, was seen significantly higher compared to the full basal treatments. The two-split treatments T_{10} and T_{11} ie. ½ basal P as super phosphate plus ½ top dress as factomphos in the former and as superphosphate in the latter were also similar to the full P basal treatments T_2 and T_3. The three-split treatments irrespective of their fertiliser combinations performed better compared to the treatments which received the entire dose of P as top dress either as superphosphate or as factomphos. It was also noticed that the three-split treatments were similar among themselves and among these, T_7 which received all the three splits exclusively in the form of factomphos performed better. The control treatment registered lowest straw yield (3659 kg ha^{-1}) which was significant.

Graphic representation of the straw yield obtained from the different treatments is furnished in Fig. 3.

Phosphorus content in plant

Table 6 contains the mean values of phosphorus content in plants estimated at four sampling stages viz., prior to top dressing at AT, 15 days after top dressing at AT stage, 10 days after top dressing at PI stage and at harvest. The P content in the grain and straw are also contained in the Table. The P contents of plant at the four stages are illustrated in Fig. 4 graphically.

With regard to the P content in plants prior to top dressing at AT stage, the data in the table indicated, difference among the various treatments. The treatment T_3 which received full basal P in the form of factomphos registered the highest plant concentration of P (0.38 per cent) followed by the two-split P treatments T_{13} and T_{10} to T_{12} which were similar. All the above said treatments were significantly superior over the others. It may be noted that all these treatments except T_3 are the split treatments of P with ½ basal and ½ top dressed at AT stage. The treatments T_6, T_2, T_7 and T_9 were statistically on par and were superior to T_8, T_4, T_5 and T_1. The lowest plant-phosphorus content was recorded in the no-P control (0.28%).

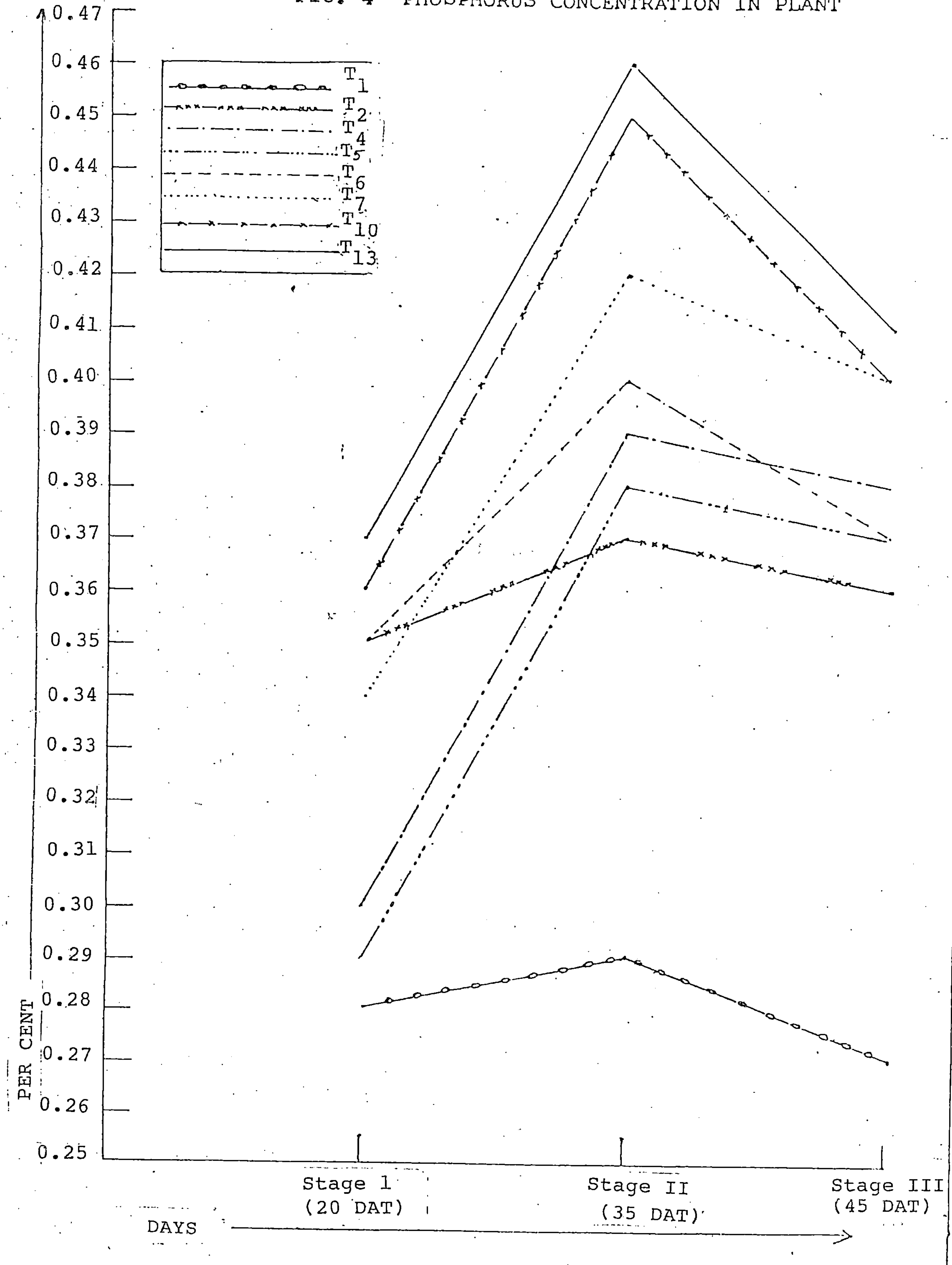
The phosphorus content in the plant determined at 15 days after top dressing at AT stage was found to be

Table 6. Mean phosphorus content (per cent) in plant as influenced by basal and top dressed P treatments

Treat-	Prior to top dress-ing at AT	15 days after top dressing at AT	10 days after top dressing at PI	Grain	Straw
T_1	0.28	0.29	0.27	0.25	0.14
T_2	0.35	0.37	0.36	0.36	0.23
T_3	0.38	0.38	0.37	0.37	0.21
T_4	0.30	0.39	0.38	0.35	0.23
T_5	0.29	0.38	0.37	0.33	0.24
T_6	0.35	0.40	0.37	0.35	0.24
T_7	0.34	0.42	0.40	0.37	0.23
T_8	0.32	0.40	0.37	0.35	0.23
T_9	0.34	0.40	0.38	0.37	0.22
T_{10}	0.36	0.45	0.40	0.38	0.24
T_{11}	0.36	0.42	0.38	0.36	0.24
T_{12}	0.36	0.45	0.37	0.37	0.24
T_{13}	0.37	0.46	0.41	0.39	0.25
F	30.00**	58.00**	10.33**	18.00**	50.00**
CD	0.017	0.021	0.026	0.027	0.013

** Significant at 1% level

FIG. 4 PHOSPHORUS CONCENTRATION IN PLANT



significantly influenced by the top dressed P treatments. It was noticed that the treatments which received phosphorus in two splits increased the P content in the plant compared to the three split treatments, single P treatments and the control. The maximum content of 0.46 per cent P was recorded in T_{13} which received P in two splits of half basal as factomphos and half top dressed as factomphos at AT. However, T_{13} was statistically on par with T_{12} and T_{10} and were superior to the rest of the treatments. The treatments T_{11}, T_7, T_9, T_8 and T_6 were similar and were significantly superior over T_4, T_5 and T_3 which were also similar. Among the top dressed treatments, two splits performed best with regard to the plant concentration of phosphorus. The control recorded the least P content (0.29 per cent).

It was observed that the phosphorus content of the plant at 10 days after top dressing at PI stage was significantly influenced by the various treatments. The top dressed treatments T_{10} and T_{13} performed better over the full basal treatments with regard to the plant P content. The treatment T_{13} resulted in the highest content of P in the plant which was followed by T_7 and T_{10}. The treatments T_{13}, T_7 and T_{10} were statistically on par and were superior to the others. The treatments T_4, T_9, T_{11}, T_3, T_8, T_6, T_{12}, T_5 and T_2 were on par and the lowest plant phosphorus content (0.27 per cent) was recorded by the control.

