# EVALUATION OF MATON ROCKPHOSPHATE IN THE ACID RICE SOILS OF KERALA

By

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## THESIS

Submitted in partial fulfilment of the requirement for the degree of

## Master of Science in Agriculture

Faculty of Agriculture
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**1997**

## DECLARATION

I hereby declare that the thesis entitled "**Evaluation of Maton rockphosphate in the acid rice soils of Kerala**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma fellowship associateship or other similar title of any other university or society

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## CERTIFICATE

Certified that the thesis entitled "**Evaluation of Maton rockphosphate in the acid rice soils of Kerala** is a record of research work done independently by **Ms Suja Thomas** under my guidance and supervision and that it has not previously formed the basis for the award of any degree fellowship or associateship or other similar titles to her


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SUJA THOMAS

Dedicated to my parents

# CONTENTS

## LIST OF ABBREVIATIONS USED IN THE STUDY

| | |
|---|---|
| MTRP | Maton rockphosphate |
| MRP | Mussoorie rockphosphate |
| SSP | single superphosphate |
| DAP | diammonium phosphate |
| C | control |
| MT | maximum tillering |
| PI | panicle initiation |
| H | harvest |
| K | Kuttanad alluvium |
| L | laterite |
| B | Bray I |
| M | Mathew's triacid extractant |

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# Introduction

# INTRODUCTION

Rice productivity has to be enhanced and sustained at a high level for achieving the target food grain production of the country as 240 million tonnes by 2000 AD (Anon 1996a) Increased application of high analysis fertilisers alone will not help in this task as evidenced from multiple nutrient deficiency and stagnating yields in the lowland rice environments Besides there is a widening gap between the demand and supply of fertiliser nutrients in the country Unless steps are taken to bridge this gap large scale imports may become necessary imposing severe strains in India s economy and food security Recently the subsidy on indigenous phosphatic fertiliser was increased to Rs 3000/tonnes from Rs 1000/tonnes with a view to promote the use of local reserves of phosphorus (Anon 1996b) In this context the use of indegenous phosphorus (P) carriers for crop production has gained more and more importance as the efficient use of this cheaper source may lead the farmers receiving the best possible returns from their expenditure

Efficiency in the management of any system requires the fullest information of the properties of the major components of the system soil crop and fertilisers But the effective P nutrition to wetland rice is very difficult due to three main reasons low P content of the soil less availability of native P and fixation of added P So to increase the availability of P to rice its fixation has to be reduced This can be achieved by the judicious application of rockphosphates which are widespread significant and economically attractive

The major rice growing tracts of Kerala are acidic in nature where the direct application of rockphosphates has a great potential The sedimentary rock phosphates are the most suitable ones for direct application as they are more reactive and become easily available to crop plants The reactivity of rockphosphate is correlated with its chemical composition particularly with the degree of isomorphous substitution of carbonate ion with phosphate We have already recognised the popularity of Mussoorie rockphosphate over the chemically processed fertilisers which is a carbonate substituted francolite with 1 14% organic carbon and 24% $P_2O_5$ But the source of P from the mines of Mussoorie is getting exhausted Many new deposits are being mined in different parts of the country and Maton rock phosphate is one from the mines that occurs in the Aravally hills of Rajasthan It is exclusively associated with algal stromatolite structure which has 1 5% organic carbon and about 24% $P_2O_5$ (Anon 1994) Hindustan Zinc (Ltd ), (A Government of India undertaking) is mining and producing rockphosphate and the suitability of the same for crop cultivation is being evaluated in different parts of the country The efficiency of this rockphosphate has not been evaluated in Kerala soils

The cropping pattern of the major rice growing tracts consists of one or two paddy crops followed by either pulses or oilseeds So these paddy fields with many edaphoclimatological peculiarities is considered as a problem area with respect to P fertilisers By the same reason lack of response to P in lowland rice have been reported even after intensive fertilisation particularly under conditions of light textured soils Kuttanad alluvium and laterites that develop under high rainfall areas of our state

Transformation of P under waterlogged condition will result in large amount of P becoming available to flooded rice crop and this knowledge is necessary for evaluating the efficiency of commercial phosphatic fertilisers Further the residual effect which refers to the carryover benefit of an application available to the succeeding crop is a promising property of P treatment to the soil So a study bringing out information on pattern of release of P and residual effect are therefore of much practical utility

Balance sheet of P in India shows that removal of crop is several times greater than amount supplied by current inputs (Tandon 1987) The situation cannot ofcourse continue for a long time and therefore proper use of P sources is inevitable for profitable agriculture on a sustained way Such an approach necessarily involves a strategic shift from the overdependence of costly and imported P fertilisers to that of local P resources emphasising low energy input system

It is under this context the problem entitled "Evaluation of Maton rockphosphate in the acid rice soils of Kerala was taken up with the following main objectives

1 To evaluate the effectiveness of Maton rockphosphate as a source of P compared to single superphosphate diammonium phosphate and indigenous rockphosphate in acid rice soils of Kerala

2 To study the pattern of release of phosphorus from all the above sources of P

# Review of Literature

# REVIEW OF LITERATURE

Phosphorus deficiency is very widespread in Kerala soils especially in the rice growing tracts of coastal Kuttanad region and laterite belt of middle lands Fertilisers in the form of insoluble P sources have a major role in minimising the nutrient depletion and ensuring better residual effect for an intensive cropping Since India has got large reserves of low grade phosphate rocks it calls for the encouragement of direct application of rockphosphates Literature regarding these various aspects have been reviewed and classified as under

1 Status of P in rice soils of Kerala with special reference to Kuttanad alluvium and laterite soils
2 Phosphorus release and transformation in rice soils
3 Movement of P in soil
4 Availability of major nutrients as affected by P nutrition of rice
5 Comparison of rockphosphates with other water soluble phosphatic fertilisers
6 Residual effect of rockphosphates

## 1 Status of P in rice soils of Kerala

### 1 1 Kuttanad alluvium

Kuttanad soils were found to be very low in P content (Venugopal 1969 Varghese *et al* 1970 and Ghosh *et al* 1973) Mathews (1985) recorded total P of 793 4 ppm in Kari soils of which only 3 84 ppm was found to be as available fraction Among the different inorganic fractions there was predominance of Fe P and Al P According to Vijayan (1993) the total P content of Kuttanad alluvium varied from 178 0 to 1490 80 ppm of which only 4 53 per cent was found to be available The predominant inorganic fractions were Fe P Al P Ca P and saloid P

1 2 Laterite soil

Koshy and Thomas (1972) reported that laterite soils in general were poor in available P and had high P fixing capacity Mathews (1985) reported total P content of 887 2 ppm of which only 4 79 per cent was available The predominant inorganic fraction was Fe P followed by Al P The total reserve of $P_2O_5$ was found to be very low in laterite soils of Kerala due to domination of quartz in sand fraction (Jacob 1987 Krishnakumar 1991) The total P content of laterite soil varied from 468 3 to 1806 0 ppm and the available P was only 13 28 ppm (1 34% of total P) In laterite soils Ca P was dominant followed by Fe P Al P saloid P (Vijayan 1993)

## 2 Phosphorus release and transformation in rice soils

2 1 Available P release under submergence

Patrick and Mahapatra (1968) reported that waterlogging released native P and hence lowland rice did not respond to additions of P fertilizers Islam (1970) reported that levels of soil P first increased and then decreased with time of submergence under rice cropping With increase in moisture content Turner and Gilliam (1976) noticed ten fold increase in P diffusion in the soil system

Mandal and Khan (1977) in their study on the transformation of fixed P in soils under waterlogged conditions reported that the applied P which was left in the soil in the fixed form after the crop harvest could significantly contribute to the pool of available P in the succeeding season especially during the initial period of plant growth

According to Mohanty and Patnaik (1977) submergence increased available P for 30 days because of reduction of Fe and Mn compounds and afterwards there was a decrease because of precipitation of phosphates Khalid *et al* (1979) found the relationship between rice yield and soil P They reported that soils exhibiting higher P sorption had a greater yield response to P under reduced conditions Flooded condition increased the efficiency of phosphatic fertilisers (Sharma and Sinha 1979) In waterlogged soils large amount of $CO_2$ and organic acids were formed which would convert insoluble tricalcium phosphate to more soluble di or monocalcium phosphate thereby the P availability was increased (Mandal 1979) According to Boro (1980) continuous submergence of rice was an effective management practice for increasing the efficiency of P fertilisers

According to Mathews and Jose (1984) flooding the soil resulted in an increase in the content of available P which was high in laterite compared to Kari soil Mathews (1986) reported that submergence resulted in the release of native P in rice soils of Kerala Reduction of free hydrous iron oxide during flooding and liberation of sorbed and co precipitated P resulted in a rise in extractable P (Willet 1989)

2 2 Transformation of inorganic P as influenced by periods of incubation and waterlogging

2 2 1 Fate of native P

Mahapatra and Patrick (1969) found that waterlogging generally increased Al P and Fe P decreased reductant soluble P and did not much affect the

Ca P Jose (1973) reported a decrease in available P saloid bound P and Al P with increasing periods of incubation Singh and Bahaman (1976) found that there was an increase in available P Fe P and Al P decrease in Ca P and negligible changes for saloid bound P with the advancement of periods under submergence

De Datta (1981) summarised the P transformation in submerged soil as follows

1 Reduction in soluble ferric phosphate to a more soluble ferrous phosphate
2 Hydrolysis of aluminium and iron phosphate at a higher soil pH
3 The dissolution of apatite because of the higher $CO_2$ pressure in the soil solution
4 Desorption of P from clay and oxides of Al and Fe
5 Release of occluded phosphate by reduction of hydrated ferric oxide coating
6 Displacement of phosphate from ferric and aluminium phosphate by organic anions

Verma and Thripathi (1982) observed that all the native inorganic P fractions increased upon waterlogging with the maximum increase of 70 7 per cent in Fe P The fractions of P increased upto panicle initiation and then decreased till the stage of harvest (Saravanan *et al* 1984)

2 2 2 Reaction products of added P fertilisers

Minhas and Kick (1974) reported that major part of the added rock phosphate was transformed into water soluble P and loosely bound Al P and Fe P Experiments of Singh and Ram (1977) recorded an increase in Fe P and a decrease in Al P with advancement of the period of incubation According to Sarangamath *et al* (1977) application of water soluble and citrate soluble P to acid soils increased the Al P and Fe P fractions whereas application of rockphosphates increased Ca P Similar observations were recorded by Menhilal and Mahapatra (1979) and Chandrappa (1990)

According to Dhillon and Dev (1986) the applied P would be converted into saloid bound P and Al P at the initial stages and later to Fe P with time of incubation

Kumaraswamy and Sreeramulu (1992) reported the fate of added P with the advancement of the stages under incubation as the transformation of Al P into Fe P in soils originally predominant in Fe P and into Ca P in the soils originally predominant in Ca P Bhatta (1993) found that MTRP application resulted in a higher Ca P while superphosphate recorded higher Al P

2 3 Contributions of various inorganic P fractions to available P

The P uptake by plants was highly correlated with the amount of Fe P and not with the amount of other fractions (Singlachar and Samaniego 1973) Jose (1973) observed a close correlation between labile phosphorus Al P and Fe P Puranik and Bapat (1977) observed positive correlation between available P Al P and Ca P Mandal and Khan (1977) found that 60 to 75 per cent of the applied phosphate was fixed as Fe P Al P and Ca P after the harvest of rice and they stated that these fractions significantly contributed to available phosphorus of the succeeding crop

**3 Movement of P in soil**

Since P was immobile in the soils it would move little from the site of application But a number of results were becoming available which showed that downward movement of P would take place under certain conditions (Tandon 1987)

Due to P application it was found that there was an increase in available P for the sandy loams under coconut cultivation at a depth of 45 to 60 cm (Muliyar and Wahid 1973) Based on the analysis of run off water Padmaja and Koshy (1978) reported that compared to N and K losses of P was negligible Maximum loss of two per cent was found to occur on the third day after fertilizer application According to Rao and Datta (1979) in soils with high P fixing capacity there was no tangible accumulation of $^{32}P$ in the leachate Nisha (1995) reported that significant leaching loss of P occurred only in the early periods of rice crop

**4 Availability of major nutrients as affected by P nutrition to rice**

Ramanathan *et al* (1973) observed an increase in the uptake of N by straw in the presence of added P According to Ramaswami and Raj (1979) P and K uptake by the straw was enhanced by P application Venkatramaiah (1979) observed an increase in the uptake of K in the presence of added P Mathews and Jose (1984) reported that application of P resulted in better utilisation of major nutrients by the rice plant However the uptake of N P and K by the straw was significantly higher in treatments receiving superphosphate

The concentration of P in rice grains did not increase proportionately to the amount of P applied especially through rockphosphate whereas concentration of calcium in rice grains increased with increasing levels of rockphosphate apparently through higher quantum of Ca from rockphosphate (Mathur and Lal 1987) Sushama (1990) reported a higher availability of N and K for the rice crop with increased levels of P application According to Policegowder (1991) MTRP recorded higher content of Ca and lower content of Mg as compared to superphosphate in the soil after the harvest of paddy crop However K content was on par with SSP TSP and DAP Srinivasamurthy *et al* (1995) reported a higher availability of N when rockphosphate was applied to an acid soil seven days before transplanting

**5 Comparison of rockphosphate with water soluble P fertilisers**

5 1 Performance of fertilisers in acid soils

Mandal and Khan (1972) observed that within fifteen days of application more than 86 per cent of the P added as superphosphate was converted to the unavailable form in acid soil whereas rockphosphate maintained a higher amount of available P Singh and Datta (1973) observed that citrate solubility of rock phosphate and pH of the soil were the most important factors governing the P availability Ground rockphosphate had been considered as a good source of P in acid soils due to its easy dissolution (Patnaik *et al* 1974 Sarangamath and Shinde 1977 Nair 1978 Kadrekar *et al* 1983 and Luthra *et al* 1983)

Singh and Datta (1974) reported that MRP was as good as superphosphate in acid soil of Coorg using paddy as test crop Nair (1977) conducted experiments to assess the suitability of MRP to rice in six acid soils of Kerala viz Kari Kayal Karappadam Kole Pokkali and Lateritic alluvium In all these soils performance of rockphosphate was found to be as good as superphosphate Khaswaneh and Doll (1978) reported that phosphate rock was most effective when used in acid soils that were extremely deficient in P Nair and Aiyer (1979) stated that in acid soils of Kerala where paddy respond to P both MRP and SSP were found to be equally good

According to Chaudhary and Mishra (1980) transformation of rock phosphate in soil was mainly related to soil acidity and phosphate potential as these two parameters accounted for 94 per cent of variation in the degree of transformation of rockphosphate Zende (1983) reported that percentage recovery of P added through rockphosphate was low or negligible in calcareous soil but it was fairly high in acid soils

Banik and Mukhopadhyay (1986) studied the dissolution characteristics of MRP with SSP in the acidic laterite soil of West Bengal Higher amount of increase in available P was observed in superphosphate than rockphosphate treated soils They observed a gradual increase in the amount of exchangeable Ca with time of incubation in rockphosphate treated soils indicating solubilisation of added P source

According to Subramanian (1986) the Ca P present in the phosphatic rock was found to be less stable and hence easily acidulated by the soil acidity and organic acids Mackay *et al* (1986) reported that phosphate rock dissolution increased as exchangeable Ca decreased and P sorption capacity of soil increased Results of multilocation trials involving indigenous source of P including MRP under varying agroclimatic condition indicated the possibility of substituting more soluble chemically processed P sources with MRP for direct application in acid soils (Pillai *et al* 1986) Jagadesan *et al* (1986) experimenting in an acid sandy loam soil of pH 5 7 with rice observed higher efficiency of MRP over SSP in influencing rice yield Pandurangaiah *et al* (1986) and Guruprasad *et al* (1988) reported that in low pH soils MRP was found to be equally good or even better than single superphosphate

Kanabo and Gilkes (1987) reported that phosphate rock dissolution increased linearly with decreasing pH According to Rajaram *et al* (1988) rice crop responded to rockphosphate sources than superphosphate in acidic soils of Moncompu (pH 5 1) and Pattambi (pH 5 8) They concluded that rice crop responded favourably to P applied as rockphosphate in soils of pH range below 5 5 and that increase in yield followed a linear pattern with acidity According to Policegowder *et al* (1994) MTRP can be used in place of SSP as a source of P for rice in low pH soils Prakash and Badrinath (1995) concluded that rockphosphate could be used as potential source of P and Ca under acidic condition owing to their steady release of P fairly high Ca content and cost effectiveness Jose *et al* (1995) reported that the performance of rockphosphate in acid rice soils of Kerala was almost equivalent to that of water soluble phosphatic fertilizer

5 2 Availability and uptake of P by rice

Panda (1986) reported that higher available P concentration in soil solution was due to steady dissolution of rockphosphate and reduction of Fe and Al activity through liming effect of the rockphosphate Pohcegowder (1991) reported that MTRP recorded more available P as compared to SSP and DAP at the harvest of rice m acid soil Bhatta (1993) reported that there was gradual increase in the available P content by MTRP with the period for incubation days in an acid soil while for SSP there was a decline According to Shivanna *et al* (1995) MTRP maintained a steady level of P fraction and release throughout the incubation period in acid soils of pH 4 5

Mathews and Jose (1986) reported a sıgnıficant ıncrease ın the uptake of P by rıce ın treatments receıvıng superphosphate On an average Rajasthan rock phosphate and Mussorie rockphosphate were 92 43 and 93 18 per cent as effectıve as superphosphate wıth regard to the total uptake of P and graın yıeld by rıce Sharma and Sınha (1989) observed a hıgher P uptake by rıce due to applıcatıon of SSP followed by rockphosphate ın a rıce graın rotatıon of an acıd soıl Bhujbal *et al* (1992) reported that P derıved by rıce shoot and graın was the hıghest from DAP followed by SSP and ammonıum polyphosphate and ıt was ın lower amounts from rockphosphates Srınıvasamurthy *et al* (1995) reported a hıgher P uptake by rıce plant when rockphosphate was applıed to an acıd soıl seven days before transplant ıng

5 3 Crop growth and yıeld of rıce

Mussoorie rockphosphate was evaluated ın comparıson wıth super phosphate for rıce ın Kerala No sıgnıficant dıfference was observed for the response of dıfferent crops to dıfferent sources of phosphate whıch ındıcated that ındegenous rockphosphate can substıtute superphosphate as a source of P (KAU 1987) Mathur and Lal (1987) conducted a field experıment on clay loam soıl to test the response of rıce to rockphosphate as compared wıth superphosphate and reported a sıgnıficant dıfference among P sources ın ıncreasıng the yıeld of rıce But no sıgnıficant dıfference ın yıeld was notıced by them among the levels of P of the same sources

Accordıng to Venugopal *et al* (1988) there was superıorıty of MRP over DAP ın ıncreasıng the yıeld of rıce ın the acıdıc soıls of Goa Dwıvedı *et al* (1989) reported that performance of MRP was always superıor to SSP ın crop yıeld and phosphate availability of an acid soil Farm trials conducted by University of Agri cultural Sciences Bangalore showed than MTRP and partially acidulated rock phosphate were superior to SSP for both grain and straw yield of rice (Anon 1994) Sahu and Acharya (1995) reported that grain and straw yield increased significantly with increased levels of phosphate and the yield between SSP DAP and insoluble phosphate sources were statistically at par