At harvest stage the P content in the rice grain was significantly influenced by the treatments. The treatments T_{13} and T_{10} which received P in two splits recorded the maximum concentration of P in the grain (0.39 and 0.38 per cent respectively), followed by the full basal treatments T_3 and T_2 with grain phosphorus contents of 0.37 and 0.36 per cent respectively. The control recorded the lowest content of P (0.25 per cent).

The phosphorus concentration in the straw was also found to be influenced by the treatments. The control recorded the lowest concentration of P (0.14 per cent) which was significant while the highest percentage was recorded by T_{13} (0.25). The treatments T_{13}, T_5, T_{12}, T_{11}, T_{10} and T_6 were superior to T_4, T_2, T_8 and T_7 and were on par. The treatments T_9 and T_3 were similar and were superior over the control.

From the graphical representation of the phosphorus content of the plant given in Fig. 4, it is clear that the phosphorus concentration was maximum in the split P treatment T_{13}, estimated at 15 days after top dressing at AT stage.

This was followed by T_{10} and T_{12}. The single top dressed treatments, viz., T_4 and T_5 registered lower contents of phosphorus. The control showed the least.

In general, it was noticed that the phosphorus content of the plant was higher in the split treatments of phosphorus than in full basal treatments and full top dressed treatments. It was also noticed that the two-split treatments of phosphorus were superior when compared to the three-split ones.

Phosphorus uptake

Table 7 shows data on the mean uptake of phosphorus by the rice plant at four stages viz., prior to and 15 days after top dressing at AT stage, 10 days after top dressing at PI stage and at harvest. The data on the phosphorus uptake of the rice plant at the above mentioned growth stages are graphically presented in Fig. 5.

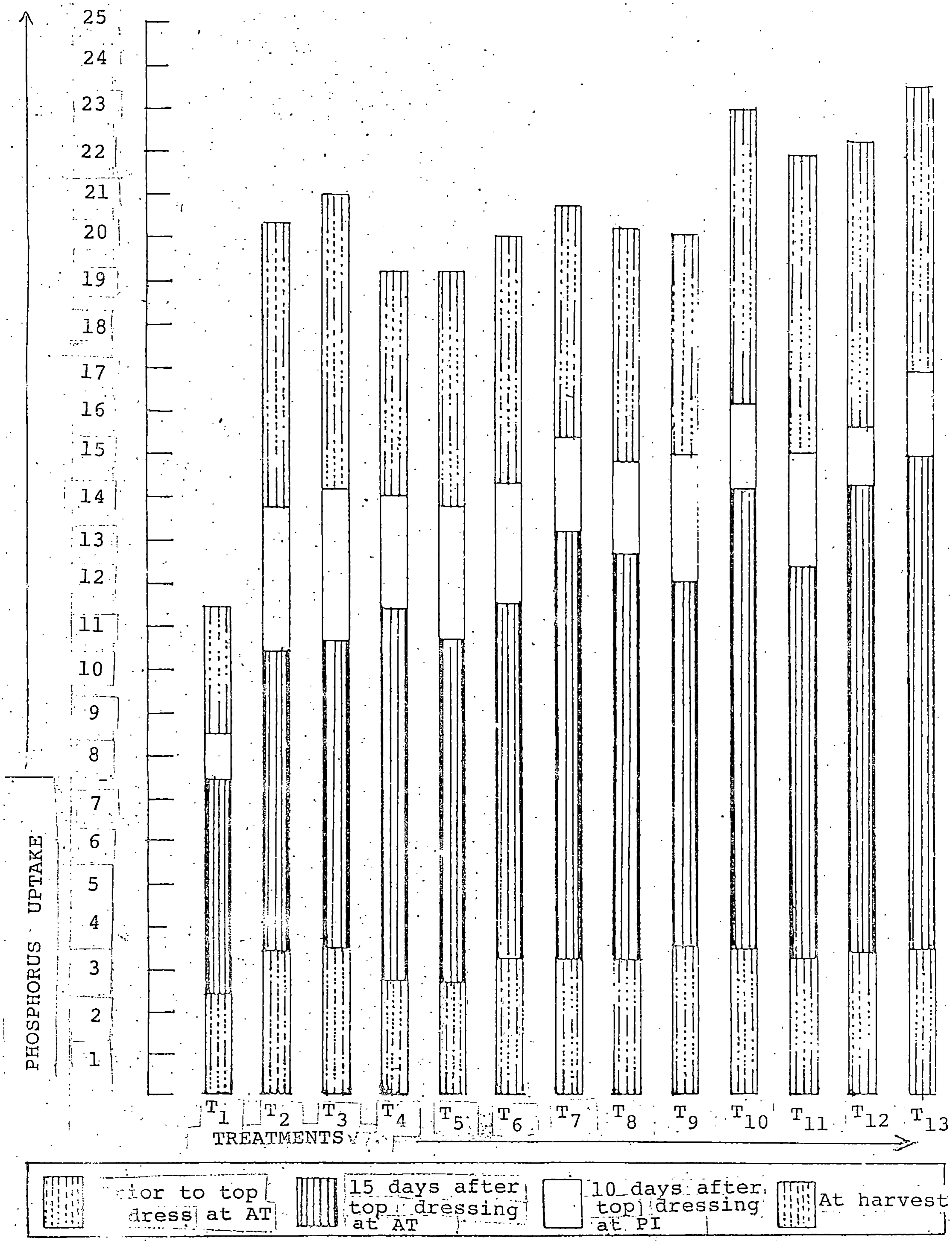
The data relating to the first sampling stage, ie. just prior to top dressing at AT indicated significant difference in the uptake of phosphorus by plant under the influence of the various treatments. All the treatments which received basal dressing of phosphorus irrespective of its source and time of application indicated similar uptake of phosphorus. Treatments without basal application

Table 7. Mean phosphorus uptake (in kg ha^{-1}) by plant as influenced by basal and top dressed P treatments

Treatments	Prior to top dressing at AT	15 days after top dressing at AT	10 days after top dressing at PI	Harvest
T_1	2.41	7.43	8.57	11.42
T_2	3.42	10.37	13.78	20.41
T_3	3.56	10.72	14.36	21.08
T_4	2.82	11.43	14.04	19.27
T_5	2.81	10.82	13.82	19.24
T_6	3.36	11.54	14.39	20.04
T_7	3.35	13.28	15.43	20.78
T_8	3.25	12.73	14.82	20.26
T_9	3.54	12.08	15.05	20.11
T_{10}	3.51	14.25	16.20	23.03
T_{11}	3.32	12.48	15.10	21.97
T_{12}	3.42	14.34	15.50	22.49
T_{13}	3.56	15.02	16.97	23.66
F	1**	44.00**	16.00**	57.05**
CD	0.29	0.89	1.42	1.03

** Significant at 1% level

FIG. 5 PHOSPHORUS UPTAKE BY PLANT (Kg ha^{-1})



of phosphorus viz. T_1, T_4 and T_5 recorded lesser uptake of P compared to top dressed treatments. The highest P uptake was recorded by the basally applied P treatments, viz. T_3 and the lowest by control.

Data relating to the phosphorus uptake at 15 days after top dressing at AT stage which was the second sampling stage indicated significant influence among various treatments. In general, the application of P in two splits viz., half as basal and half at AT, irrespective of the source of phosphorus recorded similar and increased P uptake, compared to all the other treatments. The application of P exclusively as basal recorded lesser uptake of P compared to single top dressing at AT and the three-split application. The least value of 7.43 kg ha^{-1} was recorded by control.