5 4 Fertiliser use efficiency

Jaggi (1986) concluded that the value of additional crop response obtained for MRP in acid soils varied from 0-10 per cent over water soluble sources on equal $P_2O_5$ application rate Economic efficiency is the increase in profit per unit investment of P (Tandon 1987) According to Krishnappa *et al* (1988) MRP recorded the highest cost benefit ratio and DAP the least for paddy in acid soils of Karnataka Awasthi (1988) reported that rockphosphate gave more monetory gains through larger crop production with low investment on fertilizer as compared to processed phosphate fertilizers Rockphosphates had a better profitability and fertilizer use efficiency as compared to superphosphate Devi *et al* (1993) reported that MTRP alone or 25 per cent acidulation or mixing of MTRP with SSP (3 1) gave comparable Benefit Cost ratio (12 7 to 14 1) as against 6 7 with SSP MTRP recorded more P use efficiency as compared to superphosphate

## 6 Residual effect of rockphosphates

De Datta *et al* (1966) observed that only 8 to 27 per cent of the total P in the rice plant was derived from the applied P while 80 to 90 per cent of the applied P remained in the soil for the succeeding crop Panda and Panda (1969) reported that short term evaluation of rockphosphate would be meaningless in case of lateritic soil as the residual effects were more important than the immediate effect According to Motsara and Datta (1971) superphosphate and rockphosphate gave same yield for rice when applied at the same dose However rockphosphate was found to have a better residual effect Lehr and Mccellan (1972) reported good yield of rice from first crop by rockphosphate application but poor yield from second and third crops

Singh and Datta (1973) observed that the availability of P from rock phosphate increased with its time of contact with the soil Ramaswamy (1981) reported that superphosphate recorded a slightly higher paddy production and P uptake than MRP in the case of direct effect while in the residual effect the two sources were statistically on par Sarkar and Sarkar (1982) suggested that the fertilizer value of rockphosphate in rice rice cropping system must be assessed on the basis of residual effect Response of residual rockphosphate was curvilinear (Gupta *et al* 1983) Ramaswamy and Arunachalam (1983) reported that super phosphate was found to be slightly superior for the main crop of paddy but for the second crop of paddy MRP gave better yield Considering the total uptake of P for both the crops there was no significant difference between the two forms of P fertilizers at the same level of phosphorus

Goedert (1984) while evaluating the comparative residual effect of rockphosphate under field conditions for six years reported that about 20 per cent of the P as rockphosphate remained in apatite and the efficiency of rockphosphate ranged from 69 to 89 per cent According to Mathews (1985) considerable amount of P applied as rockphosphate remained in the soil after growing rice for two seasons and therefore it was possible that the availability of P to third and subsequent crops could be better in soils receiving rockphosphate as compared to superphosphate Omana (1986) reported that the rice crop that followed the main crop of cowpea was benefitted by the residual effect of rockphosphate than that of superphosphate alone applied to cowpea and rice

Rabindra (1995) and Patil *et al* (1995) rockphosphate had better residual effect than single superphosphate in an acid soil Paulraj and Velayudham (1995) reported that residual effect of rockphosphate was more than SSP in rice blackgram sequence

# Material and Methods

# MATERIALS AND METHODS

The study entitled "Evaluation of Maton rockphosphate for the acid rice soils of Kerala" was conducted at the College of Horticulture Vellanikkara during the period 1994 96 consisted of two experiments

1) An incubation experiment in order to study the transformation of P from four different sources at three levels using laterite and Kuttanad alluvial soils of Kerala
2) A pot culture experiment with the same sources and levels as in the incubation experiment using rice as test crop grown continuously for two seasons in order to study the direct and residual effect of Maton rockphosphate in comparison with superphosphate diammonium phosphate and Mussoorie rockphosphate

## 3 1 Collection of soil sample

Laterite soil was collected from Mudikodu (Trichur district) and Kuttanad alluvium from Nedumudy (Allepey district) Taxonomical classification of these soil types are provided in Appendix I The soils were collected from a depth of 0-15 cm dried in shade powdered and used for the experiments

## 3 2 Experimental details

Incubation study

Sources

i) Maton rockphosphate supplied by Hindustan Zinc Ltd Udaipur

ii) Mussoorie rockphosphate

iii) Single superphosphate

iv) Diammonium phosphate

The data regarding the composition of fertilisers are provided in Appendix II

Levels

i) 22 5 kg $P_2O_5$/ha

ii) 45 0 kg $P_2O_5$/ha

iii) 67 5 kg $P_2O_5$/ha

Soils

1) Laterite

2) Kuttanad alluvium

Design Completely Randomised Design

Replication 3

The treatment combinations are as follows

| Treatment No | Notation | | Forms and level of $P_2O_5$ kg ha $^{-1}$ | |
|---|---|---|---|---|
| 1 | 2 | | 3 | |
| 1 | MTRP | $P_1$ | MTRP | 22 5 |
| 2 | MTRP | $P_2$ | MTRP | 45 0 |
| 3 | MTRP | $P_3$ | MTRP | 67 5 |
| 4 | MRP | $P_1$ | MRP | 22 5 |
| 5 | MRP | $P_2$ | MRP | 45 0 |
| 6 | MRP | $P_3$ | MRP | 67 5 |
| 7 | SSP | $P_1$ | SSP | 22 5 |
| 8 | SSP | $P_2$ | SSP | 45 0 |

Contd

| 1 | 2 | | 3 | |
|---|---|---|---|---|
| 9 | SSP | $P_3$ | SSP | 67 5 |
| 10 | DAP | $P_1$ | DAP | 22 5 |
| 11 | DAP | $P_2$ | DAP | 45 0 |
| 12 | DAP | $P_3$ | DAP | 67 5 |
| 13 | C | | Control (without P fertiliser) | |
| 14 | SSP ($P_2$ + $P_2$) | | SSP (45 + 45) P was given twice on the 1st and 120th day of incubation | |

The same treatments were imposed for both the soil types under study

## 3 3 Experimental procedure

About 500 g soil was transferred to incubation dishes The phosphatic fertilisers were incorporated in the soil as described in 3 2 The soils were incubated at room temperature A water level of 2 cm was maintained uniformly throughout the experimental period of 240 days Soil samples were drawn at an interval of 30 days for the analysis of pH and available nutrient status of N P K Ca and Mg Fractions of P namely aluminium phosphate iron phosphate and calcium phosphate were also estimated for the two soil types before and after the experiment

## 3 4 Analytical procedure

Mechanical analysis

Mechanical analysis of the soil was carried out by the International Pipette Method (Piper 1942)

Soil pH

Soil pH was measured in 1 2 5 soil water suspension using Elico pH meter (Jackson 1973)

Available nitrogen

Available nitrogen content of the soil was determined by alkaline potassium permanganate method (Subbaiah and Asija 1956)

Available phosphorus

The available phosphorus of the wet sample was extracted using Bray No 1 (0 03 N $NH_4F$ in 0 025 N HCl) (Bray and Kurtz 1945) and Mathew s extractants (0 06 N $H_2SO_4$ + 0 06 N HCl + 0 05 N Oxalic acid) (Mathews 1979) and estimated by Ascorbic acid Blue colour method (Watnabe and Olsen 1965) Necessary moisture corrections were made by calculating the moisture content of soil samples and the corresponding volume was adjusted in the added extractants

Available potassium

Available potassium was determined flame photometrically in the neutral normal ammonium acetate extract of the soil (Jackson 1973)

Available calcium and Available magnesium

Available calcium and available magnesium were determined by EDTA titration method (Hesse 1971)

Fractions of P

Fraction of P was carried out using the modified procedure as described by Hesse (1971)

## 3 5 Pot culture experiment

A pot culture experiment was conducted using Jaya variety of rice as a test crop as per the details given in 3 2

Design CRD

Replication 3

The treatment combinations were same as that of the incubation study as detailed in section 3 2

Earthern pots were filled with 10 kg soil and each pot was fitted with outlets for collecting the leachate Fertilisers were applied as as per package of practice recommendation (KAU 1993) The crops were grown under waterlogged condition for the first and second crop season Twenty five day old rice seedling were planted at the rate of three hills per pot and after the harvest of first crop the same pots were utilised for raising the residual crop Periodical prophylatic measures were taken against pest and disease attack Plant and soil samples were drawn at the maximum tillering panicle initiation and harvest stages of the crop At these stages of crop growth changes in pH avalable nutrient status of N P K Ca and Mg of the soil were also monitored Dry matter yield was recorded for the two consecutive crops under study Leachate samples were collected for analysis

## 3 6 **Analytical procedure**

Soil samples were subjected to the analysis as outlined in section 3 4

Plant sample

Nitrogen content was determined by the microkjeldahl digestion and distillation method as described by Jackson (1973)

The phosphorus content from the diacid extract ($HNO_3$ $HClO_4$ as 2 1) was determined colorimetricaly by the vanadomolybdophosphoric yellow colour method in nitric acid system (Jackson 1973) For potassium the extract was diluted and read in EEL flame photometer (Jackson 1973)

Available calcium and available magnesium was determined by EDTA titration method (Hesse 1971)

Leachate sample

Leachate sample was collected uniformly from all the pots and were analysed for nitrogen by alkaline permanganate method phosphorus by ascorbic acid blue colour method and potassium using flame photometric method (Jackson 1973)

Fertiliser sample

The fertilisers were analysed for major components such as N P K Ca Mg Fe Al Na Si and the fractions of P (Chopra and Kanwar 1982)

## 3 7 Statistical analysis

Statistical analysis of the data was carried out by adopting the standard methods as outlined by Panse and Sukhatme (1985) The correlations were also worked out (Snèdecor and Cochran 1967)

# Results and Discussion

# RESULTS AND DISCUSSION

In order to evaluate the effectiveness of Maton rockphosphate (MTRP) as a source of P compared to Mussoorie rockphosphate (MRP) single superphosphate (SSP) and diammonium phosphate (DAP) in acid rice soils of Kerala an incubation study and pot culture experiments for two consecutive seasons were conducted The results are presented and discussed as follows

General characteristics of the soil types under study

The physico-chemical properties of Kuttanad alluvium and laterite soils are presented in Table 1 Kuttanad alluvium was a sandy loam soil with a pH of 3 75 and organic carbon content of 1 80 per cent Laterite soil of sandy loam texture had a pH of 4 75 and organic carbon of 1 14 per cent The total P content of laterite soil was high (0 078%) as compared to Kuttanad alluvium (0 066%) Available P content of both the soil types belonged to low fertility class The available P content registered a value of 4 70 and 16 26 kg ha $^{1}$ respectively with Bray No 1 and Mathew s triacid extractant for the Kuttanad alluvium But for the laterite the values were slightly high as 9 40 and 20 6 kg ha $^{1}$ Available N K Ca and Mg status were relatively higher for Kuttanad alluvium as compared to laterite soil Fractionation of inorganic P revealed that Fe P was the predominant form followed by Al P and Ca P in both the soil types Though the contents of Fe P and Al P were higher for laterite the Ca P content was lower than that of Kuttanad alluvium

Table 1 Physico chemical characteristics of the soil

| Characteristics | Kuttanad alluvium | Laterite |
|---|---|---|
| Coarse sand (%) | 5 88 | 8 80 |
| Find sand (%) | 67 45 | 50 20 |
| Silt (%) | 15 00 | 34 80 |
| Clay (%) | 12 50 | 6 20 |
| pH | 3 75 | 4 75 |
| Organic carbon (%) | 1 80 | 1 14 |
| Available N (kg ha $^{1}$) | 476 60 | 363 60 |
| Available P (kg ha $^{1}$) (Bray 1) | 4 70 | 9 40 |
| Available P (kg ha $^{1}$) (Mathew s extractant) | 16 26 | 20 60 |
| Available K (kg ha $^{1}$) | 476 00 | 125 60 |
| Available Ca (kg ha $^{1}$) | 440 00 | 140 40 |
| Available Mg (kg ha $^{1}$) | 480 00 | 120 00 |
| Total P (%) | 0 06 | 0 07 |
| Fe P (ppm) | 245 40 | 310 50 |
| Al P (ppm) | 211 20 | 215 70 |
| Ca P (ppm) | 80 60 | 63 81 |

## 4 1 Incubation study

### 4 1 1 Kuttanad alluvium

#### 4 1 1 1 Soil reaction

Soil reaction as influenced by the treatments at different periods of incubation are provided in Table 2 The values of soil pH ranged from 3 90 to 5 08 with a mean value of 4 44

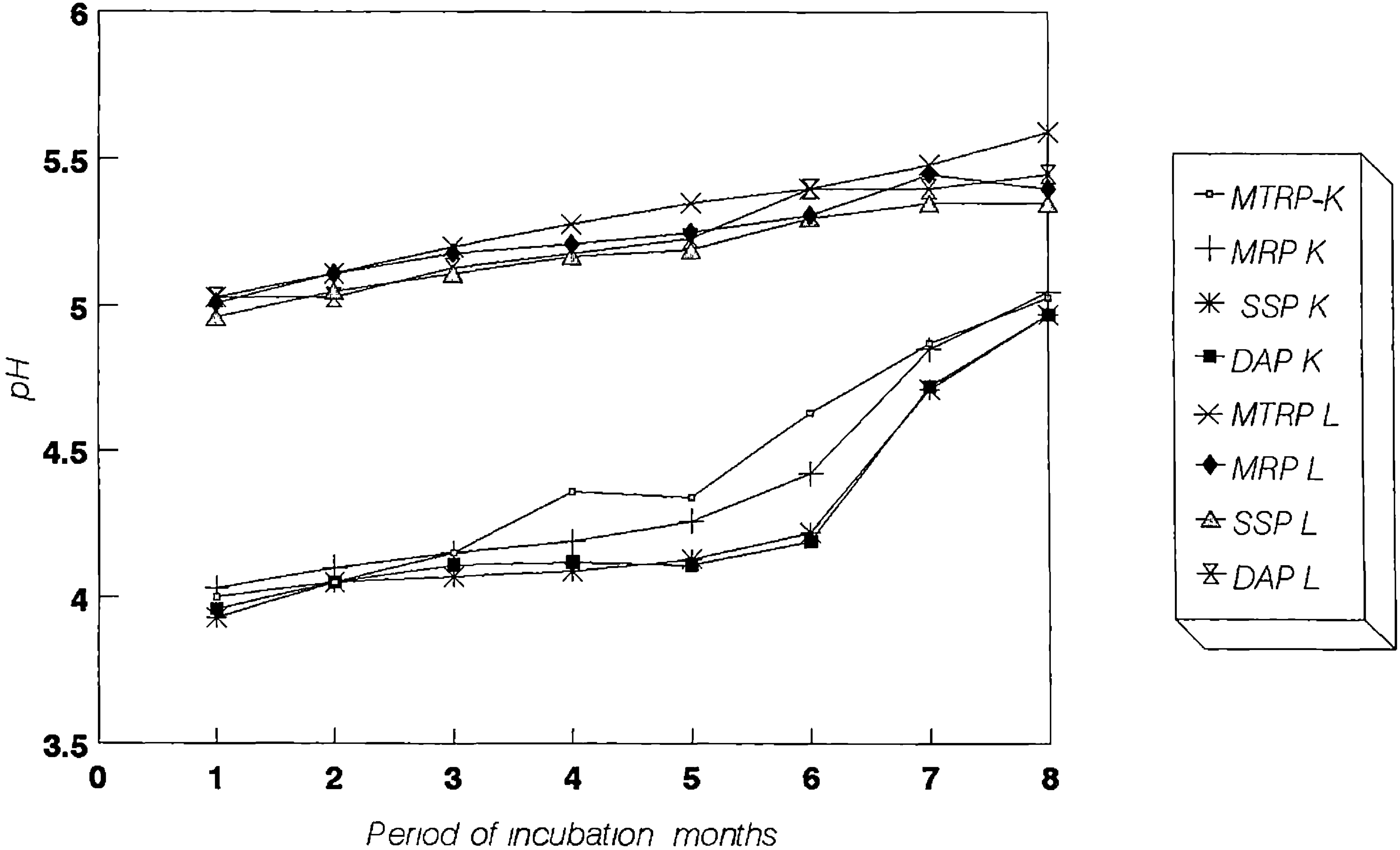
The pH of the soil gradually increased with periods of incubation irrespective of the treatments including the control There was no significant difference in values of soil pH among the various treatment combinations in all the periods under study Though there was significant difference in pH of the soil due to the different levels of P application the trend was not found to be uniform throughout the incubation period

The relationship between pH values recorded by different sources of fertilizers under different periods of incubation is illustrated in Fig 1 In general the rock phosphates maintained significantly higher pH as compared to water soluble P sources throughout the incubation period Between the rockphosphates MTRP recorded significantly higher pH value than MRP at the 4th 5th and 6th months of incubation However at the last two periods the values were on par for both MRP and MTRP

The increase in pH with increasing periods of incubation was because of the reduced condition provided during the experimental period The pH buffering action of submerged soil was due to the Fe and Mn redox systems and the formation of carbonic acid (Ponnamperuma *et al* 1965) Due to this reason the pH

Table 2 The influence of treatments on pH of Kuttanad alluvium at different period of incubation

| Treatment | | Period of incubation months | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No | Notation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | MTRP $P_1$ | 4 00 | 4 05 | 4 10 | 4 35 | 4 30 | 4 60 | 4 85 | 5 00 |
| 2 | MTRP $P_2$ | 4 00 | 4 05 | 4 20 | 4 35 | 4 40 | 4 70 | 4 90 | 5 05 |
| 3 | MTRP $P_3$ | 4 00 | 4 05 | 4 15 | 4 40 | 4 33 | 4 60 | 4 87 | 5 05 |
| 4 | MRP $P_1$ | 4 00 | 4 10 | 4 10 | 4 13 | 4 42 | 4 65 | 4 87 | 5 08 |
| 5 | MRP $P_2$ | 4 10 | 4 10 | 4 15 | 4 20 | 4 35 | 4 15 | 4 93 | 5 00 |
| 6 | MRP $P_3$ | 4 00 | 4 10 | 4 20 | 4 25 | 4 00 | 4 45 | 4 75 | 5 08 |
| 7 | SSP $P_1$ | 3 90 | 4 10 | 4 10 | 4 10 | 4 05 | 4 35 | 4 73 | 5 05 |
| 8 | SSP $P_2$ | 4 00 | 4 05 | 4 20 | 4 10 | 4 10 | 4 10 | 4 80 | 4 93 |
| 9 | SSP $P_3$ | 3 90 | 4 00 | 4 10 | 4 02 | 4 12 | 4 20 | 4 60 | 4 98 |
| 10 | DAP $P_1$ | 3 95 | 4 05 | 4 10 | 4 10 | 4 40 | 4 15 | 4 63 | 5 00 |
| 11 | DAP $P_2$ | 3 90 | 4 00 | 4 15 | 4 10 | 4 10 | 4 20 | 4 73 | 4 90 |
| 12 | DAP $P_3$ | 4 00 | 4 10 | 4 10 | 4 15 | 4 07 | 4 00 | 4 80 | 4 95 |
| 13 | C | 3 90 | 4 00 | 4 10 | 4 10 | 4 00 | 4 30 | 4 70 | 4 75 |
| 14 | SSP ($P_2+P_2$) | 3 90 | 4 00 | 4 15 | 4 40 | 4 05 | 4 10 | 4 75 | 4 96 |
| CD(0 05) | | NS | NS | NS | NS | NS | NS | NS | NS |
| Source | | | | | | | | | |
| MTRP | | 4 00 | 4 05 | 4 15 | 4 37 | 4 34 | 3 1 | 4 87 | 5 03 |
| MRP | | 4 03 | 4 10 | 4 15 | 4 19 | 4 26 | 4 42 | 4 85 | 5 05 |
| SSP | | 3 93 | 4 05 | 4 07 | 4 09 | 4 13 | 4 22 | 4 71 | 4 97 |
| DAP | | 3 96 | 4 05 | 4 11 | 4 12 | 4 11 | 4 19 | 4 72 | 4 97 |
| CD(0 05) | | 0 05 | 0 05 | 0 05 | 0 05 | 0 05 | 0 05 | 0 05 | 0 05 |
| Level | | | | | | | | | |
| $P_1$ | | 3 96 | 4 08 | 4 10 | 4 17 | 4 29 | 4 44 | 4 77 | 5 03 |
| $P_2$ | | 4 00 | 4 05 | 4 18 | 4 19 | 4 24 | 4 29 | 4 84 | 4 97 |
| $P_3$ | | 3 97 | 4 06 | 4 14 | 4 00 | 4 13 | 4 31 | 4 75 | 5 02 |
| CD(0 05) | | 0 04 | 0 03 | 0 04 | 0 04 | 0 04 | 0 05 | 0 05 | 0 04 |