At 10 days after top dressing at PI stage of rice growth significant difference in the uptake of phosphorus could be noticed among the different treatments. It can be noticed that the treatments T_{13} and T_{10} which received phosphorus in two-splits showed similar and better uptake values of P compared to the rest of the treatments. Among the split P treatments, the two splits ie. half basal and half at AT recorded more increased uptake, and among the two split treatments of different P sources, the factomphos top dressed plots performed best. Among the basal P treatments, full P in the form of superphosphate recorded less uptake of P compared to full P in the form of factomphos application. The three-split treatments performed comparatively better than single top dress at AT stage. The maximum value of 16.97 kg ha^{-1} was recorded by T_{13} and the lowest (8.57kg ha^{-1}) by the control.

At harvest stage the uptake of P by plant was significantly influenced by the various treatments. The treatments T_{13} and T_{10} which received P in two splits of which the top dressing was with factomphos were on par and significantly superior over the remaining treatments. The treatments T_{12} and T_{11} were on par. The application of phosphorus in three splits was not found as good in increasing the uptake of P by the plant as the two splits. The treatments which received full P top dress showed much lesser P uptake though better than the control. The least value of uptake was recorded by the control.

Available phosphorus in the soil at different stages

Table 8 shows the available P content of soil at different stages of sampling viz., prior to and 15 days after top dressing at AT, 10 days after top dressing at PI and at harvest.

Table 8. Available P in the soil as influenced by basal and top dressed P treatments

Treatments	Prior to top dressing at AT	15 days after top dressing at AT	10 days after top dressing at PI	At harvest
T_1	25.20	21.50	18.50	20.05
T_2	41.50	33.00	29.60	35.40
T_3	42.50	35.00	30.20	36.90
T_4	25.70	38.60	30.50	35.80
T_5	25.50	37.90	29.30	34.60
T_6	30.50	38.20	29.60	36.30
T_7	32.50	39.50	30.90	35.90
T_8	31.60	38.90	30.40	36.90
T_9	32.05	37.90	29.80	35.80
T_{10}	35.40	42.50	32.64	38.40
T_{11}	36.10	41.05	31.10	37.50
T_{12}	36.17	41.90	31.50	37.30
T_{13}	37.80	43.60	34.50	39.50
F	19.09**	11.67**	4.68**	12.82**
CD	5.10	6.52	6.73	5.48

** Significant at 1% level

The data on available P status of the soil recorded just prior to top dressing at AT indicated significant difference among the various treatments. The treatments T_2 and T_3 which received the entire dose of P as basal either as superphosphate or as factomphos were similar. These two recorded higher available phosphorus compared to those which received fractional doses of basal phosphorus, which were also similar. All the treatments, where the basal application of phosphorus was skipped, recorded less of the available soil phosphorus and were on par. The highest value of 42.5 kg P ha^{-1} was recorded by T_3 and the lowest value of 25.2 was recorded by the control.

Significance in available P content of the soil was also observed among the treatments at the second stage of sampling viz. 15 days after top dressing at AT. At this stage, all the top dressed P treatments registered higher available P content in the soil over the full basal P treatments and the control. However, among the top dressed P treatments, no significant difference could be seen. The two-split P treatments were found better in soil phosphorus compared to three-split treatments and the full P top dressed treatments, though not significant. The highest value of 43.60 kg P ha^{-1} was noticed in the half basal and ½ top dressed factomphos treatment T_{13}, and the lowest (21.50 kg P ha^{-1}) was recorded by the control.

The data on the available phosphorus content of the soil recorded at 10 days after top dressing at PI indicated that all the treatments except control were similar. The control registered significantly low available phosphorus. Among the treatments, the two-split P treatments showed trends of higher available phosphorus in the soil. Between the superphosphate and factomphos treatments, the latter gave higher available P though not significant. The highest available phosphorus (34.5kg ha^{-1}) was recorded by T_{13}, while the control gave the lowest value (18.5).

The available phosphorus status of the soil estimated at harvest, contiaued to show the same trend as that of the previous sampling stage, without any significant difference among the treatments, except control. The lowest value of 20.05 kg ha^{-1} available phosphorus was recorded by the no - P control, while the two-split factomphos treatment resulted in the highest available phosphorus content (30.50).

Concentration of nitrogen in grain and straw

Table 9 provides the mean values of the nitrogen concentration in rice grain and straw estimated at the crop maturity stage.

Table 9. Mean nitrogen concentration (per cent) in grain and straw as influenced by time and method of application of P fertilizers

Treatments	Grain	Straw
T_1	1.27	0.65
T_2	1.35	0.71
T_3	1.36	0.73
T_4	1.36	0.74
T_5	1.35	0.69
T_6	1.36	0.69
T_7	1.38	0.74
T_8	1.38	0.74
T_9	1.36	0.71
T_{10}	1.40	0.75
T_{11}	1.36	0.70
T_{12}	1.38	0.73
T_{13}	1.40	0.75
F	57.80**	26.00**
CD	0.012	0.016

** Significant at 1% level

The data revealed that the different P treatment significantly influenced the nitrogen concentration in the grain. The two-split P treatments T_{10} and T_{13} where factomphos was used for top dress at AT registered highest grain nutrient content of 1.40 per cent, which was significant. The three-split treatments T_5 to T_9 and the two split treatments T_{11} and T_{12} were similar. The control recorded the least nitrogen content (1.27 per cent).

The data relating to the nitrogen content of straw also showed significant difference under the influence of applied phosphorus. The lowest nitrogen content was estimated in the control (0.65 per cent). The treatments T_{13}, T_{10}, T_8, T_7 and T_4 which received factomphos for top dressing recorded more or less similar nitrogen contents and were superior to the rest of the treatments. The treatments with superphosphate alone as the source of phosphorus were benefited less when compared to factomphos.

Concentration of potassium in grain and straw.

Table 10 provides data on the mean values on the potassium content of grain and straw estimated at the time of harvest.

The data relating to mean potassium content of grain, has indicated no significant difference due to

Table 10. Mean potassium content (per cent) of rice grains and straw as influenced by the source and time of application of phosphorus

Treatments	Grain	Straw
T_1	0.29	1.01
T_2	0.39	1.05
T_3	0.40	1.06
T_4	0.34	1.09
T_5	0.34	1.05
T_6	0.36	1.09
T_7	0.38	1.13
T_8	0.36	1.06
T_9	0.35	1.07
T_{10}	0.39	1.16
T_{11}	0.38	1.12
T_{12}	0.36	1.11
T_{13}	0.40	1.13
F	1.56 NS	<1
CD	-	-

NS Not significant

the different treatments of phosphorus. The control which did not receive any phosphate fertilizer has evidently recorded the lowest potassium concentration.

The data pertaining to the potassium content of straw also revealed the absence any influence due to the split application of phosphorus. Lowest potassium content of straw could be recorded in the control.

Correlation studies

The values of simple correlation coefficients are presented in Table 11.

Correlation studies were conducted on the available phosphorus content of the soil estimated at different growth stages and the plant P content as well as grain yield. The relationship between the plant P content estimated at different stages and grain yield was also studied.

Positive and significant correlation existed between the available P in the soil and plant phosphorus estimated at 15 days after top dressing at AT, 10 days after top dressing at PI and at harvest. The available P in the soil was also positively and significantly correlated with grain yield. Similar relationship existed between the plant P content estimated at different stages and the grain yield as well.

Table 11. Correlations among various characters

Sl. No.	Characters	Correlation coefficients
1.	Available P in soil at 15 days after top dressing at AT (kg ha^{-1}) and P content of plant	0.3538*
2.	Available P in soil at harvest (kg ha^{-1}) and grain P	0.4049*
3.	Available P in soil at 15 days after top dressing at AT (kg ha^{-1}) and grain yield	0.3186*
4.	Available P in soil at 10 days after top dressing at PI (kg ha^{-1}) and grain yield	0.4121*
5.	Available P in soil at harvest (kg ha^{-1}) and grain yield	0.4312
6.	Phosphorus content in plant (per cent) at 15 days after top dressing at AT and grain yield	0.8696*
7.	Phosphorus content in plant (per cent) at 10 days after top dressing at PI and grain yield	0.8226*
8.	Phosphorus content in grain (per cent) and grain yield	0.8951*

* Significant at 0.05 level

DISCUSSION

DISCUSSION

The results of the field experiment to study the feasibility of top dressing of water soluble phosphatic fertilizer on the yield of rice are discussed below.

Effect of top dressing of phosphate fertilizer on the growth and yield characters of rice.

1. Plant height

From the observations just before top dressing at AT stage as recorded in Table 2, neither the source of soluble P nor the combination of phosphate fertilizers nor the time of P application was found to exert any significant influence on the height of plant. Increased plant height is the result of uniform basal application of nitrogen to all the plots. Though P was basally applied to some plots, its effect was too early to be manifested in the growth characters due to the possible fixation of phosphorus as well as due to the initial stage of root development with its limited ability to absorb nutrients.

These results are mostly in agreement with the findings of Gopal Rao (1972); and Bhardwaj et al. (1974), who had reported the absence of any influence of time of application of P on the height of rice. However, Subramonian (1970) and Singh et al. (1987) observed that the basal application of P enhanced the plant height.

The results recorded at 15 days after top dressing at AT have indicated that the time and form of application of phosphate fertilizer had significantly influenced for increasing the plant height. In general, it was found that the top dressing of factomphos at AT stage is effective in increasing the plant height. The maximum height of 59.6cm was recorded by T_{13} which received factomphos, both at basal as well was at top dressing at AT stage. When compared with this, the performance of the treatments T_{11} and T_{12} which received top dressing of superphosphate at this stage was not very encouraging and this was on par with the full P basal treatments T_2 and T_3.

The increased plant height due to top dressing by factomphos may be due to the effect of nitrogen present in factomphos as well as the increased ability of roots to absorb nutrients. Moreover, it was also observed that all the treatments which had received top dressing of factomphos have behaved similarly with regard to the plant height at this stage.

Bhardwaj et al. (1974) reported that application of phosphorus half at planting and half at tiller initiation favoured in height of plant. Vijayan et al. (1977) reported that top dressing of P increased the height of plant at all the stages compared to no P control.

At the harvest stage, however, no significant difference existed among the treatments, probably due to the uniform NPK application in all the plots and the greater influence exerted by the absorbed nutrient on the improvement in grain yield in preference to the vegetative growth. In addition, the level of NPK was maintained uniform in all the treatments, only the source of P and time of application varied. Sahu and Sahoo (1969) have reported similar non-significant results in rice.

2. Number of tillers

It is seen that neither the time of application nor the source of phosphorus could influence the total number of tillers. The result is in agreement with the findings of Sahu and Sahoo (1969), Subramonian (1970) and Bhardwaj (1974). However, the findings of Roy and Jha (1987) and Singh et al. (1987) are in favour of enhanced tiller count resulting from full basal application of phosphorus.

Tiller count observed at 15 days after top dressing at AP stage indicated no significant difference between full P basal treatments and two-split P treatments, even though there was significant difference among the rest of treatments. However, the two-split P treatments viz. T_{13}, T_{10}, T_{11} and T_{12}, invariably resulted in higher tiller count compared to the full P basal treatments. The full top dressed P treatments performed less, compared to the three-split treatments. The maximum tiller count of 413.33 was recorded by T_{13} which received factomphos for basal as well as top dressing at AT followed by T_{10} with 411.67. The lowest number of tillers was recorded from the control plot (316.67). The increased tiller count resulting from top dressing of phosphorus can be attributed to the increased absorption of N and K under the influence of added P, which has strengthened the root system. The result is in conformity with the findings of Sethi (1943) who reported that application of N and P at 30 DAT resulted in maximum number of tillers that at any time of application. Vijayan et al. (1977) also observed that top dressing of 40 kg P ha^{-1} increased the number of tillers than basal application.

At harvest stage also, the treatments which received top dressing of P in addition to a basal dose of P produced higher number of tillers irrespective of the source of P. All the two split P treatments were on par. Among these, the treatment T_{13} which received factomphos for basal as well as top dressing at AT stage recorded the maximum tiller count of 514.17 followed by T_{10} (501.67) with half dose of P applied as superphosphate as basal and half top dressed as factomphos at AT stage. The increased and steady availability of P resulting from split application may be the reason. The treatments T_2 and T_3 which received the entire P as basal were found superior to the single top dressed P treatments at AF stage and the three-split treatments. The lowest value was recorded by the control (336.67).

Yield attributes

1. Number of productive tillers per square metre

The results in Table 4 revealed that basal and top dressing of phosphate fertilizer significantly influenced the mean number of earheads per square metre.

The phosphorus is known to have the major function in rice in improving seed set. Since the productive tiller count is an yield parameter, the quality of which is decided during the period between AF and PI stage, when the element is actively absorbed, it is probable that the P absorbed during this period has contributed more towards increased productive tiller count. Top dressed P during this period is immediately available to the crop which has already been benefitted by an earlier instalment of P basally applied. The basal as well as the freshly top dressed P have together enriched the crop with sufficient amount of the nutrient, which is reflected in the increased productive tiller count. The results revealed that treatment T_{10} and T_{13} yielded maximum number of productive tillers. These are the treatments which have received two instalments of P viz., one as basal and other top dress at AT stage. In both T_{10} and T_{13}, factomphos has been used for top dressing at AT stage which has produced better yield of productive tillers compared to the corresponding treatments top dressed with superphosphate. It is also noted that the treatment T_{13} which has received factomphos for both the basal and top dressing has produced the maximum productive tillers (491.66), though it was similar to the other two-split treatments.

The present results are supported by the findings of Bhardwaj et al. (1974) and Vijayan et al. (1977).

2. Mean length of panicle

As is evident from the Table 4 this yield attribute remained unaffected by either the source of phosphorus or combination of fertilizers or the time of application.

Sahu and Sahoo (1969) and Gopal Rao (1972) have reported that the time of phosphorus application had no effect on panicle length, though Singh (1987) found enhanced length of panicle by full P basal application.

3. Number of filled grains per panicle

The results in Table 4 showed increase in the mean number of filled grains per panicle resulting from the top dressing with phosphorus though not significant. The number of filled grains per panicle was observed to be higher in the two-split plots, even though they were on par with full basal treatments, and three-split treatments. The highest count was recorded by T_{13} (67.37) which received ½ P as factomphos as basal and half at AT as factomphos, followed by T_{10} (63.27). However, between the top dressed treatments, the different combinations of factomphos and superphosphate failed to show any significant difference in this parameter. It was found that single application of P at AT, as well as its application in three splits with the third application beyond AT stage was not beneficial when compared to two-split P treatments or full basal treatments.

The results are, however, not in conformity with the findings of Sahu and Sahoo (1969), Subramoniam (1970), Gopal Rao (1972) etc. who could not obtain any statistical significance with regard to this yield parameter.

Phosphorus is essential for ensuring satisfactory filling of grain. When full dose of P is applied as basal, some quantity may be utilised for the development of initial root system, while the remaining part gets fixed in the soil and its further availability to the plant is rather slow particularly in acid soils. However, if half the recommended dose is applied at a later stage say at AT, when the roots are very active, the plant can absorb more P at this stage without giving much chance for fixation. It was also observed from uptake studies that maximum quantity of phosphorus was absorbed during the period between the stages of AT and PI. Hence the application of P beyond this stage is not likely to be utilised by the plant for productive purpose. This might be the reason for the enhanced number of filled grains per panicle in the top dressed treatments.

4. Number of chaff per panicle

Results given in the Table 4 revealed that top dressing of phosphorus resulted in the reduced number of unfilled grains per panicle compared to its full basal application, eventhough they were statistically similar. The applications of P in two splits, half as basal and half at AT, irrespective of the type of fertilizer and its combination showed lesser number of chaff per panicle. The control treatment, had the highest chaff content and that was followed by the full top dressed P treatments T_4 and T_5. Three split treatments invariably recorded higher chaff content than the two-split treatments. Splitting and application of P beyond AT stage does not appear to be desirable.

The mean values of the number of chaff per panicle recorded for T_{13}, T_{12}, T_{11} and T_{10} were 14.67, 15.33, 15.96 and 16.00 respectively, as against the highest mean chaff content of 26.66 in the control.