The pH of Kuttanad alluvium & laterite soil at different periods of incubation as influenced by sources of P of the soil was almost maintained at 5 0 The increase in pH by rockphosphate as compared to SSP and DAP may be attributed to the liming action of Ca and Mg carbonate content of the same The findings of Mathur and Lal (1986) are also in line with this

4 1 1 2 Available nitrogen

Available N (kg ha $^{1}$) as influenced by the treatments at different periods of incubation are presented in Table 3 Available N content ranged from 357 5 kg ha $^{1}$ (control) to 1122 60 kg ha $^{1}$ (DAP $P_3$) with a mean value of 740 1 kg ha $^{1}$

In general there was decrease in available N content with increasing periods of incubation in all the treatment combinations The control treatment always registered a lower content of available nitrogen as compared to other treatments The values registered by SSP ($P_2+P_2$) were found to be on par with that of SSP applied at $P_2$ level

All the sources showed significant variation in nitrogen release The higher levels of DAP registered significantly higher available N as indicated by DAP at $P_3$ (1122 60 kg ha $^{1}$) and $P_2$ level (1059 95 kg ha $^{1}$) followed by SSP and MRP treatments Among the sources MTRP recorded the lowest values There was significant increase in available N content with increased doses of P at the 1st 5th 6th and 7th period of incubation

The high N content in DAP treatments may be due to the nitrogen present in the fertilizer itself (Appendix II) The decreasing trend observed with periods of incubation may be attributed to the losses of nitrogen through denitrification and volatalisation under waterlogged condition (Patrick and

Table 3 Available N (kg ha $^{1}$) as influenced by treatments at different periods of incubation (Kuttanad alluvium)

| Treatment No | Notation | Period of incubation months 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MTRP $P_1$ | 627 73 | 652 20 | 558 24 | 581 20 | 595 85 | 526 83 | 495 42 | 508 05 |
| 2 | MTRP $P_2$ | 746 30 | 589 54 | 520 52 | 639 70 | 633 43 | 558 25 | 478 75 | 413 90 |
| 3 | MTRP $P_3$ | 871 81 | 777 75 | 702 43 | 721 25 | 740 00 | 595 83 | 551 90 | 491 22 |
| 4 | MRP $P_1$ | 815 30 | 915 70 | 765 10 | 752 65 | 708 73 | 602 14 | 545 63 | 551 90 |
| 5 | MRP $P_2$ | 896 80 | 898 90 | 710 82 | 706 65 | 640 23 | 564 45 | 528 92 | 365 85 |
| 6 | MRP $P_3$ | 972 15 | 723 32 | 646 50 | 411 83 | 627 25 | 526 80 | 497 51 | 622 10 |
| 7 | SSP $P_1$ | 953 35 | 821 60 | 721 21 | 752 62 | 707 80 | 639 75 | 570 73 | 564 45 |
| 8 | SSP $P_2$ | 972 15 | 664 83 | 545 65 | 570 73 | 652 25 | 614 65 | 551 93 | 539 33 |
| 9 | SSP $P_3$ | 990 90 | 752 65 | 694 18 | 708 73 | 727 50 | 663 05 | 589 54 | 508 00 |
| 10 | DAP $P_1$ | 990 90 | 702 42 | 685 70 | 708 73 | 727 50 | 643 95 | 520 25 | 489 23 |
| 11 | DAP $P_2$ | 1059 95 | 775 60 | 740 00 | 727 50 | 765 10 | 671 18 | 539 33 | 451 53 |
| 12 | DAP $P_3$ | 1122 60 | 815 32 | 702 43 | 727 50 | 880 18 | 689 90 | 564 45 | 501 70 |
| 13 | C | 606 82 | 545 63 | 484 80 | 413 90 | 432 73 | 395 18 | 372 15 | 357 50 |
| 14 | SSP ($P_2$+$P_2$) | 966 38 | 656 40 | 537 32 | 568 63 | 658 50 | 610 40 | 550 80 | 533 10 |
| CD(0 05) | | 11 28 | 12 77 | 12 56 | 15 70 | 12 70 | 11 28 | 12 54 | 13 90 |
| Source | | | | | | | | | |
| MTRP | | 748 61 | 673 16 | 598 73 | 647 35 | 656 42 | 560 30 | 508 69 | 471 05 |
| MRP | | 894 75 | 845 97 | 707 47 | 623 71 | 658 73 | 564 46 | 524 02 | 513 28 |
| SSP | | 972 13 | 746 36 | 653 68 | 677 36 | 695 85 | 639 15 | 570 73 | 537 26 |
| DAP | | 1057 81 | 764 44 | 709 37 | 721 24 | 790 92 | 668 34 | 541 34 | 480 |
| CD(0 05) | | 6 51 | 7 37 | 7 25 | 91 0 | 7 36 | 6 52 | 7 23 | 8 08 |
| Level | | | | | | | | | |
| $P_1$ | | 846 82 | 772 98 | 682 56 | 698 8 | 684 97 | 603 16 | 537 77 | 528 40 |
| $P_2$ | | 918 8 | 732 21 | 629 24 | 661 14 | 672 75 | 602 13 | 624 73 | 442 65 |
| $P_3$ | | 989 36 | 767 26 | 686 38 | 642 32 | 743 73 | 618 89 | 550 85 | 530 75 |
| CD(0 05) | | 5 63 | 6 39 | 6 28 | 7 80 | 6 38 | 5 64 | 6 27 | 6 98 |

Mahapatra 1968) Though the exact mechanism for the increased rate of N mineralisation due to P additions was not clear the biological activity might have geared up resulting in more mineralisation of organic matter The high N avail ability and simultaneously lesser immobilisation under submerged condition must have favoured the anaerobic bacteria functioning at lower level of energy release (Tisdale 1975)

4 1 1 3 Available P

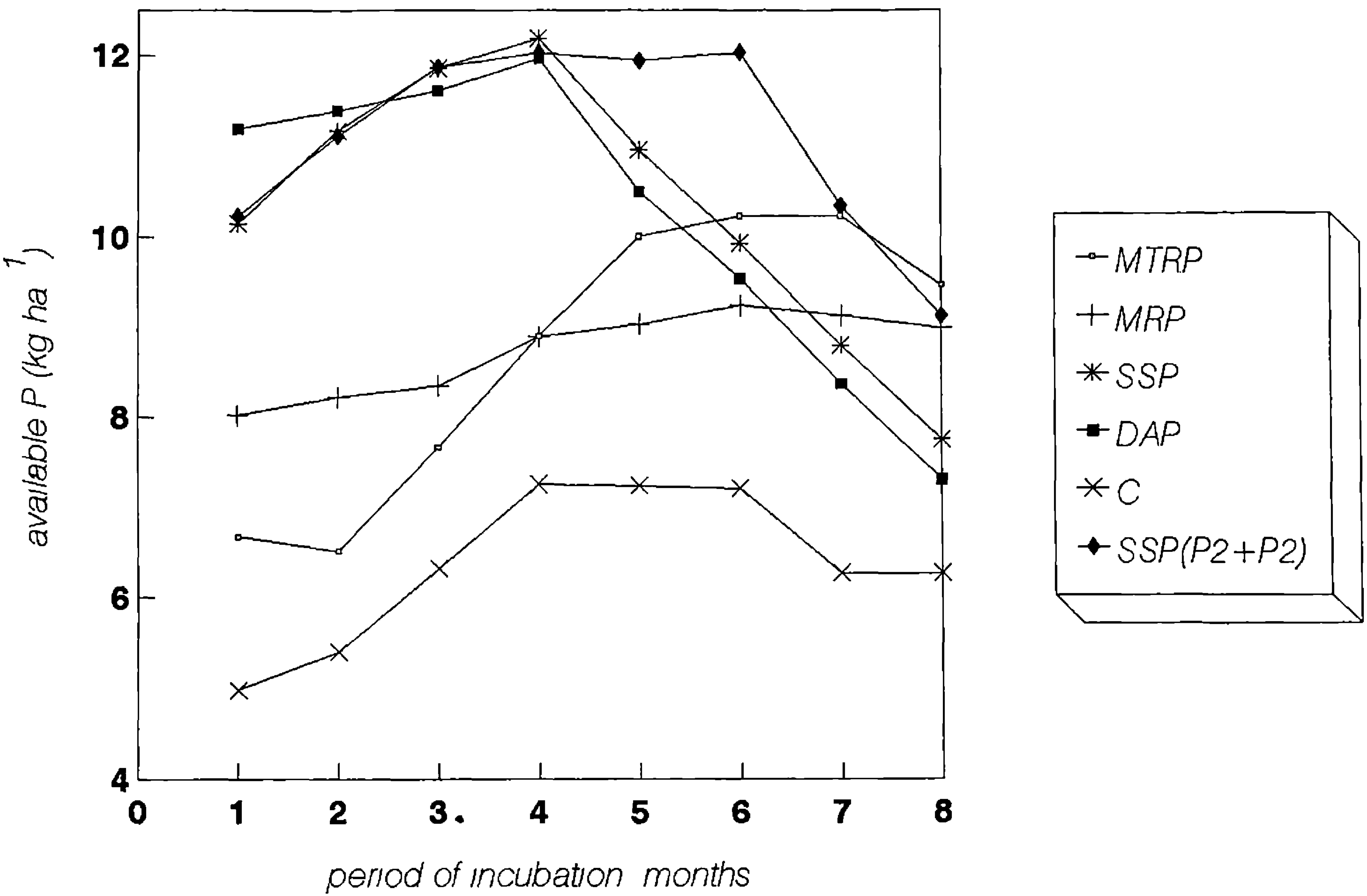
The available P of the soil was determined with the use of two extractants namely Bray 1 and Mathew s triacid extractants The variations in available P as influenced by different treatment is given in Table 4 and Table 5 Available P of the soil using Bray 1 was found to range from 4 98 (C) to 13 73 kg $ha^{1}$ (SSP $P_3$) with a mean of 9 35 kg $ha^{1}$ while for Mathew s extractant it ranged from 25 31 (C) to 49 79 kg $ha^{1}$ (SSP $P_3$) with mean of 37 55 kg $ha^{1}$

The continuous release of available P under the influence of different periods of waterlogging is presented in Fig 2 (Bray 1) and Fig 3 (Mathew s triacid extractant) In general there was a continuous increase in available P content of the soil upto 6th month (varying with source) followed by a decrease as indicated by the values From this it is inferred that the transformation of added P to different inorganic fractions has taken place But its contribution to the available phosphate pool is considerably low

Additions of P fertilisers had a marked influence on P availability This is evident from the low values registered by the control The maximum value recorded by control treatment was only 7 25 kg $ha^{1}$ (Bray 1) and 34 57 kg $ha^{1}$

Table 4 Available P (kg ha $^{1}$) as influenced by treatments at different periods of incubation Bray (Kuttanad alluvium)

| No | Notation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | | Period of incubation months | | | | | | | |
| 1 | MTRP $P_1$ | 5 71 | 5 96 | 6 94 | 7 97 | 8 33 | 8 48 | 8 33 | 7 73 |
| 2 | MTRP $P_2$ | 6 36 | 6 38 | 7 57 | 8 89 | 9 67 | 10 19 | 10 34 | 9 56 |
| 3 | MTRP $P_3$ | 7 97 | 7 19 | 8 49 | 9 87 | 12 03 | 12 03 | 12 03 | 11 11 |
| 4 | MRP $P_1$ | 6 78 | 6 74 | 6 89 | 8 02 | 8 17 | 7 97 | 7 80 | 6 47 |
| 5 | MRP $P_2$ | 8 02 | 8 33 | 8 60 | 8 80 | 8 99 | 9 50 | 9 00 | 7 66 |
| 6 | MRP $P_3$ | 9 25 | 9 56 | 9 56 | 9 88 | 10 03 | 10 25 | 10 39 | 9 88 |
| 7 | SSP $P_1$ | 8 33 | 9 60 | 10 19 | 10 51 | 9 25 | 8 17 | 7 10 | 6 36 |
| 8 | SSP $P_2$ | 10 19 | 11 11 | 11 67 | 12 34 | 11 67 | 10 60 | 8 95 | 7 94 |
| 9 | SSP $P_3$ | 11 94 | 12 81 | 13 73 | 13 73 | 11 98 | 11 03 | 10 35 | 8 97 |
| 10 | DAP $P_1$ | 9 52 | 9 76 | 9 92 | 10 19 | 8 65 | 7 79 | 6 95 | 6 65 |
| 11 | DAP $P_2$ | 11 22 | 11 76 | 12 01 | 12 50 | 10 75 | 8 93 | 8 05 | 6 94 |
| 12 | DAP $P_3$ | 12 85 | 12 65 | 12 90 | 13 22 | 12 12 | 11 92 | 10 11 | 8 32 |
| 13 | C | 4 98 | 5 40 | 6 32 | 7 25 | 7 23 | 7 20 | 6 27 | 6 27 |
| 14 | SSP ($P_2+P_2$) | 10 23 | 11 11 | 12 87 | 12 03 | 11 94 | 12 03 | 10 34 | 9 13 |
| CD(0 05) | | 0 57 | 0 53 | 0 47 | 0 47 | 0 47 | 0 46 | 0 85 | 0 47 |
| Source | | | | | | | | | |
| MTRP | | 6 67 | 6 51 | 7 66 | 8 91 | 10 01 | 10 23 | 10 23 | 9 47 |
| MRP | | 8 02 | 8 22 | 8 35 | 8 90 | 9 04 | 9 24 | 9 13 | 9 00 |
| SSP | | 10 15 | 11 17 | 11 86 | 12 19 | 10 96 | 9 93 | 8 80 | 7 75 |
| DAP | | 11 19 | 11 39 | 11 61 | 11 97 | 10 50 | 9 54 | 8 37 | 7 30 |
| CD(0 05) | | 0 33 | 0 30 | 0 27 | 0 27 | 0 27 | 0 26 | 0 49 | 0 32 |
| Level | | | | | | | | | |
| $P_1$ | | 7 58 | 8 02 | 8 48 | 9 17 | 8 60 | 8 10 | 7 54 | 6 80 |
| $P_2$ | | 8 94 | 9 39 | 9 96 | 10 63 | 10 27 | 9 80 | 9 08 | 8 03 |
| $P_3$ | | 10 50 | 10 55 | 11 17 | 11 67 | 11 54 | 11 30 | 10 72 | 9 57 |
| CD(0 05) | | 0 28 | 0 26 | 0 24 | 0 24 | 0 24 | 0 23 | 0 43 | 0 26 |




g 2 Available P as influenced by sources of P at different periods of incubation Bray 1 (Kuttanad alluvium)

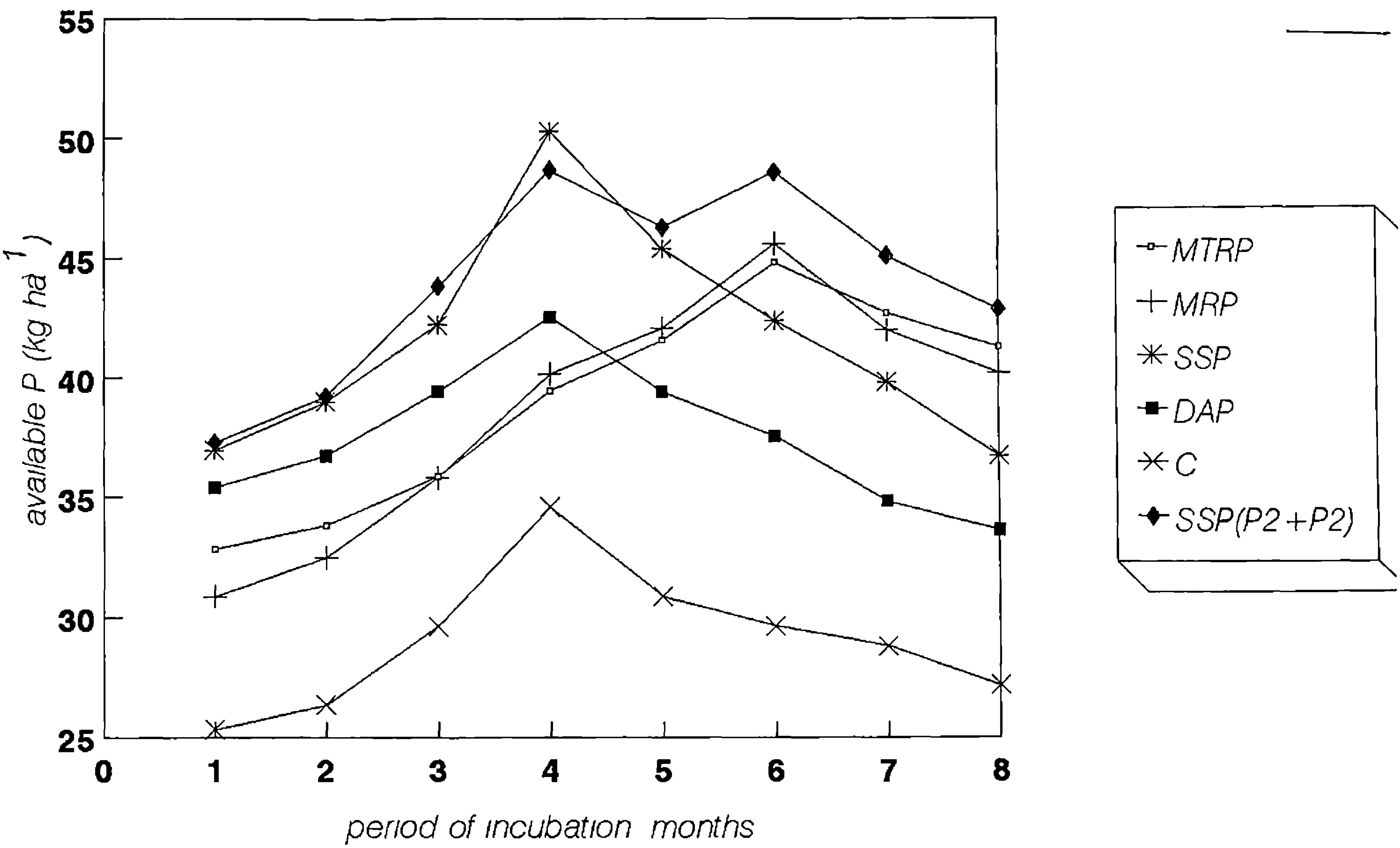
(Mathew s extractant) at the 4th month of incubation In the SSP ($P_2+P_2$) treatment the second application on 120th day (4th period) resulted in significantly higher P release at the 6th period as compared to SSP $P_2$ However it was found to be on par with MTRP $P_3$ In the 7th and 8th period there was a steady decrease as that of SSP $P_2$ and was found to be on par with MTRP $P_2$ and MRP $P_3$ while MTRP $P_3$ was significantly higher