The extent of chaffness in rice crop is decided mainly by the availability of phosphorus in the plant at milky and grain setting stages. In this connection the phosphorus applied to the soil at AT stage or post AT stage is most beneficial to the crop. The basally applied P undergoes fixation in acid soils and its availability to the plant is rather slow. At the AT stage, when soluble P was freshly applied, the plant is likely to be benefitted since this top dressing is immediately followed by the panicle initiation stage when the nutrient content of the plant should be optimum for ensuring full maturity of the grains. Though the reduced chaff content can also be due to various other constraints such as pests, diseases, drought etc. the result obtained need not necessarily be the consequence of phosphorus application.

5. Thousand grain weight

The results in Table 4 revealed that the thousand grain weight was not influenced by the time of application, source or combination of P fertilizers. The non significance due to time of application of phosphorus on the thousand grain weight parameter was also supported by Sahu and Sahoo (1969), Gopal Rao (1972), Vijayan et al. (1977) and Singh et al. (1987).

Yield of grain

From the results furnished in Table 5 the mean yield of rice was found to be influenced by split application of phosphorus. Top dressing of paddy with water soluble P in addition to a basal dose of P was found to be more beneficial in increasing the grain yield than the basal treatments of P alone, though not significant. Highest grain yield of 3363 kg ha^{-1} could be obtained from the factomphos application in two splits viz. half dose as basal and half as top dress at AT stage. The other two-split treatments also behaved almost similarly with not much difference in grain yield. Between the three-split treatments there was no significance but they showed significant difference over the control and the trend towards decreased grain yields compared to two-split P treatments and single basal P treatments could be noticed. Yogeswar Rao et al. (1973) could obtain increased grain yield by P application to IET 1991 (Sona) rice in three splits. Chandrasekharappa (1985) obtained highest yield by NPK application made in three splits or two splits.

However, the Package of Practices Recommendation of KAU (1986) insist on basal dressing of the entire P presumably because the applied P in acid soils undergoes temperory immobilization through fixation and gets transformed in to iron and aluminium phosphates from which the P gets released only slowly or gradually to meet the crop requirement up to the completion of its reproductive phase. Basal dressing of the entire dose of P is recommended since the plant in its initial stages of growth in the main field does not need much phosphorus. Under such situations, the phosphorus reserve gradually supplies P to the roots as the plant grows up to PI stage. Several farmers cultivating rice in Kerala either skip the basal dose or use only a small quantity of phosphorus as basal treatment and apply either the entire P or larger quantity of P as factomphos when the crop reaches the active tillering stage or approaches the PI stage and claim better yields of rice. The results of the present study also indicated that top dressing of phosphorus is beneficial. Split application of phosphorus may be useful in cases where the initial part-supply of the nutrient as basal is sufficient to meet the growth requirements of the crop or when full basal application is difficult under flooded or water stress situations in the field. Halappa et al. (1970) and Gupta et al. (1975) have suggested that for rice, 50 per cent of P should be applied at transplanting and the rest 50 per cent at tillering. Almost similar observations have been made for paddy (Rao and Bhardwaj, 1973). Recently pot culture studies have shown that DAP applied in splits was superior to full basal application of the fertilizer to wheat as judged by grain yield, total P uptake and per cent Pdff values (Raju, 1985). It was also revealed that the rice crop showed better utilisation of P from DAP than SSP when applied in splits. Alternate tagging technique indicated that the utilisation of phosphate from top dressing was more in case of rice, wheat and barley, while maize absorbed more from basal dose (Raju, 1985). Split application of P at 60 kg P_2O_5 ha^{-1} as DAP resulted in higher utilization of P in the case of rice under field conditions as compared to full basal application of the fertilizer, the respective figures being 12.4 and 10.0 per cent respectively. Similarly in the case of wheat, split applications of the P resulted in greater uptake of fertilizer phosphorus (Raju, 1985). In the present study although the two-splits and the three-splits of P application have given definite indications of significantly higher grain yield over the control, the full basal treacments and two-splits of ½ basal and ½ top dress were found to be similar and were in the order $T_{13} > T_{12} > T_{10} > T_{11}$. The three-split P treatments wherein the third split was given at near PI stage, have been found to be inferior to the two-split treatments, probably because, the P contained in the plant at the AT stage is the deciding factor with respect to grain yield. Moreover, the phosphorus applied at the PI stage can also undergo fixation in the soil and the P released gradually from the fixed form is not fully useful to the plant since the grain characteristics have already been decided under the conditions of available quantities of the plant nutrient prior to PI stage.

Active tillering is one of the major critical growth stages of rice, when roots are very active and capable of absorbing considerable quantities of the nutrient. With the availability of adequate nutrients at this stage, the vegetative as well as the ensuing reproductive stages are benefitted. Top dressing at the AT stage can therefore be expected to be helpful in boosting grain yield as well as the uptake of N, P and K which together constitute the deciding factor for the formation of quality grain. The fact that no significant difference with regard to grain yield existed among the two-split or three-split treatments given either as single superphosphate or as factomphos or both, gives an indication that the source of P has no special role in deciding the yield. The trend in increasing the yield by the factomphos included treatment over single super-phosphate as indicated in the study is, however, statistically not significant. Samad et al. (1956) and Vijayan et al. (1977) have reported maximum grain yield by soil application of phosphorus at 25 DAT as top dressing. Fried and Breeshart (1963) reported that P applied at later stages was as effective as its basal application. Bhumbla and Rana (1965) and Ray et al. (1966) obtained highest grain yield by NPK application at AT stage and reported that application of P at boot leaf stage gave lower grain yield than when applied at maximum tillering stage. Bhardwaj et al. (1974) obtained highest grain yield when P was applied at planting or at tillering or was split between these two stages but delaying the P application upto PI stage reduced the yield. In the present study also the third split dose was top dressed at PI stage (45 DAT) and those treatments have given lower grain yields than the two-splits where the second split dose was top dressed at AT stage (20 DAT). The findings of Rana and Bhumbla (1969), Eid et al. (1970), Halappa et al. (1970), Mellu and Bhandari (1978), Choudhari and Virmani (1975), Katyal (1978) and many others are in favour of higher grain yields resulting from split - P applications to rice. Field experiments conducted at Rice Research Station (RRS), Monkompu, Kerala during 1981 puncha season, revealed maximum grain yield where P was applied half as basal and half at AT stage. Later, in the experiment repeated in 1983 Puncha season, 3 splits of P application resulted in maximum grain yield but none of these results was significant. The better performance of top dressing with 20:20 complex fertilizers applied at 50 DAS at Monkompu indicated the desirability of top dressing of P though the result was not significant. Tagged p^{32} experiments conducted at Monkompu also revealed the desirability of top dressing rice with complex fertilizer (20:20 ammophos) though again the results were not significant. In view of this, in terms of economics of phosphate application, the present results are in favour of the single nutrient carriers as against the complex viz., factomphos. However, an adaptive trial conducted in farmer's field under the Operational Research Project at Monkompu during Rabi of 1989-90 indicated significantly higher grain yield in rice by full dose of P_2O_5 application as factomphos at 15 DAS.

Yield of straw

Yield data in relation to straw as governed by time and sources of P fertilizer application as furnished in Table 5 indicate the desirability of top dressing of P fertilizer in addition to a basal dose. As with grain yield data, the two-split P treatments, in general, performed better with regard to straw yield also. Among the two-split P treatments, the treatment where factomphos alone was applied as half basal and half top dress at AT stage, ie. T_{13}, has resulted in the highest straw yield, although the yield differences were not significant among these two-split treatments viz., T_{10} to T_{13}. The results agree with the findings of Gupta et al. (1975) and Rabindra (1978) who found that 50 per cent P applied at transplanting and 50 per cent at tillering at 3 weeks after transplanting resulted in highest straw yield. Chandrasekharappa (1985) also has reported similar findings. The treatment which received the entire dose of P as abasal dressing was next in the decreasing order of straw yield.