In general the treatments of SSP and DAP were significantly higher than MRP and MTRP upto the 4th month of incubation From the 5th period onwards rockphosphates were significantly superior for the available P content of the soil The peak contents of available P released by SSP and DAP were observed in the 4th period after which there was a steady decrease The rockphosphates registered maximum release at the 5th and 6th period after which there was slight decrease Between the rockphosphates MTRP was significantly higher The release of available P as influenced by different sources of P fertilisers at the 4th and 8th month of incubation is illustrated in Fig 4 It is clear that at 120th day (4th month) SSP DAP and SSP $P_2+P_2$ were similar in P release and were considerably higher than MTRP and MRP At 240th day (8th month) there was drastic decrease for SSP and DAP while for MTRP and MRP there was slight increase as compared to 120th day release and were higher as compared to SSP and DAP Among the rock phosphates MTRP was superior to MRP From Table 4 it is also evident that increased levels of P had significant influence on P availability

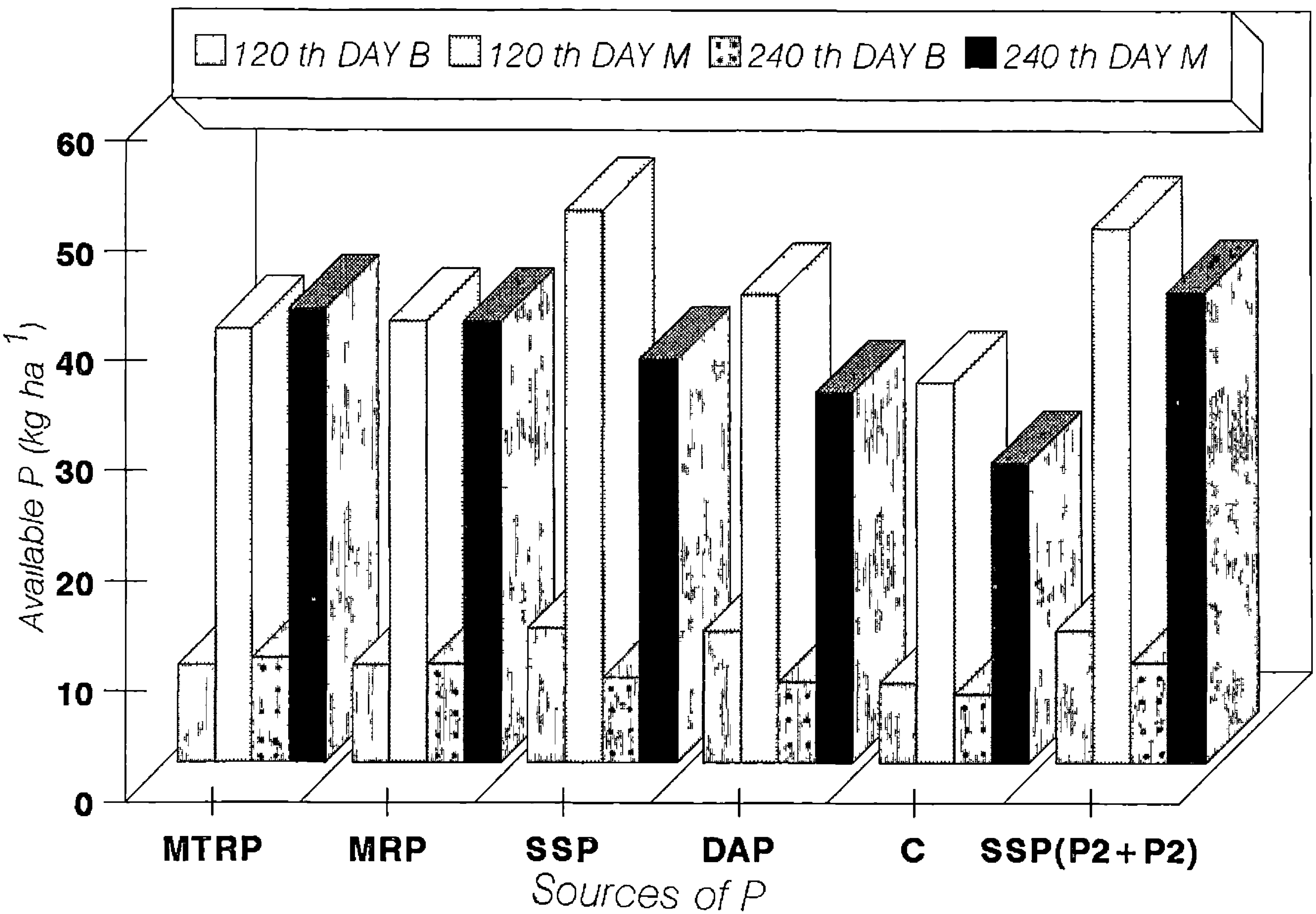
The increase in available P on waterlogging may be due to the release of native P by reduction of free hydrous Fe Al and Mn oxide and higher solubilities of $FePO_4\ 2H_2O$ and $Al\ PO_4\ 2H_2O$ due to the increased soil pH The retention of

Table 5 Available P (kg ha $^{1}$) as influenced by treatments at different periods of incubation Mathew s triacid extractant (Kuttanad alluvium)

| Treatment | | Period of incubation months | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No | Notation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | MTRP $P_1$ | 30 55 | 31 38 | 33 33 | 35 19 | 38 65 | 40 50 | 39 33 | 38 72 |
| 2 | MTRP $P_2$ | 32 73 | 33 95 | 35 19 | 40 12 | 41 26 | 44 20 | 42 60 | 41 17 |
| 3 | MTRP $P_3$ | 35 19 | 36 10 | 38 88 | 43 01 | 45 06 | 49 79 | 46 30 | 44 20 |
| 4 | MRP $P_1$ | 28 40 | 29 63 | 32 95 | 34 12 | 37 53 | 41 97 | 39 82 | 37 25 |
| 5 | MRP $P_2$ | 30 87 | 32 61 | 35 19 | 42 40 | 43 30 | 45 27 | 41 26 | 39 51 |
| 6 | MRP $P_3$ | 33 35 | 35 19 | 39 20 | 42 98 | 45 67 | 49 79 | 45 07 | 43 84 |
| 7 | SSP $P_1$ | 34 27 | 36 42 | 37 25 | 43 84 | 41 26 | 39 51 | 37 05 | 34 50 |
| 8 | SSP $P_2$ | 37 05 | 39 40 | 44 20 | 49 79 | 45 06 | 42 66 | 39 51 | 36 30 |
| 9 | SSP $P_3$ | 39 51 | 41 17 | 45 27 | 57 21 | 49 79 | 45 07 | 42 89 | 39 51 |
| 10 | DAP $P_1$ | 31 78 | 32 61 | 34 56 | 39 40 | 35 82 | 33 95 | 31 49 | 30 24 |
| 11 | DAP $P_2$ | 33 95 | 34 98 | 36 42 | 42 60 | 39 52 | 38 28 | 34 56 | 34 30 |
| 12 | DAP $P_3$ | 36 93 | 38 59 | 39 04 | 45 67 | 42 98 | 40 34 | 37 25 | 36 30 |
| 13 | C | 25 31 | 26 34 | 29 63 | 31 49 | 34 57 | 29 63 | 28 80 | 27 16 |
| 14 | SSP ($P_2$+$P_2$) | 37 25 | 39 20 | 43 84 | 48 69 | 46 30 | 48 59 | 45 10 | 42 89 |
| CD(0 05) | | 0 88 | 0 90 | 1 11 | 1 21 | 1 29 | 1 28 | 1 06 | 1 20 |
| Source | | | | | | | | | |
| MTRP | | 32 82 | 33 82 | 35 81 | 39 45 | 41 60 | 44 80 | 42 70 | 41 30 |
| MRP | | 30 87 | 32 48 | 35 77 | 40 16 | 42 10 | 45 60 | 42 00 | 40 20 |
| SSP | | 36 94 | 38 99 | 42 24 | 50 29 | 45 40 | 42 39 | 39 82 | 36 70 |
| DAP | | 35 39 | 36 69 | 39 42 | 42 56 | 39 40 | 37 52 | 34 82 | 33 60 |
| CD(0 05) | | 0 51 | 0 52 | 0 64 | 0 69 | 0 74 | 0 74 | 0 61 | 0 74 |
| Level | | | | | | | | | |
| $P_1$ | | 31 25 | 32 51 | 34 52 | 38 14 | 38 32 | 38 98 | 36 92 | 35 18 |
| $P_2$ | | 33 65 | 35 23 | 37 75 | 43 72 | 42 28 | 42 60 | 39 48 | 37 82 |
| $P_3$ | | 36 24 | 37 76 | 40 59 | 47 22 | 45 87 | 46 25 | 42 87 | 40 96 |
| CD(0 05) | | 0 44 | 0 45 | 0 55 | 0 59 | 0 64 | 0 64 | 0 53 | 0 55 |




3 Available P as influenced by sources of P at different periods of incubation Mathew's extractant-Kuttanad alluvium




4 Available P as influenced by sources of P at 120th & 240th day with Bray 1 & Mathews extractant- Kuttanad alluvium

released P gradually in the form of less soluble Fe P in the solid phase may be the reason for the decrease in the later periods The water soluble sources recorded peak values at the earlier phase of incubation period as compared to rockphosphates This is because of slow dissolution rate of rockphosphates The high fixation of water soluble P resulted in drastic decrease after the 4th period while in the case of rock phosphate it was at a slower rate as the insoluble form of P present in them is subjected to least fixation The high P content at the 8th month indicates the gradual dissolution of rockphosphates especially that of MTRP Mathew s triacid extracted more amount of available P than Bray 1 from the soil This may be due to the presence of an organic acid (oxalic acid) in the extractant which is capable of extracting more P Similar observation was recorded by Devi (1986)

4 1 1 4 Available K

The contents of available K (kg ha $^{1}$) in the soil as influenced by treatments at different periods of incubation are presented in Table 6 The values ranged from 459 2 (control) to 683 20 kg ha $^{1}$) (MTRP $P_3$) with a mean value of 571 2 kg ha $^{1}$

In general waterlogging increased the available K content With advancement of period of incubation there was decrease in available K content The control treatment recorded a maximum available K of 582 4 kg ha $^{1}$ at the 2nd month of incubation Among the other treatments SSP ($P_2$+$P_2$) maintained the same trend as that of SSP $P_2$ It can be inferred that even after the application P after 120 days there was a decrease in contents of available K and the values were found to be on par with SSP $P_1$ at the 5th and 6th period of incubation

Table 6 Available K (kg ha 1) as influenced by treatments at different periods of incubation (Kuttanad alluvium)

| Treatment | | Periods of incubation months | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No | Notation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | MTRP $P_1$ | 545 00 | 533 80 | 533 80 | 526 40 | 601 00 | 638 40 | 537 60 | 537 60 |
| 2 | MTRP $P_2$ | 563 70 | 526 40 | 492 80 | 530 10 | 634 60 | 586 10 | 515 20 | 526 40 |
| 3 | MTRP $P_3$ | 545 00 | 526 40 | 518 90 | 541 30 | 683 20 | 608 50 | 548 80 | 339 70 |
| 4 | MRP $P_1$ | 597 30 | 552 50 | 448 00 | 399 40 | 526 40 | 616 00 | 530 10 | 522 60 |
| 5 | MRP $P_2$ | 526 40 | 545 00 | 507 70 | 537 60 | 530 10 | 616 00 | 515 20 | 526 40 |
| 6 | MRP $P_3$ | 567 40 | 571 20 | 462 90 | 601 00 | 675 70 | 582 40 | 537 60 | 507 70 |
| 7 | SSP $P_1$ | 593 60 | 563 70 | 567 40 | 537 60 | 627 20 | 567 40 | 571 20 | 560 00 |
| 8 | SSP $P_2$ | 560 00 | 518 90 | 552 50 | 533 80 | 675 70 | 597 30 | 526 40 | 582 00 |
| 9 | SSP $P_3$ | 537 60 | 545 00 | 500 20 | 593 60 | 616 00 | 638 40 | 526 40 | 537 60 |
| 10 | DAP $P_1$ | 582 40 | 556 20 | 462 90 | 563 70 | 638 40 | 675 60 | 481 60 | 481 60 |
| 11 | DAP $P_2$ | 537 60 | 589 80 | 433 00 | 518 90 | 586 10 | 571 20 | 538 80 | 537 60 |
| 12 | DAP $P_3$ | 571 20 | 586 10 | 526 40 | 530 10 | 675 70 | 459 20 | 470 40 | 462 90 |
| 13 | C | 571 80 | 582 40 | 507 70 | 552 50 | 530 10 | 571 20 | 526 40 | 530 10 |
| 14 | SSP ($P_2$+$P_2$) | 574 90 | 567 40 | 511 40 | 537 60 | 612 20 | 574 90 | 459 20 | 470 40 |
| CD(0 05) | | 16 15 | 12 41 | 14 51 | 15 29 | 14 79 | 17 08 | 17 55 | 13 07 |
| Source | | | | | | | | | |
| MTRP | | 551 23 | 528 86 | 515 16 | 532 60 | 639 60 | 611 00 | 533 86 | 467 90 |
| MRP | | 563 70 | 556 23 | 472 86 | 512 66 | 577 40 | 604 80 | 527 63 | 518 90 |
| SSP | | 563 73 | 542 53 | 540 03 | 555 00 | 639 63 | 601 03 | 541 33 | 559 86 |
| DAP | | 563 73 | 577 36 | 474 10 | 531 56 | 633 40 | 568 66 | 496 93 | 494 03 |
| CD(0 05) | | 9 30 | 7 16 | 8 38 | 8 83 | 8 54 | 9 86 | 10 13 | 7 54 |
| Level | | | | | | | | | |
| $P_1$ | | 579 57 | 551 55 | 503 02 | 506 77 | 598 25 | 624 35 | 530 12 | 525 45 |
| $P_2$ | | 546 92 | 545 02 | 496 50 | 530 10 | 606 62 | 592 65 | 523 90 | 543 10 |
| $P_3$ | | 555 30 | 557 17 | 502 10 | 566 50 | 662 65 | 572 12 | 520 80 | 461 97 |
| CD(0 05) | | 8 05 | 6 20 | 7 25 | 7 64 | 7 39 | 8 54 | 8 77 | 6 54 |

There was no specific trend in available K release by the different treatments In general the sources did not differ significantly in available K content The source MRP was superior in K content in early stages of incubation followed by MTRP SSP and DAP This may be due to the original K content of the fertilizer (Appendix II) Though there was significant difference in available K content of the soil due to the different levels of P application the trend was not found to be uni form

In submerged soil large amount of $Fe^{2+}$ ion and $Mn^{2+}$ ion are brought into solution which displace $K^{+}$ in soil solution (Ponnamperuma 1972) This accounted for the high availability of K during incubation The high value registered by the control was due to the high content of K in the original soil

4 1 1 5 Available Ca

Available Ca (kg ha $^{-1}$) contents of the soil as influenced by treatments at different periods of incubation are tabulated in Table 7 It ranged from 496 0 (control) to 1744 6 kg ha $^{-1}$ (MTRP $P_3$) with a mean value of 1120 3 kg ha $^{-1}$

Submergence increased the Ca content in soil solution Maximum Ca release was observed at the 5th and 6th period and decreased after these periods

The control treatment recorded a maximum value of 626 8 kg ha $^{-1}$ at the 4th month of incubation All the treatments were significantly higher than control at all the periods of incubation The second application of SSP ($P_2+P_2$) recorded only a marginal increase of Ca as compared to SSP $P_2$ as the values indicated by these treatments were not statistically significant

Table 7 Available Ca (kg ha$^{-1}$) as influeced by treatments at different periods of incubation (Kuttanad alluvium)

| Treatment No | Notation | Period of incubation months 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MTRP $P_1$ | 1015 4 | 1299 2 | 1373 8 | 1388 8 | 1702 4 | 1642 4 | 1344 0 | 1254 0 |
| 2 | MTRP $P_2$ | 1254 4 | 1358 9 | 1344 0 | 1478 4 | 1478 4 | 1657 6 | 1344 0 | 1299 0 |
| 3 | MTRP $P_3$ | 1209 6 | 1254 4 | 1344 0 | 1448 5 | 1744 6 | 1478 4 | 1209 6 | 1120 0 |
| 4 | MRP $P_1$ | 1254 4 | 1344 0 | 1488 5 | 1478 4 | 1523 2 | 1642 4 | 1388 0 | 1284 2 |
| 5 | MRP $P_2$ | 1269 3 | 1388 0 | 1418 0 | 1433 0 | 1523 2 | 1657 6 | 1329 0 | 1299 0 |
| 6 | MRP $P_3$ | 1329 1 | 1388 0 | 1478 0 | 1523 0 | 1702 4 | 1657 6 | 1329 0 | 1299 0 |
| 7 | SSP $P_1$ | 896 0 | 940 8 | 955 7 | 1080 4 | 1120 0 | 1299 0 | 1075 0 | 1030 4 |
| 8 | SSP $P_2$ | 901 5 | 940 8 | 1015 4 | 1120 0 | 1284 0 | 1344 0 | 1299 0 | 1120 0 |
| 9 | SSP $P_3$ | 896 0 | 955 7 | 1179 7 | 1299 0 | 1388 0 | 1344 0 | 1373 0 | 1299 0 |
| 10 | DAP $P_1$ | 646 6 | 658 9 | 696 7 | 721 8 | 741 6 | 681 3 | 660 5 | 633 0 |
| 11 | DAP $P_2$ | 646 6 | 661 3 | 676 4 | 721 8 | 741 6 | 778 9 | 681 5 | 660 0 |
| 12 | DAP $P_3$ | 658 9 | 661 3 | 676 4 | 741 6 | 741 6 | 763 2 | 702 0 | 698 0 |
| 13 | C | 506 8 | 565 6 | 590 0 | 626 8 | 512 4 | 500 9 | 496 0 | 496 0 |
| 14 | SSP $(P_2+P_2)$ | 901 5 | 940 8 | 1015 4 | 1075 4 | 1299 0 | 1388 8 | 1344 0 | 1299 0 |
| CD(0 05) | | 73 86 | 68 34 | 66 41 | 76 5 | 80 5 | 65 18 | 73 81 | 85 9 |
| Source | | | | | | | | | |
| MTRP | | 1159 8 | 1304 1 | 1353 9 | 1438 5 | 1641 8 | 1592 8 | 1299 2 | 1224 3 |
| MRP | | 1284 2 | 1373 3 | 1461 5 | 1478 1 | 1582 9 | 1652 5 | 1348 6 | 1294 0 |
| SSP | | 897 8 | 945 7 | 1050 2 | 1166 4 | 1264 0 | 1329 0 | 1249 0 | 1149 8 |
| DAP | | 650 7 | 660 5 | 683 1 | 728 4 | 741 6 | 741 1 | 681 3 | 663 6 |
| CD(0 05) | | 42 61 | 39 45 | 38 31 | 4 61 | 46 49 | 37 63 | 42 61 | 49 64 |
| Level | | | | | | | | | |
| $P_1$ | | 953 1 | 1060 7 | 1128 6 | 1167 3 | 1271 8 | 1316 2 | 1116 8 | 1050 4 |
| $P_2$ | | 1017 9 | 1087 2 | 1113 4 | 1188 3 | 1256 8 | 1359 5 | 1163 3 | 1094 5 |
| $P_3$ | | 1023 4 | 1064 8 | 1169 5 | 1253 0 | 1394 1 | 1310 8 | 1153 4 | 1104 0 |
| CD(0 05) | | 36 91 | 34 17 | 33 21 | 38 68 | 40 27 | 32 59 | 36 91 | 42 99 |