Among the basally treated plots, the plot which received factomphos as basal gave higher straw yield compared to superphosphate though significant difference could not be noticed.

The treatments which received P exclusively as single top dress (T_3 and T_4) gave reduced straw yields with no significant difference among them. The lowest straw yield was recorded in the no P control indicating the need of phosphorus fertilisation for increased yield of straw.

The three-split treatments also resulted in reduced straw yield, probably due to the fact that the last top dress at the PI stage might not have benefitted the rice crop to the extent expected. The comparatively higher straw yield in the two-split P treatments over the three-split can lead to the inference that the P applied after AT stage may not be fully helpful in boosting straw yield since the reproductive phase which starts immediately after the active tillering may also need phosphorus. The need of an adequate supply of phosphorus from transplanting upto booting stage for rice has been indicated by Reyes et al. (1962). Samad et al. (1956) and Vijayan et al. (1977) obtained maximum yield of straw from soil application of 60 kg P_2O_5 ha^{-1} at 25 DAT. The present results are in agreement with the findings of Bhumbla and Rana (1965) that the application of N, P and K at maximum tillering stage would result in highest straw yield. The desirability of split application of phosphorus has been indicated by Eid et al. (1970) and Halappa et al. (1970).

Phosphorus content in plant

The data relating to the phosphorus content of the rice plant at the four stages of its growth under the influence of time and sources of phosphorus application as furnished in Table 6 gave indications of higher plant phosphorus concentrations in the two-split P treatments. Although the single basal treatments of phosphorus registered higher plant P during the pre-top dressing at AT stage, significant difference over the two-split P treatments could not be observed. This leads to the inference that even if full dose of phosphorus is applied, only part of it is absorbed by the plant and the rest gets fixed in the soil. This finding is in conformity with the earlier findings of Patil et al. (1959) who revealed that single application of P upset the balanced nutrition of nitrogen and phosphorus and recommended the split application of phosphorus in small quantities at various growth stages. The control treatment had 0.20 per cent plant phosphorus at this growth stage which was significantly low. The single top dressed P treatments T_4 and T_5 also registered significantly low plant phosphorus content, since the plants under these treatments are devoid of any phosphorus at this stage.

The treatments which received the entire dose of P as basal (T_2 and T_3) and the treatments which received half the dose (T_{10} to T_{13}) have evidencly resulted in the higher plant P concentration at this growth stage, compared to the treatments which either received no phosphorus (T_1, T_3, T_4) or ¼th dose (T_6 to T_9). Between the full basal application, factomphos performed better. The better recovery of phosphate from ammophos than from superphosphate by rice has been reported earlier by Panse and Khanna (1964) and Engelsted and Terman (1967) and this may be attributed to lesser reaction of phosphate ion with soil colloidal complex.

The results indicate that the seedlings immediately after transplanting are unable to absorb the entire dose of applied P due to their underdeveloped root system and also due to the fixation of part of the applied phosphorus in the soil and its resultant lesser availability.

With regard to the growth stage viz., 15 days after top dressing at AT and 10 days after top dressing at PI the plant P content was found to follow more or less similar trends, with higher plant P in the two-split treatments. However, the plant P content at 15 days after top dressing at AT was also fairly high compared to the full top dressed and full basal treatments and that the two-splits and three-splits were significantly different. The control as well as the treatment which received single basal P had significantly low plant phosphorus contents over the two-split treatments.

This is in conformity with the earlier finding of Rabindra (1978) that application 50 kg P_2O_5 ha^{-1} in two splits (½ basal + ½ tillering) recorded higher P content of leaves compared to single application treatment (full basal) and no P control.

At the AT stage the higher activity of the plant roots enabled more efficient absorption of the nutrient immediately when applied to the soil which was reflected in the higher plant P content in all the top dressed treatments, while in the single dose basal treatment, the fixation of the applied P and consequent restricted availability might have contributed towards its lesser absorption by roots and lower plant P content. The treatments T_4 and T_5 which have received the entire phosphorus as single top dress recorded least plant P content, as in the control, probably due to the complete absence of the basally applied nutrient in these treatments. This observation reveals the desirability of applying at least a portion of phosphorus as basal.

The phosphorus content of the plant estimated at 10 days after top dressing at PI stage indicated that the two equal splits of P either as superphosphate and factomphos (T_{10}) or factomphos and factomphos applied basally and top dressed respectively, performed better over the other treatments. In the treatments T_{10} and T_{13}, the water soluble phosphorus top dressed in the form of factomphos has resulted in the increased plant phosphorus content which can be attributed to the influence of the ammonium component of the complex fertilizer. The presence of ammoniacal nitrogen must have provided more favourable conditions and have influenced better absorption of phosphorus by the rice roots. It is also clear from the Table that the treatments T_4 and T_7 which have also received factomphos exclusively for top dressing performed similarly along with T_{10} and T_{13}. Similar results have been reported by Shinde and Patil (1980) who compared N alone and with P and K in different forms and found that application of ammophos gave the highest yield. According to them ammophos was better, due to its granular nature, water soluble form of P and ammoniacal form of nitrogen utilised by rice. Raju (1983, 1985) also noted the superiority of Diammonium phosphate complex fertilizer over single superphosphate.

With regard to the phosphorus content of the grain, significant difference could be observed in the treatments. The treatment T_{13} which received factomphos for top dressing has resulted in the maximum grain phosphorus content. However, the treatments T_{10} and T_{12} were on par with T_{13}. Basally applied treatments T_2 and T_3 and the three-split treatments T_7 and T_9 also recorded nearly identical grain phosphorus contents. Similar results have been reported by De Datta (1978). According to him application of phosphorus is essential for root elongation when applied during the tillering stage and it is most efficiently utilised for grain production. The better recovery of phosphate from ammophos than from superphosphate by rice was attributed to lesser reaction of phosphate ion with soil colloidal complex as reported by Panse and Khanna (1964) and Englested and Terman (1967). Bhumbla and Rana (1965) reported that application of P at maximum tillering stage resulted in higher phosphorus content in rice grain.

It is clear that the treatments T_{10}, T_{12} and T_{13} have given indications of high plant P content during all the three previous sampling periods, which has resulted in greater translocation of the nutrient in to the grain.

Phosphorus content of the straw also differed significantly over the control. However, much difference in the phosphorus content of straw could not be observed among the treatments. In general, it was found that the two-split treatments behaved better in this regard. These treatments showed uniformly better response during all the sampling stages. It has to be noted that the treatments T_4 and T_5

which are the solely top dressed treatments have registered grain P contents not much different from those of the two-split treatments.

The percentage content of the plant phosphorus was found to increase upto the second sampling period which nearly coincides with the maximum tillering stage of the crop and thereafter it decreased gradually. In fact the maximum absorption of phosphorus in rice roots normally occurs at the active as well as the maximum tillering stages.

The results are in agreement with the findings of Rai and Murthy (1976) who noticed increased P content in plants from 14 to 42 DAP and slow P absorption in the early stages and retarded during lag phase. Also from the graphical presentation of the peak stage of phosphorus content of plant in Fig. 4 it is clear that maximum plant content of P was recorded when estimated at the stage of 15 days after top dressing at AT which corresponds to 35 DAT, ie., near PI stage. It can thus be presumed that the peak period of absorption is somewhere between AT and MT stages and in any way not at or beyond PI stage.

Plant phosphorus estimated at 10 days after top dressing at PI stage showed decreases. This might be due to the dilution effect resulting from the increased vegetative growth of the crop.

Among the three-split and two-split P treatments, the latter has given better results in relation to the plant phosphorus content. This might be due to the supply of the remaining half of the recommended dose of P at the critical growth stage of maximum tillering, when absorption by root is at its maximum, while in the three-split treatments, only one fourth of the recommended dose was basally applied and half top dressed at AT stage, thus making up only three fourth of the total dose. The remaining one fourth dose was applied only at the PI stage part of which might have been fixed and part might have been absorbed. However, this partly absorbed phosphorus might not have contributed towards the increased grain P content. From the study it is inferred that the last stage of top dressing should be limited to the maximum tillering period and that any P applied beyond PI stage may not be much helpful in bringing about increased plant P content.