All the treatments of MTRP and MRP were significantly higher than that of SSP and DAP due to the calcium content of the fertilizers (Appendix II) The lowest value was registered by DAP whereas the sources MTRP and MRP were on par at $P_3$ level for the 5th period while MTRP was significantly higher at the $P_1$ and $P_2$ level Rockphosphate fared well in the release of available Ca in the soil as compared to SSP

4 1 1 6 Available Mg

Available Mg (kg ha $^{-1}$) of the soil influenced by treatments are furnished in Table 8 The values ranged from 770 5 (control) to 1666 5 kg ha $^{-1}$ (MRP $P_3$) with a mean of 1218 5 kg ha $^{-1}$

There was higher Mg availability due to submergence Higher release was observed in the early periods of incubation and there was gradual decrease towards the later periods The control treatment recorded 1415 6 kg ha $^{-1}$ at the 1st period which was reduced to 770 5 kg ha $^{-1}$ at the 8th period Addition of SSP twice at $P_2$ level did not have any influence on Mg release

The sources did not indicated any constancy in Mg release with different months of incubation At the first period of incubation MTRP (1535 1 kg ha $^{-1}$) MRP (1498 5 kg ha $^{-1}$) and SSP (1511 0 kg ha $^{-1}$) were on par Among the sources DAP (1451 4 kg ha $^{-1}$) recorded the lowest Levels of P had no influence on Mg availability

The high values recorded by the control treatment was due to the high content of available Mg in Kuttanad soil as indicated in Table 1 In submerged soils

Table 8 Available Mg (kg ha $^{1}$) as influenced by treatments at different periods of incubation (Kuttanad alluvium)

| Treatment No | Notation | Period of incubation months 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | HTRP $P_1$ | 1487 3 | 1720 3 | 1379 8 | 1317 1 | 1308 2 | 1182 7 | 1388 8 | 1335 0 |
| 2 | HTRP $P_2$ | 1576 9 | 1550 0 | 1469 4 | 1084 2 | 1344 0 | 1254 4 | 1200 6 | 1272 3 |
| 3 | HTRP $P_3$ | 1541 1 | 1603 4 | 1352 9 | 1155 8 | 1361 9 | 1209 6 | 1460 4 | 1146 8 |
| 4 | MRP $P_1$ | 1576 9 | 1442 5 | 1164 8 | 1191 6 | 1173 7 | 1209 6 | 1263 3 | 1263 3 |
| 5 | MRP $P_2$ | 1556 8 | 1299 2 | 1254 4 | 1290 2 | 1236 4 | 1182 7 | 1173 7 | 1137 9 |
| 6 | MRP $P_3$ | 1361 9 | 1666 5 | 1326 0 | 1155 8 | 1370 8 | 1299 2 | 1200 6 | 1209 6 |
| 7 | SSP $P_1$ | 1630 7 | 1478 4 | 1057 2 | 1173 7 | 1200 6 | 1200 6 | 1433 6 | 1203 0 |
| 8 | SSP $P_2$ | 1505 2 | 1585 9 | 1344 0 | 1146 8 | 1194 6 | 1173 7 | 1173 7 | 1361 9 |
| 9 | SSP $P_3$ | 1397 7 | 1559 0 | 1299 2 | 1254 4 | 1370 8 | 1308 1 | 1227 5 | 1209 6 |
| 10 | DAP $P_1$ | 1352 9 | 1478 4 | 1200 6 | 1308 2 | 1344 0 | 949 7 | 1227 5 | 1227 5 |
| 11 | DAP $P_2$ | 1559 0 | 1550 0 | 1084 1 | 1236 4 | 1352 9 | 797 4 | 1245 4 | 1317 2 |
| 12 | DAP $P_3$ | 1442 5 | 1684 4 | 1361 9 | 1102 0 | 1406 7 | 1137 9 | 1209 6 | 1272 3 |
| 13 | C | 1415 6 | 1326 0 | 1245 4 | 1200 6 | 1245 4 | 1191 6 | 1388 8 | 770 5 |
| 14 | SSP $(P_2+P_2)$ | 1505 2 | 1585 9 | 1344 0 | 1146 8 | 1194 6 | 1182 7 | 1173 7 | 1335 0 |
| CD(0 05) | | 66 25 | 63 07 | 49 28 | 56 24 | 41 34 | 97 61 | 63 74 | 101 30 |
| Source | | | | | | | | | |
| MTRP | | 1535 1 | 1624 5 | 1400 7 | 1185 7 | 1338 0 | 1215 5 | 1349 8 | 1251 3 |
| MRP | | 1498 5 | 1469 4 | 1248 4 | 1212 5 | 1260 3 | 1230 5 | 1212 5 | 1203 6 |
| SSP | | 1511 2 | 1541 1 | 1233 4 | 1191 6 | 1255 3 | 1227 4 | 1278 2 | 1258 2 |
| DAP | | 1451 4 | 1570 9 | 1216 5 | 1215 5 | 1367 8 | 961 6 | 1244 1 | 1272 3 |
| CD(0 05) | | 38 25 | 36 37 | 28 45 | 56 20 | 41 41 | 56 45 | 36 80 | 17 50 |
| Level | | | | | | | | | |
| $P_1$ | | 1511 9 | 1529 9 | 1200 6 | 1247 6 | 1256 6 | 1135 5 | 1328 3 | 1257 2 |
| $P_2$ | | 1549 4 | 1496 3 | 1287 9 | 1189 4 | 1281 9 | 1102 1 | 1198 4 | 1272 3 |
| $P_3$ | | 1435 8 | 1628 3 | 1336 0 | 1167 0 | 1377 5 | 1238 7 | 972 1 | 1209 5 |
| CD(0 05) | | 33 12 | 31 50 | 24 64 | 35 30 | 35 80 | 48 80 | 31 87 | 51 77 |

the large amount of $Fe^{2+}$ and $Mn^{2+}$ brought into solutions displace cations from the clay composition increasing the concentration of $Mg^{2+}$ in the soil solution

4 1 2 Laterite soil

4 1 2 1 Soil reaction

Soil pH values as influenced by the treatments at different periods of incubation are provided in Table 9 The values ranged from 4 90 (control) to 5 65 (MTRP $P_3$)

The pH of the soil gradually increased on incubation irrespective of the treatments including the control The control treatment recorded a maximum value of 5 30 at the 8th month of incubation There was no significant difference between SSP ($P_2$+$P_2$) and SSP $P_2$ throughout the incubation period of 240 days

With regard to pH there was no significant difference among the treatments The relationship between pH values recorded by different sources of fertilizers under different periods of incubation is presented in Fig 1 It can be seen that rockphosphates maintained higher pH as compared to water soluble P sources throughout the incubation period The source MTRP recorded higher value than other treatments such as MRP DAP and SSP At the 7th period MTRP and MRP were on par Though there was significant difference in pH of the soil due to the different levels of P the trend was not found to be uniform

The probable reasons for the hike in pH due to waterlogging are dis cussed in 4 1 1 1

Table 9 The influence of treatments on the pH of laterite soil at different periods of incubation

| Treatment | | Period of incubation months | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No | Notation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | MTRP $P_1$ | 5 00 | 5 10 | 5 20 | 5 35 | 5 40 | 5 50 | 5 55 | 5 65 |
| 2 | MTRP $P_2$ | 5 05 | 5 10 | 5 15 | 5 22 | 5 30 | 5 36 | 5 45 | 5 55 |
| 3 | MTRP $P_3$ | 5 05 | 5 15 | 5 25 | 5 28 | 5 35 | 5 40 | 5 45 | 5 57 |
| 4 | MRP $P_1$ | 5 00 | 5 15 | 5 20 | 5 25 | 5 30 | 5 35 | 5 45 | 5 50 |
| 5 | MRP $P_2$ | 5 00 | 5 10 | 5 20 | 5 23 | 5 25 | 5 30 | 5 45 | 5 50 |
| 6 | MRP $P_3$ | 5 05 | 5 10 | 5 15 | 5 15 | 5 20 | 5 25 | 5 45 | 5 50 |
| 7 | SSP $P_1$ | 4 95 | 5 00 | 5 05 | 5 07 | 5 10 | 5 20 | 5 30 | 5 35 |
| 8 | SSP $P_2$ | 5 00 | 5 15 | 5 15 | 5 20 | 5 23 | 5 30 | 5 35 | 5 45 |
| 9 | SSP $P_3$ | 4 95 | 5 05 | 5 15 | 5 25 | 5 35 | 5 40 | 5 40 | 5 45 |
| 10 | DAP $P_1$ | 5 00 | 5 10 | 5 15 | 5 20 | 5 25 | 5 35 | 5 40 | 5 45 |
| 11 | DAP $P_2$ | 5 05 | 5 10 | 5 15 | 5 25 | 5 30 | 5 35 | 5 45 | 5 50 |
| 12 | DAP $P_3$ | 5 05 | 5 05 | 5 10 | 5 10 | 5 15 | 5 35 | 5 35 | 5 40 |
| 13 | C | 4 90 | 5 00 | 5 10 | 5 10 | 5 15 | 5 30 | 5 30 | 5 30 |
| 14 | SSP ($P_2+P_2$) | 5 00 | 5 10 | 5 15 | 5 15 | 5 13 | 5 30 | 5 35 | 5 35 |
| CD(0 05) | | NS | NS | NS | NS | NS | NS | NS | NS |
| Source | | | | | | | | | |
| MTRP | | 5 03 | 5 11 | 5 2 | 5 28 | 5 35 | 5 4 | 5 48 | 5 59 |
| MRP | | 5 01 | 5 11 | 5 18 | 5 21 | 5 25 | 5 31 | 5 45 | 5 50 |
| SSP | | 4 96 | 5 05 | 5 11 | 5 17 | 5 19 | 5 30 | 5 35 | 5 35 |
| DAP | | 5 03 | 5 08 | 5 13 | 5 18 | 5 23 | 5 40 | 5 40 | 5 45 |
| CD(0 05) | | 0 04 | 0 05 | 0 05 | 0 05 | 0 05 | 0 05 | 0 05 | 0 05 |
| Level | | | | | | | | | |
| $P_1$ | | 4 98 | 5 08 | 5 15 | 5 23 | 5 26 | 5 35 | 5 43 | 5 49 |
| $P_2$ | | 5 03 | 5 11 | 5 16 | 5 22 | 5 27 | 5 33 | 5 43 | 5 50 |
| $P_3$ | | 5 03 | 5 09 | 5 16 | 5 19 | 5 26 | 5 35 | 5 41 | 5 48 |
| CD(0 05) | | 0 04 | 0 04 | 0 05 | 0 05 | 0 05 | 0 05 | 0 04 | 0 04 |

4 1 2 2 Available N

The values for available N (kg ha $^{1}$) in soil as influenced by treatments at different periods of incubation are presented in Table 10 The values ranged from 302 40 (control) to 740 10 kg ha $^{1}$ (DAP $P_3$) with mean of 521 2 kg ha $^{1}$

Waterlogging increased the N content of the soil and the peak values were recorded at the 1st month of incubation With increase in periods of incubation a decrease in available N was observed

All the treatment combinations were significantly higher than control The control treatment recorded a maximum value of 420 20 kg ha $^{1}$ at the 1st month of incubation In SSP ($P_2$+$P_2$) the second application did not have significant additional influence

The DAP treatments released higher N in the first period followed by the other sources such as SSP MTRP and MRP At $P_3$ level SSP was found to be significantly higher than DAP $P_3$ at the 2nd 3rd 4th 7th period But it was on par with DAP $P_3$ at the 5th and 8th period Similarly MTRP $P_3$ was on par with DAP $P_3$ at the 3rd 4th 5th 6th and 8th period With increase in levels of P there was significant increase in nitrogen content

The high available N content of DAP treatments recorded at the initial periods of incubation may be attributed to the N present in the fertiliser itself The losses of N by denitrification and volatilisation may be the reason for the decrease in available N with periods of incubation

Table 10 Available N (kg ha $^{1}$) as influenced by treatments at different periods of incubation (laterite)

| Treatmet | | Period of incubation months | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No | Notation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | MTRP $P_1$ | 497 57 | 459 04 | 451 58 | 474 50 | 482 94 | 393 05 | 319 87 | 307 30 |
| 2 | MTRP $P_2$ | 533 12 | 476 67 | 476 67 | 505 95 | 512 22 | 413 95 | 363 78 | 334 49 |
| 3 | MTRP $P_3$ | 589 57 | 514 30 | 497 57 | 491 30 | 510 12 | 426 50 | 386 78 | 370 05 |
| 4 | MRP $P_1$ | 470 40 | 426 50 | 497 57 | 436 96 | 470 40 | 401 41 | 319 87 | 288 51 |
| 5 | MRP $P_2$ | 526 85 | 464 13 | 420 22 | 439 04 | 514 30 | 426 49 | 351 23 | 288 51 |
| 6 | MRP $P_3$ | 589 57 | 539 39 | 426 50 | 480 55 | 520 58 | 426 49 | 357 50 | 351 23 |
| 7 | SSP $P_1$ | 549 85 | 468 32 | 457 87 | 407 68 | 462 04 | 376 32 | 332 42 | 332 42 |
| 8 | SSP $P_2$ | 646 02 | 602 11 | 420 23 | 489 20 | 508 03 | 424 41 | 376 32 | 355 42 |
| 9 | SSP $P_3$ | 663 50 | 620 93 | 514 30 | 564 48 | 526 85 | 432 77 | 420 22 | 386 78 |
| 10 | DAP $P_1$ | 589 57 | 514 30 | 413 95 | 476 67 | 510 12 | 451 58 | 426 50 | 380 50 |
| 11 | DAP $P_2$ | 620 93 | 564 48 | 459 94 | 466 21 | 476 67 | 432 77 | 432 77 | 382 59 |
| 12 | DAP $P_3$ | 740 10 | 589 57 | 499 68 | 505 95 | 520 58 | 441 12 | 407 68 | 378 42 |
| 13 | C | 420 20 | 405 57 | 382 50 | 370 00 | 342 70 | 363 70 | 307 30 | 302 40 |
| 14 | SSP ($P_2$+$P_2$) | 650 19 | 589 56 | 455 70 | 491 30 | 510 12 | 432 70 | 386 70 | 343 78 |
| CD(0 05) | | 12 42 | 11 50 | 13 43 | 15 04 | 14 87 | 24 39 | 11 28 | 10 81 |
| Source | | | | | | | | | |
| MTRP | | 540 08 | 483 33 | 475 30 | 490 58 | 501 76 | 411 20 | 356 81 | 337 28 |
| MRP | | 528 94 | 476 67 | 448 09 | 452 20 | 501 76 | 418 10 | 342 80 | 309 41 |
| SSP | | 619 79 | 563 78 | 464 10 | 487 12 | 493 90 | 411 20 | 376 30 | 358 20 |
| DAP | | 650 20 | 556 21 | 457 85 | 482 94 | 5 2 40 | 441 80 | 422 30 | 380 50 |
| CD(0 05) | | 7 01 | 6 64 | 7 75 | 8 68 | 8 58 | 14 08 | 6 51 | 6 24 |
| Level | | | | | | | | | |
| $P_1$ | | 526 84 | 467 04 | 453 24 | 448 95 | 481 37 | 405 59 | 349 66 | 327 18 |
| $P_2$ | | 581 73 | 526 80 | 444 26 | 475 10 | 502 80 | 424 40 | 381 03 | 340 25 |
| $P_3$ | | 645 68 | 566 04 | 484 51 | 510 57 | 519 53 | 431 72 | 393 04 | 371 62 |
| CD(0 05) | | 6 07 | 5 75 | 6 72 | 7 52 | 7 44 | 12 19 | 5 64 | 5 41 |

4 1 2 3 Available P

The contents of available P (kg ha $^{1}$) as influenced by treatments at different periods of incubation are presented in Table 11 and Table 12 Available P using Bray 1 ranged from 10 49 (C) to 29 0 kg ha $^{1}$ (SSP $P_3$) with mean value of 13 16 kg ha $^{1}$ while with Mathew s triacid it ranged from 26 12 (C) to 64 54 (SSP $P_3$) with an average of 45 33 kg ha $^{1}$

The release of available P (Bray) under the influence of different periods of incubation are illustrated in Fig 5 (Bray 1) and Fig 6 (Mathew s extractant) In general there was continuous increase in available P upto the 6th period The rockphosphate treatments registered higher release of available P at the 6th month where as the water soluble sources at the 4th month of incubation

The control treatment recorded a maximum value at the 4th period after which there was a decrease All the treatments were statistically superior to control The second application of P as in the treatment SSP ($P_2$+$P_2$) resulted in a small increase in available P at the 5th period This was found to be significantly higher than SSP $P_2$ However at the 6th 7th and 8th period it was on par with SSP $P_2$

The comparative release of available P as recorded by the different P sources at 4th and 8th month of incubation is depicted in the Fig 7 From this it is evident that SSP and DAP were superior to rockphosphates The source SSP was superior followed by DAP at the 4th month whereas MTRP and MRP were on par At the 8th month however MTRP DAP and SSP were on par and superior to MRP There was significant increase in available P with increase in levels of P

Table 11 Available P (kg ha $^{1}$) as influenced by treatments at different periods of incubation Bray 1 (laterite)

| Treatment No | Notation | Period of incubation months 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MTRP $P_1$ | 12 85 | 12 96 | 14 20 | 16 66 | 16 97 | 17 89 | 16 35 | 16 66 |
| 2 | MTRP $P_2$ | 14 71 | 15 12 | 16 06 | 18 92 | 19 55 | 19 75 | 18 21 | 18 52 |
| 3 | MTRP $P_3$ | 17 29 | 17 60 | 19 15 | 21 61 | 22 84 | 22 73 | 20 98 | 20 36 |
| 4 | MRP $P_1$ | 12 65 | 13 88 | 14 15 | 15 43 | 17 89 | 16 57 | 15 74 | 15 50 |
| 5 | MRP $P_2$ | 15 32 | 15 32 | 16 06 | 18 92 | 20 87 | 20 87 | 16 66 | 16 03 |
| 6 | MRP $P_3$ | 16 66 | 17 38 | 18 92 | 22 22 | 23 26 | 23 87 | 19 75 | 19 55 |
| 7 | SSP $P_1$ | 15 20 | 15 74 | 17 89 | 21 60 | 20 22 | 17 89 | 17 38 | 13 88 |
| 8 | SSP $P_2$ | 17 20 | 17 60 | 20 98 | 25 31 | 24 11 | 20 36 | 18 12 | 14 15 |
| 9 | SSP $P_3$ | 18 30 | 20 65 | 23 96 | 29 00 | 28 63 | 24 28 | 20 61 | 16 06 |
| 10 | DAP $P_1$ | 13 88 | 15 51 | 16 35 | 22 12 | 19 73 | 19 61 | 13 27 | 12 26 |
| 11 | DAP $P_2$ | 16 66 | 18 38 | 19 12 | 23 80 | 20 73 | 20 68 | 15 50 | 14 62 |
| 12 | DAP $P_3$ | 18 83 | 19 52 | 21 60 | 26 39 | 23 28 | 23 23 | 17 38 | 16 36 |
| 13 | C | 10 49 | 11 42 | 12 65 | 14 81 | 14 40 | 13 60 | 12 80 | 12 20 |
| 14 | SSP ($P_2+P_2$) | 16 97 | 17 59 | 20 37 | 24 69 | 25 90 | 19 75 | 18 82 | 18 54 |
| CD(0 05) | | 0 82 | 1 89 | 1 00 | 1 14 | 1 12 | 0 97 | 0 87 | 1 07 |
| Source | | | | | | | | | |
| MTRP | | 14 95 | 15 22 | 16 47 | 19 06 | 19 79 | 20 12 | 18 51 | 18 51 |
| MRP | | 14 87 | 15 53 | 16 37 | 18 85 | 20 67 | 20 54 | 17 38 | 17 03 |
| SSP | | 16 90 | 17 99 | 20 94 | 25 30 | 23 98 | 19 84 | 18 70 | 18 05 |
| DAP | | 16 45 | 17 80 | 19 02 | 24 10 | 21 25 | 21 17 | 15 38 | 14 41 |
| CD(0 05) | | 0 47 | 1 09 | 0 57 | 0 66 | 0 65 | 0 56 | 0 50 | 0 62 |
| Level | | | | | | | | | |
| $P_1$ | | 13 64 | 14 52 | 15 64 | 18 95 | 18 70 | 17 99 | 15 68 | 14 57 |
| $P_2$ | | 15 96 | 16 60 | 18 05 | 21 73 | 21 32 | 20 41 | 17 12 | 15 83 |
| $P_3$ | | 17 77 | 18 78 | 20 90 | 24 80 | 24 50 | 23 52 | 19 68 | 18 08 |
| CD(0 05) | | 0 41 | 0 95 | 0 50 | 0 57 | 0 56 | 0 49 | 0 44 | 0 53 |

Table 12 Available P (kg ha $^{1}$) as influenced by treatments at different periods of incubation Mathews triacid extractant (laterite)

| Treatment | | Period of incubation months | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No | Notation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | MTRP $P_1$ | 33 95 | 34 87 | 38 16 | 42 08 | 45 07 | 43 20 | 41 10 | 39 80 |
| 2 | MTRP $P_2$ | 36 42 | 38 59 | 45 10 | 49 47 | 52 06 | 51 86 | 50 95 | 47 71 |
| 3 | MTRP $P_3$ | 39 82 | 41 05 | 48 42 | 61 03 | 56 38 | 55 27 | 54 20 | 51 70 |
| 4 | MRP $P_1$ | 32 49 | 35 72 | 38 42 | 44 28 | 46 50 | 44 10 | 42 20 | 39 80 |
| 5 | MRP $P_2$ | 35 95 | 37 10 | 44 97 | 49 07 | 53 22 | 54 72 | 48 21 | 44 21 |
| 6 | MRP $P_3$ | 38 42 | 40 59 | 48 65 | 52 50 | 55 32 | 54 10 | 53 80 | 49 18 |
| 7 | SSP $P_1$ | 38 79 | 41 60 | 46 97 | 54 24 | 51 24 | 47 03 | 46 03 | 40 40 |
| 8 | SSP $P_2$ | 42 08 | 45 97 | 49 44 | 57 16 | 55 39 | 53 70 | 51 60 | 46 40 |
| 9 | SSP $P_3$ | 44 75 | 46 61 | 54 11 | 64 54 | 60 95 | 59 29 | 55 65 | 53 90 |
| 10 | DAP $P_1$ | 36 42 | 38 59 | 43 11 | 49 28 | 47 30 | 45 13 | 43 50 | 39 80 |
| 11 | DAP $P_2$ | 40 74 | 42 29 | 46 06 | 54 93 | 53 56 | 51 80 | 49 18 | 46 71 |
| 12 | DAP $P_3$ | 42 89 | 45 72 | 51 45 | 56 29 | 55 55 | 52 24 | 50 64 | 48 22 |
| 13 | C | 26 12 | 29 50 | 35 47 | 39 39 | 38 25 | 36 94 | 34 68 | 32 70 |
| 14 | SSP ($P_2+P_2$) | 41 98 | 44 20 | 48 50 | 56 30 | 57 16 | 54 10 | 52 30 | 46 40 |
| CD(0 05) | | 0 93 | 0 80 | 1 39 | 1 46 | 1 36 | 1 28 | 1 87 | 1 75 |
| Source | | | | | | | | | |
| MTRP | | 36 73 | 38 17 | 43 89 | 47 52 | 51 17 | 50 11 | 48 75 | 46 40 |
| MRP | | 35 62 | 37 80 | 44 01 | 48 62 | 51 68 | 50 97 | 48 07 | 44 39 |
| SSP | | 41 87 | 44 73 | 50 17 | 58 65 | 55 86 | 53 34 | 51 09 | 46 23 |
| DAP | | 40 02 | 42 20 | 46 87 | 53 50 | 52 13 | 49 72 | 47 78 | 44 91 |
| CD(0 05) | | 0 53 | 0 46 | 0 81 | 0 85 | 0 78 | 0 74 | 1 08 | 1 01 |
| Level | | | | | | | | | |
| $P_1$ | | 35 41 | 37 69 | 41 66 | 47 47 | 47 53 | 44 86 | 43 21 | 39 95 |
| $P_2$ | | 38 79 | 40 98 | 46 39 | 52 65 | 53 55 | 53 02 | 49 98 | 46 27 |
| $P_3$ | | 41 47 | 43 49 | 50 65 | 58 59 | 57 05 | 55 23 | 53 57 | 50 25 |
| CD(0 05) | | 0 46 | 0 40 | 0 69 | 0 72 | 0 67 | 0 64 | 0 93 | 0 87 |

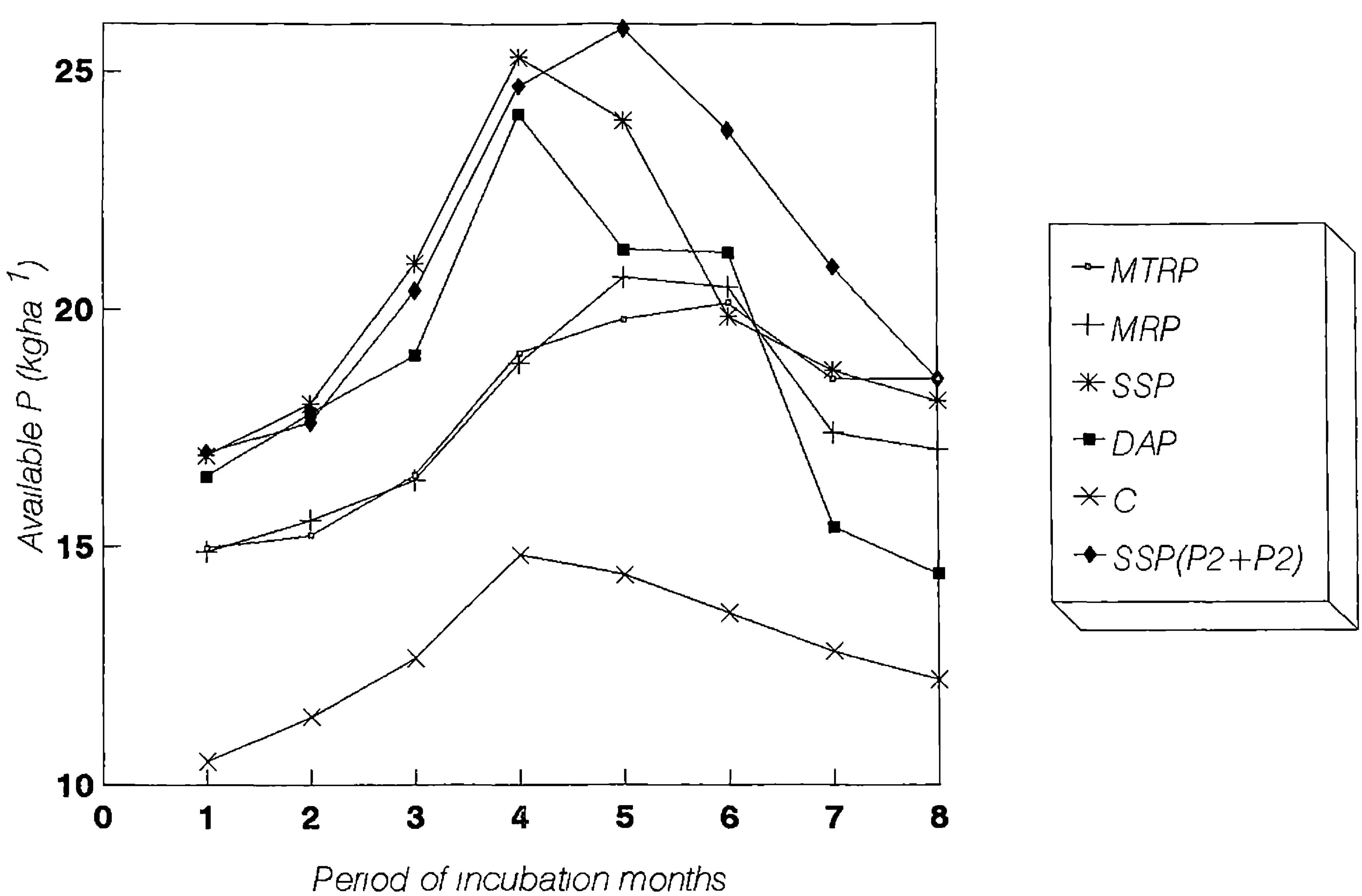
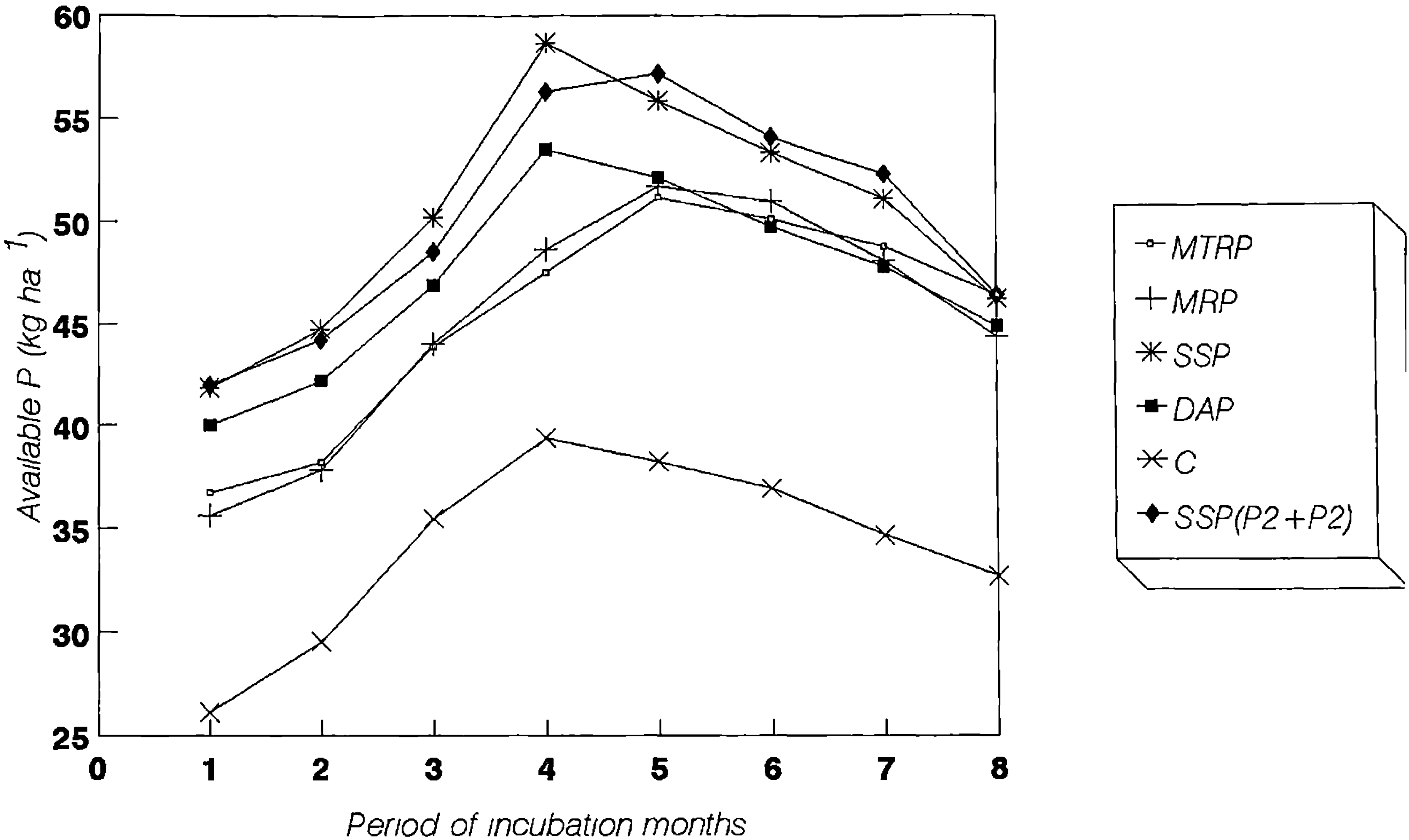
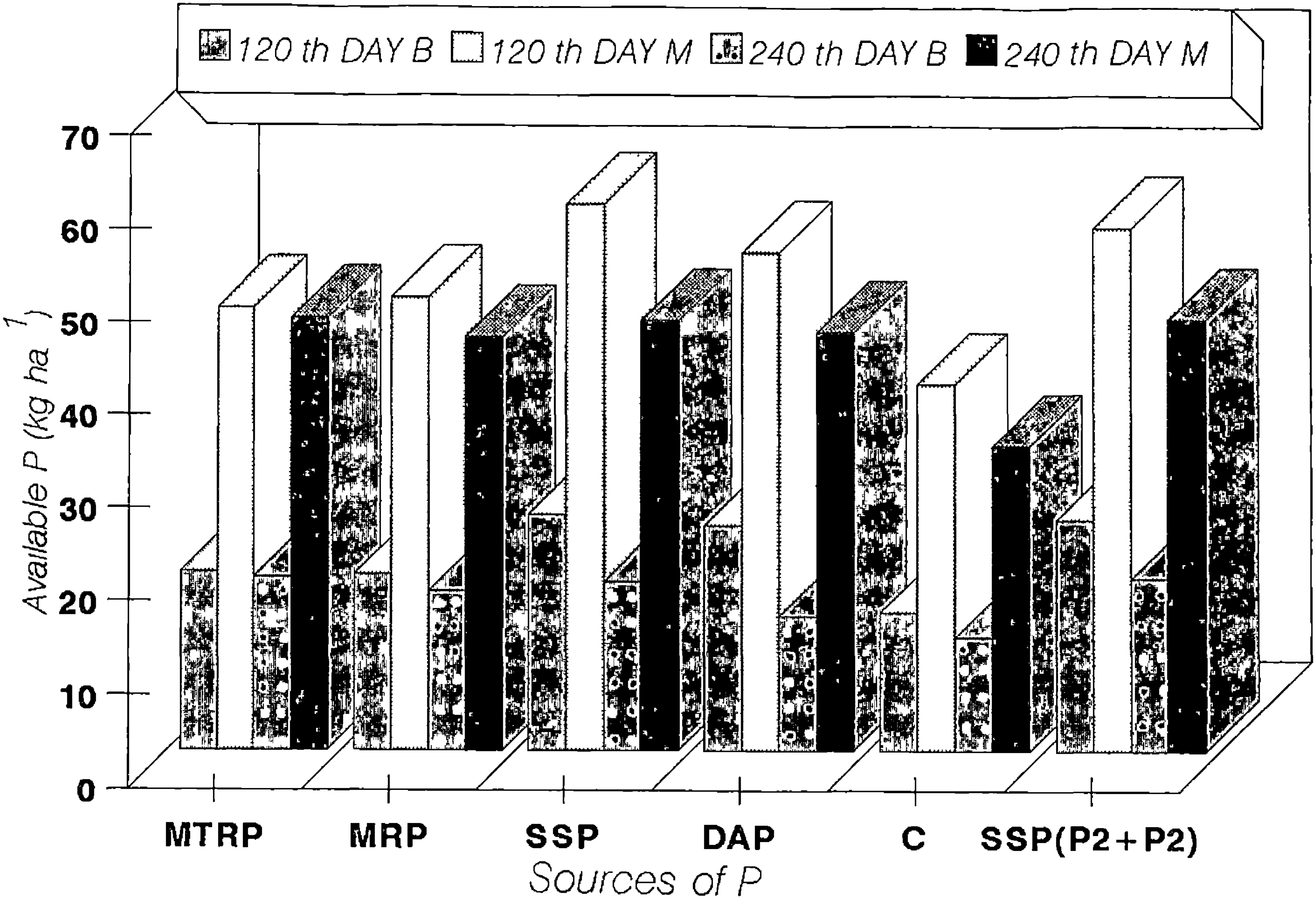



Fig 5 Available P as influenced by sources of P at different periods of incubation Bray 1




6 Available P as influenced by sources of P at different periods of incubation Mathew's extractant (laterite)




⁷ Available P as influenced by sources of P at 120th & 240th day with Bray 1 & Mathew's extractant(laterite)

Due to the highly oxidised nature of laterite soil the reduction reactions occurring as a result of flooding might have helped in the release of available P (Tandon 1987) The less release of P from rockphosphate as compared to water soluble sources may be due to the higher pH values of laterite soil as compared to Kuttanad alluvium

4 1 2 4 Available K

Available K (kg ha $^{1}$) of soil as influenced by different treatments at different periods of incubation are furnished in Table 13 The values of available K ranged from 110 4 kg ha $^{1}$ (C) to 185 9 kg ha $^{1}$ (MRP $P_1$) with a mean of 98 7 kg ha $^{1}$

Waterlogging increased the K content and maximum value was recorded at the 2nd and 3rd month of incubation after which there was gradual decrease There was slight increase at the 8th month of incubation

The control treatment recorded a maximum value of 156 8 kg ha $^{1}$ at the 2nd period after which it decreased to 110 4 kg ha $^{1}$ at the 8th period For the treatment SSP ($P_2+P_2$) a decrease in available K at the 5th 6th and 8th month of incubation was noticed

In general MRP released more available K at the initial period of incubation followed by MTRP SSP and DAP But there was no specific trend for this change with advancement of period of incubation Eventhough there was significant difference in available K content between levels of P the increase and decrease was not uniform