The results in Table 6 also indicated that factomphos top dressing at active tillering stage is more beneficial in increasing the plant phosphorus content than single superphosphate top dressing irrespective of whether the basal dressing has been given using single superphosphate or factomphos, when compared to the Package recommendation of full basal P application.

Phosphorus uptake by plant

Uptake studies indicated a progressive increase in phosphorus uptake with increase in rice growth which continued up to maturity. Results on P uptake by rice at pre-top dressed stage at AT given in Table 7 indicate similar response by all treatments receiving basal phosphorus which reveals the usefulness of basal application. Highest phosphorus uptake was recorded in T_3 where the entire dose of P in the form of factomphos was basally applied, while under similar situations the superphosphate basal treatment registered lower uptake, though not significant. It has to be noted that the treatments T_1, T_4 and T_5 have received no phosphorus at all till the first sampling stage and the crop must have utilised only the native available P which was low.

At 15 days after top dressing at AT stage, the two-split P treatments showed higher phosphorus uptake in general. The plant at this stage has developed a fairly strong root system which could absorb more phosphorus from the readily available top dressed prosphorus pool. This is further evidenced by the observation that the three-split treatments also recorded higher uptake, but significantly less, probably because these treatments have so far received only three-fourth the recommended dose as against the two-split treatments where the entire dose has been utilised. The lower uptake noticed in the basal treatments is attributed to fixation and consequent lesser availability of the nutrient to the crop. The control which has received no applied P has evidently shown the least uptake.

AT 10 days after top dressing at PI also, the same trend of P uptake could be observed. All the three-split P treatments have recorded higher uptake of the nutrient and were similar to the two-split treatments viz., T_{11} and T_{12} of superphosphate + Superphosphate and factomphos + Superphosphate respectively. However, the two-split treatment T_{13} followed by T_{10} have resulted in the highest P uptake which is indicative of the superiority of factomphos top dressing at AT. The uptake in the exclusively basal treatments T_2 and T_3 has improved though not to the extent expected. Between the treatments T_4 and T_5 which received the entire P as single top dress at AT stage, the superphosphate gave lower estimates compared to factomphos, though not significant. The fairly high uptake in the factomphos top dressed treatment is attributed to higher absorptive tendency of the already developed root system under the influence of sufficient nitrogen.

The cumulative uptake of phosphorus observed at harvest stage was also significantly higher in the two-split P treatments, ie., T_{13} and T_{10}, where factomphos was used for top dressing. The treatments T_{11} and T_{12} where top dressing was done with superphosphate recorded the next higher estimate of uptake. It can be noticed that these treatments continued to show better indications of nutrient uptake throughout the crop period. The highest P uptake in these treatments was also reflected in the yield of grain. The three-split treatments and full basal treatments were similar in this regard. Raju (1983, 1985) has reported higher dry matter yield (DMY) and uptake from the split application of phosphate as DAP compared to the basal application, while split application of superphosphate reduced the DMY and yield over its full basal application, which has to be attributed to more intimate association of NH_4^+ ion. Riley and Barber (1971) have proposed evidences for the presence of ammoniam ions around the root surface, which could increase the uptake of phosphate anion by root cell, probably due to the involvement of exchange of ammonium ions for hydrogen ions, which could make the soil acidic near the root and raise the concentration of phosphate ion in the root vicinity. Higher uptake of phosphorus from complex fertilizers by crop has been reported by Gupta et al. (19

Sahu and Dash (1972) and Shinde and Patil (1980). Panse and Khanna (1964) and Engelsted and Terman (1967) also reported the better recovery of phosphate from ammophos than from superphosphate by rice.

Available phosphorus in the soil at different stages

From Table 8, it is clear that at the pre-top dressed stage prior to AT, better soil enrichment by phosphorus has occured in the full basally treated plots. This is expected, since all the other treatments are either fully devoid of any applied P or have received only fractional dose of P at this stage. Part of the basally applied phosphorus might have undergone fixation in the acid soil while part of it might still be in the available form, which can account for the higher available P content in the full basal treatments than in the other partial basal P application, where the available phosphorus content of the soil is also proportionately lower. Between factomphos and superphosphate treatments there was no significance.

At the second stage, however, the full basal treatments, T_2 and T_3 have registered lower available phosphorus contents in the soil compared to others (except control). It is to be noted that these plots have not received any phosphorus other than the basal dose and a sizeable portion of the available phosphorus must have already been utilized by the plant during its actively growing stage, namely the post - AT stage or maximum tillering stage. In general, all the top dressed P treatments were superior over the full basal treatments with regard to the increased availability of phosphorus in the soil.

Similarly, all the top dressed P treatments registered more or less identical available P values, with a trend towards still higher availability in the two-split P treatments (T_{10} to T_{13}). The steady supply of phosphorus to soil through two or three split applications has resulted in the uniform building up of the available phosphorus and thereby in its enrichment in the soil. Between the two-splits and three-splits, the former had higher available phosphorus content in the soil, presumably due to the effect of full dose in preference to only three fourth of the recommended dose of P in the latter, which has gone in to the soil till this stage.

With regard to the third and fourth sampling stages, viz., at 10 days after top dressing at PI and at harvest, all the treatments except control were similar but significantly superior over the control, which is evidently the result of full dose of P received by all the treatments except the control, where no phosphorus has been applied. The higher contents of available P in the factomphos treated soils, compared to superphosphate, are explained as due to the influence exerted by the accompanying NH_4^+ ion in the former, which through its involvement of exchange for hydgogen ions in the soil could make the soil acidic near the root and raise the concentration of phosphate ion in the root vicinity. By this process, not only the absorption of phosphorus by plant root is favoured (Panse and Khanna, 1964) its availability from fixed form enhanced (Riley and Barber 1971).

Nitrogen concentration in grain and straw

The nitrogen concentration in the rice grain was found to be influenced by the different treatments. It could be noticed in Table 9 that the factomphos top dressing could significantly increase grain nitrogen. The favourable influence on the root zone through fresh addition of nitrogen as ammophos has helped in the increased absorption of nitrogen from the soil during the active tillering and maximum tillering stages when the need for nutrient is also more. This absorbed nitrogen must have been effectively utilized by the crop in the post flowering phase. The three-split treatments were not found inferior over the two-split treatments, thereby indicating the usefulness of the ammonium constituent in ammophos top dressed at the critical growth stages of the crop.

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As in the case of grain N, the straw N also was influenced by the treatments particularly by the top dressed factomphos. It was also noticed that all the factomphos top dressed treatments were similar. These were superior over the superphosphate top dressed treatments which further confirms the beneficial role of N P complex fertilizers if top dressed.

Potassium concentration in grain and straw

Table 10 reveals that neither the source of applied P nor the time of its application had any significant influence in building up the potassium concentration of grain or straw.

SUMMARY

SUMMARY

A field experiment was conducted in the wetlands of the Instructional Farm, College of Agriculture, Vellayani, during the second crop season of 1988 to find out the feasibility of top dressing paddy with two water soluble phosphatic fertilizers. Ammophos (factomphos) and superphosphate were used in the study as the source of phosphorus. These were applied in splits at three stages viz., as basal prior to planting, as top dressing at the active tillering and panicle initiation stages. The levels of N, P and K were as prescribed in the Package recommendations. The experiment was laid out in simple randomised block design with thirteen treatments and three replications. The paddy variety used was Jyothi.

The soil and plant samples were collected at different stages viz., prior to top dressing at AT, 15 days after top dressing at AT, 10 days after top dressing at PI and at harvest and were analysed for the available phosphorus in the soil and the phosphorus concentration in the plant. The data generated from the field experiment and laboratory studies were subjected to statistical analysis to bring out significance if any, of top dressing with phosphorus in addition to a basal dose on the growth characters and yield

and yield parameters. The important findings from these studies are summarised below.