Table 13 Available K (kg ha $^{1}$) as influenced by treatments at different periods of incubation (laterite)

| Treatment | | Period of incubation months | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No | Notation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | MTRP $P_1$ | 172 4 | 178 4 | 162 0 | 142 6 | 161 3 | 141 1 | 114 2 | 132 1 |
| 2 | MTRP $P_2$ | 171 7 | 165 7 | 174 7 | 123 9 | 136 6 | 159 0 | 118 7 | 136 6 |
| 3 | MTRP $P_3$ | 175 4 | 168 7 | 163 5 | 143 3 | 132 1 | 117 2 | 117 5 | 127 6 |
| 4 | MRP $P_1$ | 139 6 | 185 9 | 153 8 | 161 2 | 165 7 | 119 4 | 116 4 | 132 2 |
| 5 | MRP $P_2$ | 152 3 | 179 1 | 181 4 | 159 0 | 168 0 | 129 9 | 118 7 | 141 1 |
| 6 | MRP $P_3$ | 159 0 | 165 7 | 159 0 | 154 5 | 138 1 | 136 6 | 125 4 | 123 2 |
| 7 | SSP $P_1$ | 154 5 | 170 2 | 156 8 | 139 6 | 165 7 | 133 6 | 110 4 | 150 0 |
| 8 | SSP $P_2$ | 168 0 | 159 0 | 156 8 | 152 3 | 143 3 | 141 8 | 118 7 | 136 6 |
| 9 | SSP $P_3$ | 152 9 | 170 9 | 167 2 | 170 2 | 150 0 | 132 8 | 130 6 | 134 4 |
| 10 | DAP $P_1$ | 130 9 | 142 7 | 148 6 | 141 2 | 152 3 | 120 9 | 118 7 | 123 2 |
| 11 | DAP $P_2$ | 133 6 | 142 4 | 172 4 | 159 7 | 144 8 | 114 2 | 114 2 | 132 2 |
| 12 | DAP $P_3$ | 134 5 | 171 7 | 161 2 | 150 0 | 142 6 | 135 1 | 118 7 | 134 4 |
| 13 | C | 130 6 | 156 8 | 152 3 | 150 8 | 147 0 | 120 9 | 120 9 | 110 4 |
| 14 | SSP ($P_2$+$P_2$) | 150 4 | 174 4 | 182 1 | 160 5 | 144 1 | 124 6 | 118 7 | 116 5 |
| CD(0 05) | | 3 32 | 5 31 | 3 78 | 4 19 | 4 37 | 4 34 | 3 77 | 3 86 |
| Source | | | | | | | | | |
| MTRP | | 173 1 | 170 9 | 166 7 | 136 6 | 143 3 | 139 4 | 116 8 | 132 1 |
| MRP | | 150 3 | 176 9 | 164 7 | 158 2 | 157 2 | 128 6 | 120 2 | 132 1 |
| SSP | | 158 4 | 166 7 | 160 2 | 154 0 | 153 0 | 136 1 | 119 9 | 140 3 |
| DAP | | 133 0 | 152 3 | 160 7 | 150 3 | 146 5 | 123 4 | 117 2 | 129 9 |
| CD(0 05) | | 3 32 | 3 07 | 2 18 | 2 42 | 1 47 | 2 50 | 2 18 | 2 23 |
| Level | | | | | | | | | |
| $P_1$ | | 149 4 | 169 3 | 155 3 | 146 1 | 161 2 | 128 7 | 114 9 | 134 4 |
| $P_2$ | | 156 4 | 161 5 | 171 3 | 148 7 | 148 2 | 136 2 | 117 5 | 136 6 |
| $P_3$ | | 155 4 | 169 2 | 162 7 | 154 5 | 140 7 | 130 4 | 123 0 | 129 9 |
| CD(0 05) | | 2 87 | 2 65 | 1 88 | 2 09 | 2 18 | 2 17 | 1 88 | 1 93 |

4 1 2 5 Available Ca

Available Ca (kg ha $^{1}$) of soil as influenced by treatments at different periods of incubation are provided in Table 14 The values ranged from 521 3 (control) to 1075 2 kg ha $^{1}$ (MRP $P_2$ and MRP $P_3$) with an average value of 798 2 kg ha $^{1}$

Available Ca content increased under continuous submergence Maximum content was observed at the 3rd month of incubation There was decrease towards the later periods of incubation

The control treatment recorded a maximum value of 716 8 kg ha $^{1}$ at the 1st and 2nd month of incubation and it reduced to 521 3 kg ha $^{1}$ at the 8th month For the treatment SSP ($P_2$+$P_2$) the application of SSP after 120 days resulted in numerical increase of Ca content as compared to SSP $P_2$ But the values were not statistically significant

The treatments of MRP were superior throughout the incubation period It was found that the values recorded by MTRP and SSP were on par The source DAP recorded the lowest There was significant difference between levels of P but the increase was not uniform

The presence of Ca P in rockphosphate and SSP might have attributed to higher Ca release as compared to DAP Similar observations were also recorded and discussed for Kuttanad alluvium in section 4 1 1 5

Table 14 Available Ca (kg ha $^{1}$) as influenced by treatments at different periods of incubation (laterite)

| Treatment No | Notation | Period of incubation months 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MTRP $P_1$ | 806 4 | 866 1 | 761 6 | 716 8 | 672 0 | 627 2 | 612 2 | 612 2 |
| 2 | MTRP $P_2$ | 806 4 | 851 2 | 716 8 | 716 8 | 627 2 | 627 2 | 612 2 | 612 2 |
| 3 | MTRP $P_3$ | 851 2 | 881 2 | 831 2 | 806 4 | 746 0 | 672 0 | 627 2 | 627 2 |
| 4 | MRP $P_1$ | 970 6 | 985 6 | 1075 2 | 940 8 | 881 1 | 851 2 | 806 4 | 761 6 |
| 5 | MRP $P_2$ | 955 7 | 985 6 | 1075 2 | 880 9 | 806 4 | 761 6 | 716 8 | 716 8 |
| 6 | MRP $P_3$ | 910 9 | 940 8 | 970 6 | 851 2 | 806 4 | 791 4 | 761 6 | 716 8 |
| 7 | SSP $P_1$ | 880 9 | 880 9 | 761 6 | 761 6 | 716 8 | 672 0 | 627 2 | 627 2 |
| 8 | SSP $P_2$ | 806 4 | 880 9 | 806 4 | 761 6 | 716 8 | 672 0 | 672 0 | 627 2 |
| 9 | SSP $P_3$ | 806 4 | 880 9 | 716 8 | 716 8 | 627 0 | 612 2 | 612 2 | 606 3 |
| 10 | DAP $P_1$ | 761 6 | 768 9 | 716 8 | 672 0 | 627 0 | 612 2 | 606 3 | 586 0 |
| 11 | DAP $P_2$ | 761 6 | 768 9 | 716 8 | 627 2 | 627 0 | 612 2 | 612 2 | 586 0 |
| 12 | DAP $P_3$ | 761 6 | 776 5 | 716 8 | 672 0 | 627 0 | 612 2 | 606 3 | 586 0 |
| 13 | C | 716 8 | 716 8 | 672 0 | 612 2 | 612 2 | 606 3 | 537 6 | 521 3 |
| 14 | SSP ($P_2$+$P_2$) | 806 4 | 880 9 | 806 4 | 761 6 | 761 6 | 716 8 | 716 8 | 672 0 |
| CD(0 05) | | 58 25 | 65 18 | 75 55 | 72 03 | 68 33 | 60 26 | 73 81 | 72 03 |
| source | | | | | | | | | |
| MTRP | | 828 8 | 866 2 | 769 8 | 761 6 | 681 7 | 649 6 | 619 7 | 619 7 |
| MRP | | 945 7 | 963 2 | 1040 3 | 890 9 | 831 3 | 801 4 | 761 6 | 739 2 |
| SSP | | 831 2 | 880 9 | 761 6 | 739 2 | 671 9 | 642 1 | 637 1 | 616 7 |
| DAP | | 761 6 | 772 7 | 716 8 | 649 6 | 627 0 | 612 2 | 609 3 | 586 0 |
| CD(0 05) | | 44 6 | 37 63 | 43 62 | 41 59 | 39 45 | 34 79 | 42 61 | 41 59 |
| Level | | | | | | | | | |
| $P_1$ | | 854 8 | 875 3 | 828 8 | 772 8 | 724 2 | 690 6 | 668 0 | 646 7 |
| $P_2$ | | 832 5 | 871 6 | 828 8 | 746 6 | 694 3 | 668 2 | 653 3 | 635 5 |
| $P_3$ | | 832 5 | 869 8 | 808 8 | 761 6 | 701 6 | 672 9 | 651 8 | 634 0 |
| CD(0 05) | | 38 62 | 32 58 | 37 76 | 36 02 | 34 17 | 30 14 | 36 91 | 36 02 |

Table 15 Available Mg (kg ha $^{-1}$) as influenced by treatments at different periods of incubation (laterite)

| Treatment | | Period of incubation months | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No | Notation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | MTRP $P_1$ | 358 4 | 421 1 | 349 4 | 322 5 | 358 4 | 340 4 | 376 3 | 403 2 |
| 2 | MTRP $P_2$ | 376 3 | 479 5 | 430 1 | 188 1 | 259 8 | 232 9 | 259 8 | 403 2 |
| 3 | MTRP $P_3$ | 340 4 | 206 0 | 241 9 | 286 7 | 206 0 | 127 5 | 304 6 | 313 6 |
| 4 | MRP $P_1$ | 286 7 | 421 1 | 358 4 | 152 3 | 224 0 | 268 8 | 322 5 | 322 5 |
| 5 | MRP $P_2$ | 474 8 | 268 8 | 304 6 | 152 3 | 224 0 | 259 8 | 340 5 | 394 2 |
| 6 | MRP $P_3$ | 304 6 | 385 2 | 367 4 | 143 4 | 215 0 | 250 8 | 143 4 | 322 5 |
| 7 | SSP $P_1$ | 215 0 | 340 4 | 268 8 | 206 1 | 268 8 | 277 7 | 394 2 | 331 5 |
| 8 | SSP $P_2$ | 358 4 | 331 5 | 304 6 | 206 1 | 206 0 | 188 2 | 358 4 | 367 3 |
| 9 | SSP $P_3$ | 313 6 | 421 1 | 331 5 | 241 9 | 134 4 | 295 6 | 385 3 | 349 4 |
| 10 | DAP $P_1$ | 286 7 | 448 0 | 322 5 | 340 5 | 224 0 | 206 1 | 313 6 | 403 2 |
| 11 | DAP $P_2$ | 349 4 | 510 7 | 304 6 | 179 2 | 129 9 | 232 9 | 340 5 | 313 6 |
| 12 | DAP $P_3$ | 412 2 | 322 7 | 385 2 | 134 4 | 232 9 | 188 2 | 358 4 | 376 3 |
| 13 | C | 304 6 | 295 6 | 349 9 | 232 9 | 241 9 | 232 9 | 268 8 | 349 4 |
| 14 | SSP ($P_2$+$P_2$) | 340 4 | 349 4 | 341 9 | 250 8 | 224 0 | 152 5 | 322 5 | 340 5 |
| CD(0 05) | | 44 28 | 58 78 | 64 10 | 54 67 | 63 09 | 61 12 | 60 74 | 71 02 |
| Source | | | | | | | | | |
| MTRP | | 358 3 | 368 8 | 340 4 | 265 7 | 274 7 | 233 6 | 313 5 | 373 3 |
| MRP | | 355 3 | 358 3 | 343 4 | 149 3 | 221 0 | 259 8 | 263 8 | 346 4 |
| SSP | | 295 6 | 364 3 | 301 6 | 218 0 | 253 8 | 253 8 | 379 3 | 349 4 |
| DAP | | 349 4 | 427 1 | 346 5 | 218 0 | 209 06 | 209 1 | 337 5 | 364 3 |
| CD(0 05) | | 25 57 | 33 94 | 37 00 | 31 56 | 36 42 | 35 28 | 35 06 | 41 0 |
| Level | | | | | | | | | |
| $P_1$ | | 286 7 | 407 6 | 324 7 | 255 3 | 268 8 | 273 2 | 351 6 | 365 1 |
| $P_2$ | | 389 7 | 397 6 | 336 9 | 181 4 | 204 9 | 228 4 | 324 8 | 369 5 |
| $P_3$ | | 342 7 | 333 7 | 331 5 | 201 6 | 197 1 | 215 5 | 297 9 | 340 4 |
| CD(0 05) | | 22 14 | 29 39 | 32 05 | 27 34 | 31 55 | 30 56 | 30 37 | 35 51 |

4 1 2 6 Available Mg

Available Mg (kg ha $^{1}$) content as influenced by treatments at different periods of incubation are presented in Table 15 The content of available Mg ranged from 127 5 (MTRP $P_3$) to 510 7 kg ha $^{1}$ (DAP $P_2$) with a mean value of 319 1 ka ha $^{1}$

Waterlogging increased the Mg content There was slight decrease at the 4th period of incubation after which it again increased

The control treatment registered a maximum value of 349 9 kg ha $^{1}$ at the 3rd month after which it decreased to 232 9 kg ha $^{1}$ at the 6th period and again increased to 349 9 kg ha $^{1}$ at the 8th period The treatment SSP ($P_2$+$P_2$) was found to be on par with SSP $P_2$ throughout the incubation period

There was no specific trend among the sources during the different periods of incubation for the release of available Mg in the soil

**The transformation of added P into different P fractions**

Kuttanad alluvium

Data pertaining to the contents of Fe P Al P and Ca P at 120th and 240th day of incubation are given in Table 16 The effect of different treatments on the transformation of different fractions of P was studied for two specific stages of incubation experiment which corresponds to harvest stage of first and second crop Graphical illustrations are presented in Fig 8 to 13

Table 16 Fractions of P (ppm) as influenced by treatments at 120th and 240th day of incubation (Kuttanad alluvium)

| | 120th day | | | 240th day | | |
|---|---|---|---|---|---|---|
| | Fe P | Al P | Ca P | Fe P | Al P | Ca P |
| MTRP $P_1$ | 316 6 | 236 6 | 56 6 | 332 4 | 245 6 | 53 6 |
| MTRP $P_2$ | 326 2 | 245 6 | 58 7 | 341 8 | 252 3 | 54 9 |
| MTRP $P_3$ | 334 2 | 251 2 | 61 0 | 346 3 | 259 0 | 56 2 |
| MRP $P_1$ | 319 5 | 236 1 | 57 7 | 335 2 | 245 6 | 53 7 |
| MRP $P_2$ | 324 4 | 238 8 | 59 7 | 344 0 | 247 8 | 56 2 |
| MRP $P_3$ | 329 8 | 245 6 | 62 5 | 349 3 | 256 8 | 58 7 |
| SSP $P_1$ | 340 3 | 256 8 | 54 9 | 345 2 | 265 7 | 52 6 |
| SSP $P_2$ | 343 3 | 268 0 | 57 9 | 349 1 | 276 9 | 54 0 |
| SSP $P_3$ | 344 1 | 274 7 | 58 8 | 358 6 | 285 9 | 55 8 |
| DAP $P_1$ | 321 0 | 261 2 | 52 3 | 337 4 | 268 0 | 50 8 |
| DAP $P_2$ | 330 4 | 265 7 | 54 4 | 350 8 | 272 4 | 52 6 |
| DAP $P_3$ | 341 5 | 274 7 | 55 8 | 355 3 | 285 9 | 54 0 |
| C | 306 0 | 216 4 | 40 3 | 316 2 | 232 1 | 34 1 |
| SSP ($P_2$+$P_2$) | 542 3 | 268 0 | 57 9 | 349 1 | 276 9 | 54 0 |

120th day

The table revealed that Fe P ranged from 306 (C) to 344 1 ppm (SSP $P_3$) Al P ranged from 216 4 (C) to 274 7 ppm (SSP $P_3$) and Ca P from 40 3 (C) to 62 5 ppm (MRP $P_3$) As discussed in Table 1 Fe P was dominant fraction in Kuttanad alluvium soil On waterlogging as more and more water soluble P released in the soil the fixation of P started to increase in presence of Fe and Al

The maximum content of Fe P was recorded by SSP $P_3$ closely followed by DAP $P_3$ The release from MRP and MTRP were almost same From this it is clear that P from the water soluble source readily undergoes transformation to Fe P but for the rockphosphates the immediate fixation was found to be comparatively less Predominance of Fe P on addition of SSP is conceivable in view of the high solubility product of Fe P compared to other fractions Allumınium phosphate found in the initial stage of incubation might have been converted into stable Fe-P It is clear that incremental doses of P also resulted in release of Fe P irrespective of the various source of P

With regard to Al P from a native content of 211 20 ppm it increased to 216 4 ppm in the control treatment due to waterlogging As compared to other treatments control treatment registered the least content of Al P Just like Fe-P the treatments SSP $P_3$ and DAP $P_3$ dominated in raising the contents of Al P of the soil This also suggests the probable fixation of readily available P sources into Al P

Due to the effect of different treatments the value of Ca P increased from 40 3 to 62 5 ppm (MRP $P_3$) The $CO_2$ released by microbial activity might be having a solubilising effect both on the native Ca P and the Ca P in the added phosphate In contrast to the release of Fe P and Al P the maximum content of Ca P were recorded by the higher levels of MTRP and MRP The source SSP also followed the rockphosphate in raising the contents of Ca P as it is a Ca rich source Due to the same reason rockphosphates are steady releasers of Ca P (Appendix II) The source DAP recorded the least content of Ca P as indicated by the values in Table 16

240th day

The transformation of residual P to various inorganic fractions were compared with control and SSP ($P_2$+$P_2$) and the data are presented in Table 16

Almost the same pattern of release of Fe P was observed at 240th day of incubation But there was a raise in the content of Fe P released in the soil Due to waterlogging even in the control treatment Fe P was raised to 326 2 ppm Maximum content was registered by the treatment SSP $P_3$ which was closely followed by DAP $P_3$ Comparatively lower values were recorded by the rockphosphate sources In the case of SSP ($P_2$+$P_2$) the same trend was noticed as that of SSP $P_2$ From this it is clear that residual P content is less for the water soluble sources due to the high fixation and it is more for rockphosphate as there is a slow dissolution rate and less fixation

The fixation of P into Al P form was found to be maximum for the treatments of SSP $P_3$ and DAP $P_3$ which was found to be greater than other interac tions and control The native Al P content as indicated by the control treatment must have undergone transformation due to $H_2O$ logging as the values where raised from

216 4 to 232 1 ppm As the levels of P increased the convertion to Al P fraction was also found to be raised from levels $P_1$ to $P_3$ On clear examination it is indicated that values of Al P was less than that of Fe P for all the treatment combinations The increase in fixation of Al P that was noticed at 120th and 240th day of incubation was comparatively less as that of Fe P which was also released under the same period Obviously the $H_2O$ soluble form of P that were initially transformed into Al P might have been changed to Fe-P due to prolonged periods under water logging

As compared to other fraction the fixation of P as Ca P was found to be comparatively less as indicated by the values registered at 240th day of incubation The decrease in Ca P has been attributed to the decrease in $Co_2$ concentration as a result of which some of the ferrous compounds formed earlier undergo changes and oxidation to ferric oxide which absorbed some of the soluble phosphate Due to the application of Ca containing fertilizers Ca P was raised from 34 1 (C) to a maximum value of 58 7 (MRP $P_3$) As indicated in the Appendix II only DAP was devoid of Ca As the Ca content was higher for MRP the release of Ca P was also higher This was followed for other fertilisers such as MTRP and SSP Just like the control treatment release of Ca P was reduced from 120th to 240th day of incubation Even for the control it was reduced from 40 3 ppm to 34 1 ppm indicating the probable transformation of Ca P fractions to other fractions

Laterite

The Table 17 represents the various fractions such as Al P Fe P and Ca P as influenced by the treatments at 120th and 240th days of incubation Graphical illustration are depicted in Fig 8 to 13