1. The mean height of plants recorded at 15 days after top dressing at AT stage was found to be significantly influenced by the treatments over the control. Maximum height was recorded by the two-split treatment which received factomphos both for basal as well as for top dressing at AT stage. However, at harvest, the treatment differences could not be seen.

2. The mean tiller count showed significant differences, only during the post - active tillering and harvest stages with maximum count in the two-split P treatment where factomphos was used. Between the three-splits and two-splits, the performance by the latter was better.

3. The time of application of phosphorus, in general, significantly influenced the number of productive tillers over the control. The two split P applications where factomphos was used for the second split gave maximum productive tillers per sq.m. Single basal, single top dress and three-split P treatments were on par and were inferior. Of these three, the single top dress had the least effect.

4. Neither the source of phosphorus, nor the time of application had any influence on the mean length of panicle.

5. The filled grains per panicle was influenced by the different P treatments. Single basal application and the split application were similar and showed encouraging trends. Full top dressed treatments wereinferior.

6. Significant difference in the chaff content could not be seen between the two-split and full basal treatments. These two-split treatments which produced the least chaff content, were similar. Entire P top dressed and the three-split P applications recorded the higher chaff content.

7. The thousand grain weight was not significantly influenced either by the source of phosphorus or by the time of application.

8. The application of P in two splits of half basal and half top dress at AT resulted in increased grain yield which was significant over the control, three splits and the single top dressed treatments. The two-split treatments and the full basal treatment were similar in their influence. Between superphosphate and factomphos used for top dressing, no significant difference could be noticed. In general, the full top dressed P and the three-split treatments were similar and both were inferior.

9. With regard to straw yield, the phosphorus applied in two splits showed better performance when compared to the others. However, among the different treatments, there was no significant difference. Control was significantly inferior. Between superphosphate and factomphos used in the two-split treatments, the latter was found better. The full top dressed and the three-split treatments were similar and gave lower straw yield.

10. It was seen in general, that the phosphorus concentration of the plant increased with the growth of plants up to a maximum till the maximum tillering stage and there after showed decreases.

11. Significant difference in plant phosphorus content could be noticed among the different treatments during all the four sampling stages studied.

12. Higher plant phosphorus content could be estimated in the two-split P treatments during growth stages, viz., 15 days after top dressing at AT and 10 days after top dressing at PI stage.

13. The phosphorus content of the rice grain showed no significant difference between the treatments of full basal phosphorus and the split P applications. The full top dressed P treatments and the control had low grain P contents.

14. The phosphorus content of the straw followed more or less similar trend as that for the grain.

15. Comparatively higher phosphorus uptake by rice could be noticed in the two-split P treatments, during the later sampling stages. The maximum P uptake was recorded in the factomphos treatment as against superphosphate.

16. Available phosphorus in the soil was initially higher in the full basal treatments. However, beyond the active tillering stage, the two-split P treatments recorded increased available P in soil and at harvest, no treatment significance could be noticed except for the control, which recorded lowest available phosphorus.

17. The nitrogen concentration of the grain and straw was influenced by the top dressed factomphos treatments, which showed better performance over superphosphate thereby indicating the nutritional benefits accrued from the top dressed NP complex fertilizer.

18. The potassium concentrations of the grain and straw were seen unaffected by the source of applied phosphorus as well as the time of P application.

19. Correlation studies indicated positive and significant correlations between available P in the soil and plant P content. Similar relationship was also noticeable between the plant P content and grain yield.

From the investigation carried out it was inferred that the top dressing paddy with water soluble P in addition to half dose applied as basal, resulted in the yield increase in grain and straw though not significant over the presently followed Package recommendation of applying entire dose of phosphorus as basal. The top dressing done between the AT and maximum tillering stages has been found more helpful, but delaying top dressing upto PI would result in yield reduction.

The results of the present study also indicated the N and P interaction effect of the complex fertilizer factomphos, which might be a contributing factor towards increased yield.

Between superphosphate and factomphos top dressings studied, the latter was found to be more beneficial. When the entire dose of P was applied basally, the superphosphate and factomphos did not show any significance.

In short, neither split application nor using a combined N P fertilizer such as factomphos, has been found to be statistically superior in a well laid out experiment, where adequate compensation for the N carried by the factomphos has been made in the corresponding other phosphatic treatments. In view of this, it is obvious that most of the cultivator's observation of better effect for factomphos top dressing has been attributed to the concomittant addition but not cognised effect of the added nitrogen.

The beneficiary effects of factomphos as found in the present study under the possible influence of its NH_4^+ component has to be confirmed in a separate experiment incorporating an equivalent amount of N as in factomphos as a straight fertilizer mixed with superphosphate and top dressed at AT stage. The full basal P treatment can also be top dressed by the same amount of N, so as to conclude on the actual contribution of nitrogen. A tagged experiment on these lines will give the actual contribution by the native as well as the applied phosphorus. This is suggested as a follow up study.

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EFFECT OF TOP DRESSING WITH COMPLEX FERTILIZER ON THE YIELD OF RICE

By

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ABSTRACT OF THE THESIS

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ABSTRACT

A field experiment was conducted in the wet lands of the College of Agriculture, Vellayani campus during the second crop season of 1988 to study the effect of top dressing paddy with phosphorus in the form of ammophos and superphosphate in addition to a basal application on the yield of grain and straw.

The experiment was carried out in a simple randomised block design with thirteen treatments. Factomphos and superphosphate were applied at different times viz., full basal, full top dress at AT, ½ basal + ½ at AT, ¼ basal + ½ at AT + ¼ at PI. A control treatment without any phosphorus was also included. The Package recommendation of 90:45:45 kg ha^{-1} of N:P:K was given uniformly to all plots except in the control which received N and K only. The variety used was Jyothi. A destructive row for collection of plant samples was also maintained. Soil and plant samples were withdrawn from each plot at different stages viz. prior to and 15 days after top dressing at AT, 10 days after top dressing at PI and at harvest and analysed for available P in the soil and the phosphorus content of the plant. The growth, yield and yield characters were also studied.

Increased plant height and tiller count could be observed during the active tillering and maximum tillering stages

when factomphos was applied half as basal and half top dressed at AT. The two-split treatments of factomphos recorded highest tiller count at harvest.

Among the yield characters, increase in the productive tiller count alone was significant under the influence of split application of P either as superphosphate or factomphos.

The application of P in two splits of half basal and half top dress at AT resulted in increased grain yield which was significant over the control, three splits and the single top dressed treatments. The two-split treatments and the full basal treatment were similar in their influence. Between superphosphate and factomphos used for top dressing, no significant difference could be noticed. In general, the full top dressed P and the three-split treatments were similar and both were inferior.

With regard to straw yield, the phosphorus applied in two splits showed better performance when compared to the others. However, among the different treatments, there was no significant difference. Control was significantly inferior. Between superphosphate and factomphos used in the two-split treatments, the latter was found better. The full top dressed and the three-split treatments were similar and gave lower straw yield.

Studies on the phosphorus absorption by rice plant made during three sampling stages indicated that increased absorption of phosphorus was during the period between the first and second sampling stages, which nearly coincided with the active tillering and maximum tillering stages respectively of the crop, with peak absorption at the second stage and thereafter it decreased gradually. In this regard the two-split P treatments recorded higher values among which factomphos application resulted in the highest plant P content of the harvest stage which was significant.

The uptake of phosphorus studied in the various stages was also found to be higher in the two-split P treatments of factomphos. Maximum available phosphorus in the soil could be noticed in the treatments where P application was made in two-splits, which was however on par with full basal P treatments.

In general the nitrogen content of grain and straw were higher in the two-split P treatments with a maximum content in the factomphos top dressed treatment. However, no treatmental difference could be seen in the case of potassium content of grain or straw.

Correlation studies revealed that the available P in the soil and the phosphorus content of the plant estimated at various stages were positively and significantly correlated with yield.

The result indicated that peak phosphorus absorption by rice occurs at maximum tillering stage and that the phosphate application at or after PI is not likely to be helpful in bringing about the desired yield increase in rice.