Table 17 Fractions of P (ppm) as influenced by treatment at 120th and 240th day of incubation (laterite)

| | 120th day | | | 240th day | | |
|---|---|---|---|---|---|---|
| | Fe P | Al P | Ca P | Fe P | Al P | Ca P |
| MTRP $P_1$ | 316 6 | 252 3 | 43 0 | 321 3 | 256 8 | 37 7 |
| MTRP $P_2$ | 327 0 | 256 8 | 45 7 | 329 2 | 263 5 | 40 0 |
| MTRP $P_3$ | 334 8 | 265 7 | 49 1 | 341 7 | 272 5 | 42 4 |
| MRP $P_1$ | 319 5 | 261 2 | 46 3 | 323 4 | 263 5 | 39 2 |
| MRP $P_2$ | 324 4 | 268 0 | 49 8 | 331 3 | 272 5 | 42 4 |
| MRP $P_3$ | 331 6 | 276 9 | 51 8 | 338 5 | 281 4 | 44 3 |
| SSP $P_1$ | 340 4 | 281 4 | 41 8 | 346 2 | 290 4 | 39 3 |
| SSP $P_2$ | 345 0 | 288 1 | 45 7 | 351 1 | 299 4 | 41 2 |
| SSP $P_3$ | 348 6 | 292 6 | 48 6 | 356 4 | 303 8 | 42 9 |
| DAP $P_1$ | 315 0 | 285 9 | 40 1 | 329 0 | 292 6 | 37 1 |
| DAP $P_2$ | 332 7 | 288 1 | 43 6 | 341 9 | 294 8 | 40 0 |
| DAP $P_3$ | 341 9 | 297 1 | 46 1 | 346 2 | 306 6 | 42 4 |
| C | 307 7 | 236 6 | 35 4 | 317 8 | 252 3 | 29 5 |
| SSP ($P_2$+$P_2$) | 345 0 | 288 1 | 45 7 | 349 3 | 296 5 | 41 2 |

Among the different treatments lowest value of Fe P was recorded by control (307 7 ppm) and maximum by SSP $P_3$ (348 6 ppm) Again the nature of fixation was same as that of Kuttanad alluvium as there was more fixation of P into Fe P form Since laterite soil contained more Al and Fe hydroxide under waterlogged condition the change into Fe P and Al P fractions is more visible Both water soluble and water unsoluble forms recorded considerable amount of Fe P at 120th day of incubation

With regard to Al P the trend in the release was almost same as that of Fe-P at 120th day of incubation but the value were found to be much less The lowest content was recorded by control (236 6) which was higher than initial content Among the sources DAP treatment recorded the maximum closely followed by SSP As the levels of P increased the change into Al P fraction was also found to be raised

On examination of the values recorded as Ca P at 120th day of incubation the range was indicated from 35 5 ppm in control to a maximum of 51 8 ppm in MRP $P_3$ In contrast to Fe P and Al P formation there was more Ca P formation for the rockphosphates (MRP and MTRP) as that of water soluble ones (SSP and DAP)

240th day

As observed in Kuttanad alluvium there was increase in Fe P content at 240th day The continuous waterlogging increased Fe P from 236 6 ppm (120th day) to 252 3 ppm in the case of control There was also increase in the case of other treatments Among the treatments maximum content of Ca P was observed in SSP

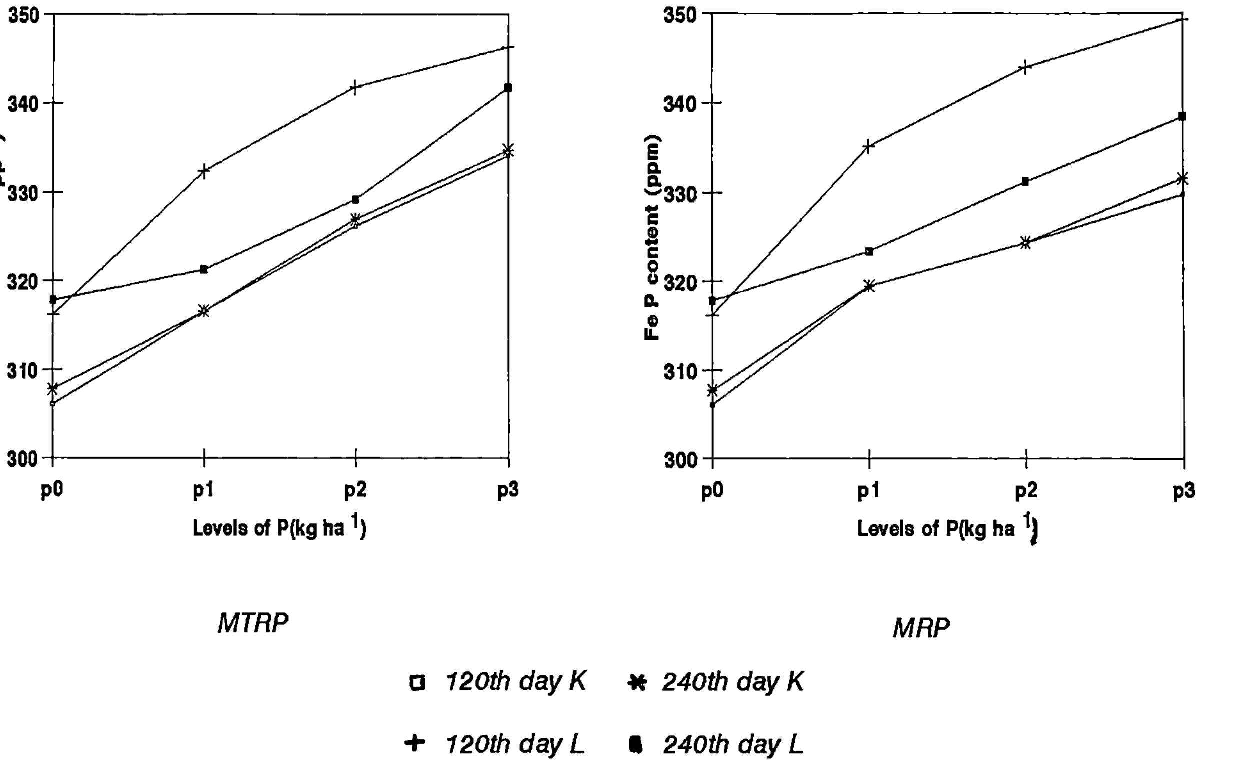



*Fig 8 Fractions of Fe-P in Kuttanad alluvium & laterite soil as influenced by levels of P*

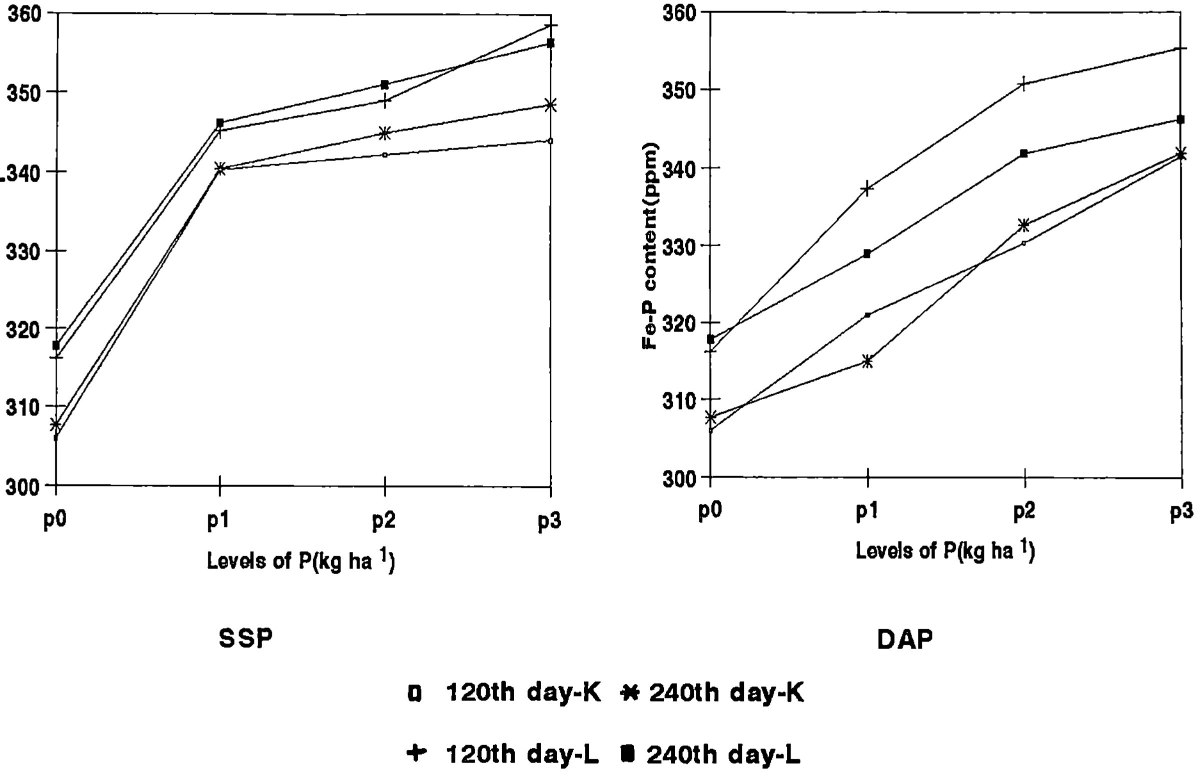



**Fig.9 Fractions of Fe-P in Kuttanad alluvium & laterite soil as influenced by levels of P**

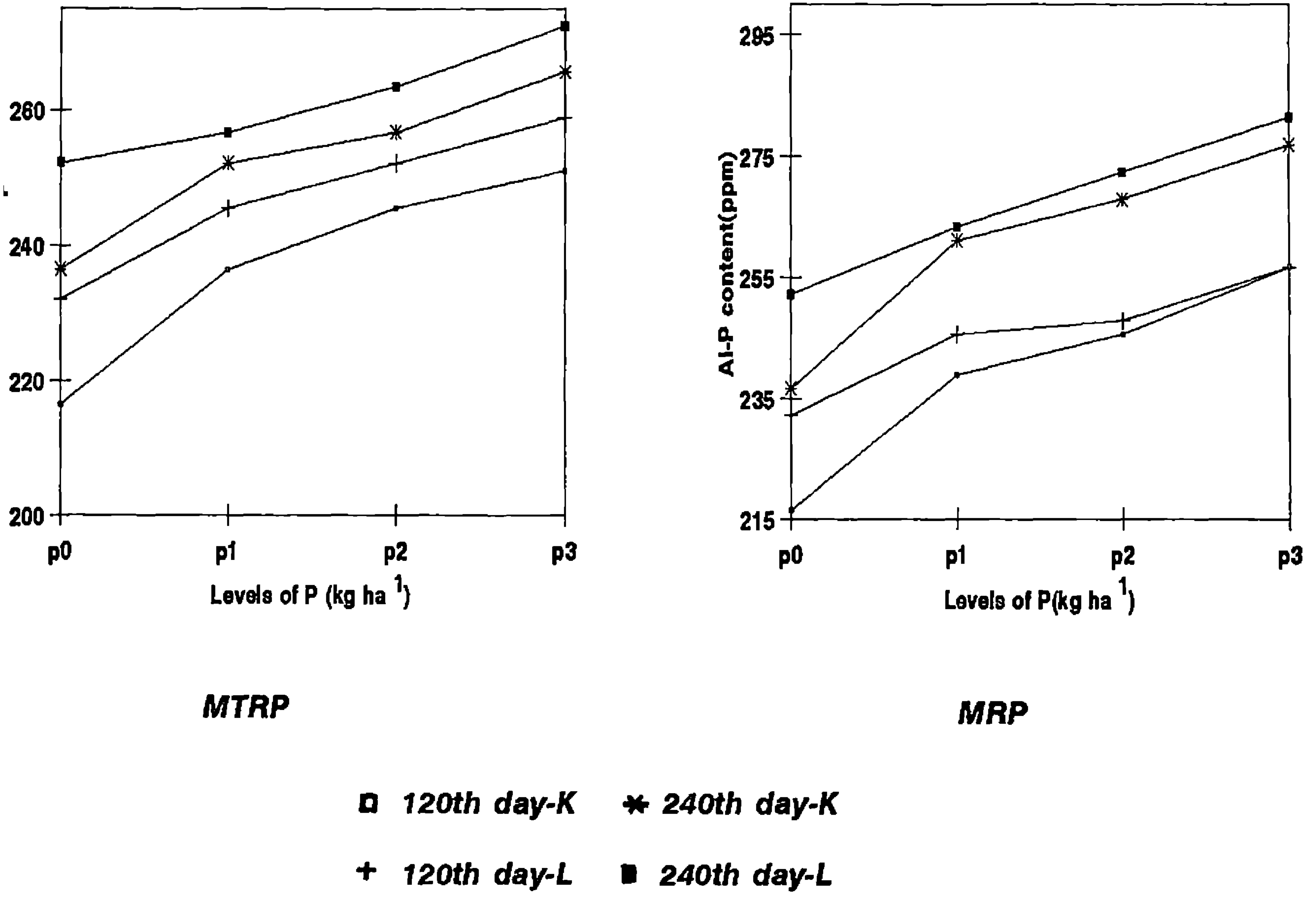



*Fig. 10 Fractions of Al-P in Kuttanad alluvium &laterite soil as influenced by levels of P*

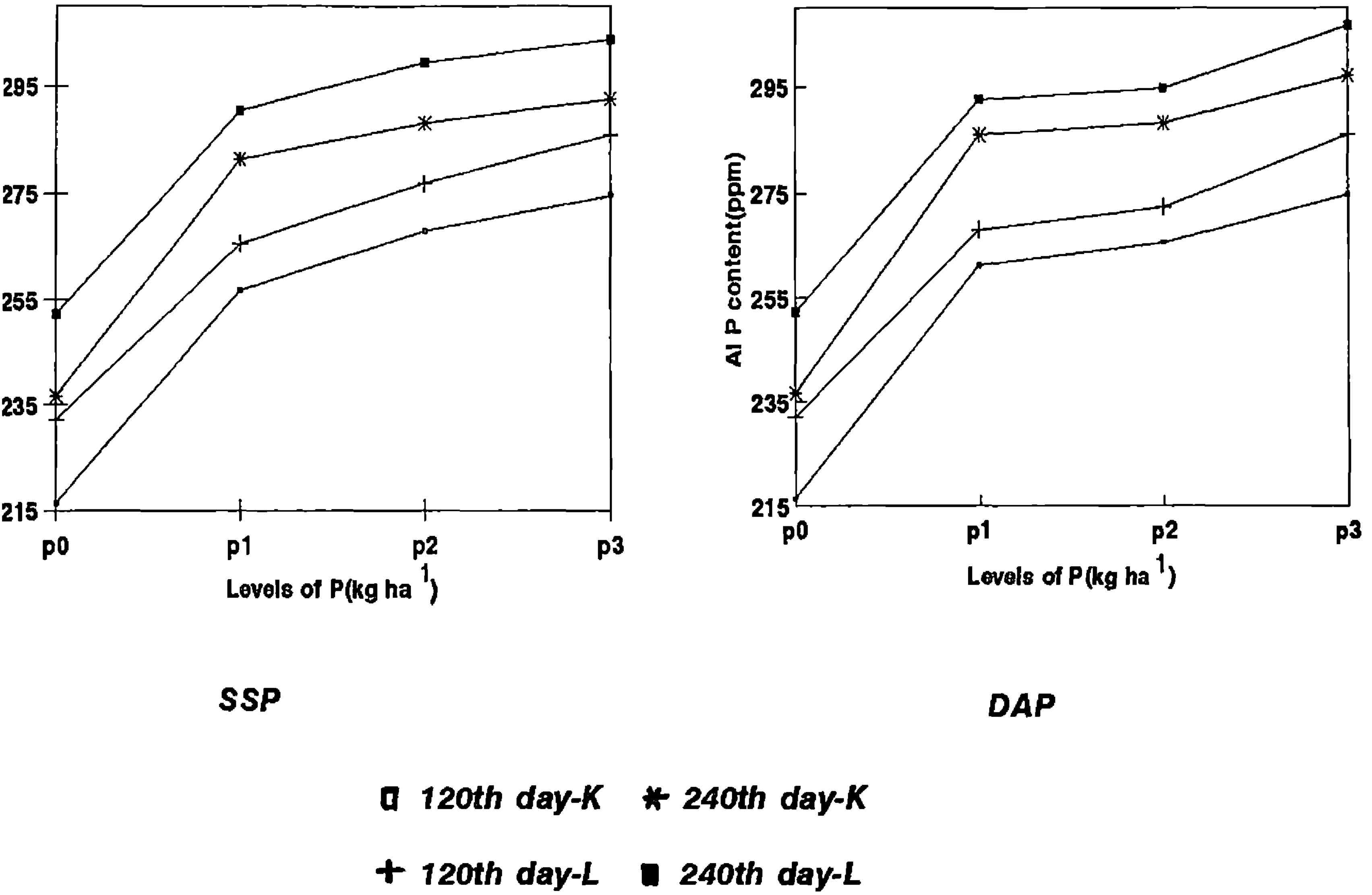



***Fig.11 Fractions of Al-P in Kuttanad alluvium & laterite soil as influenced by levels of P***

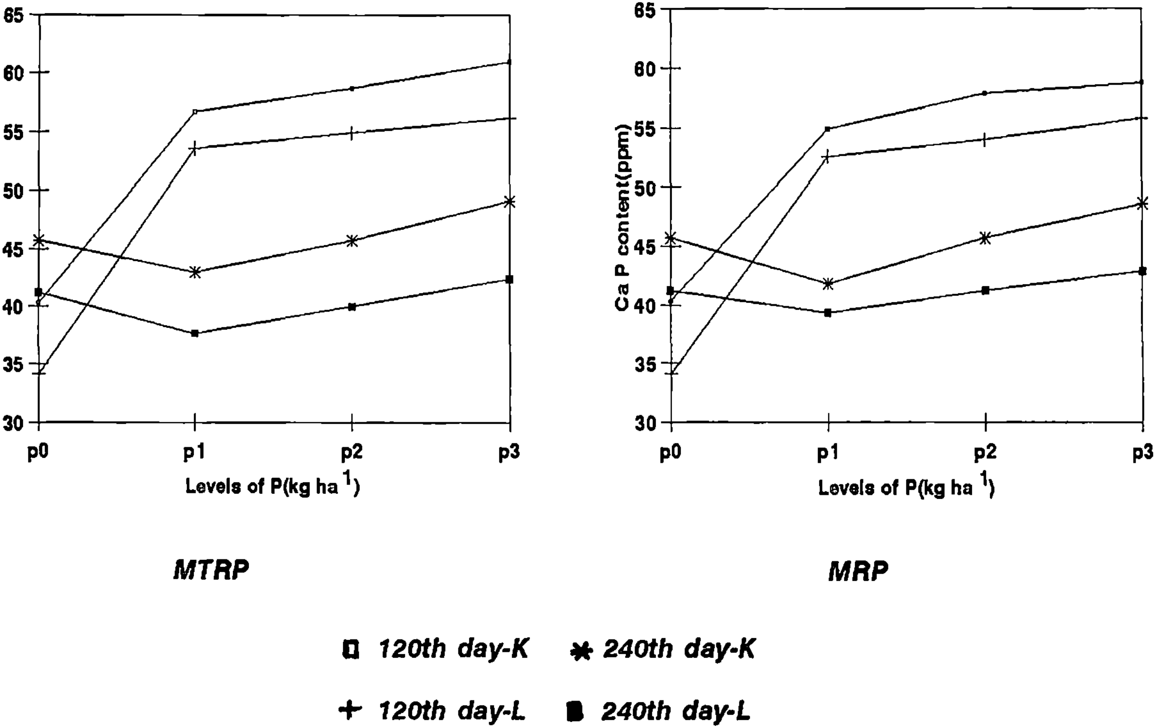



***Fig.12 Fractions of Ca-P in Kuttanad alluvium & laterite soil as influenced by levels of P***

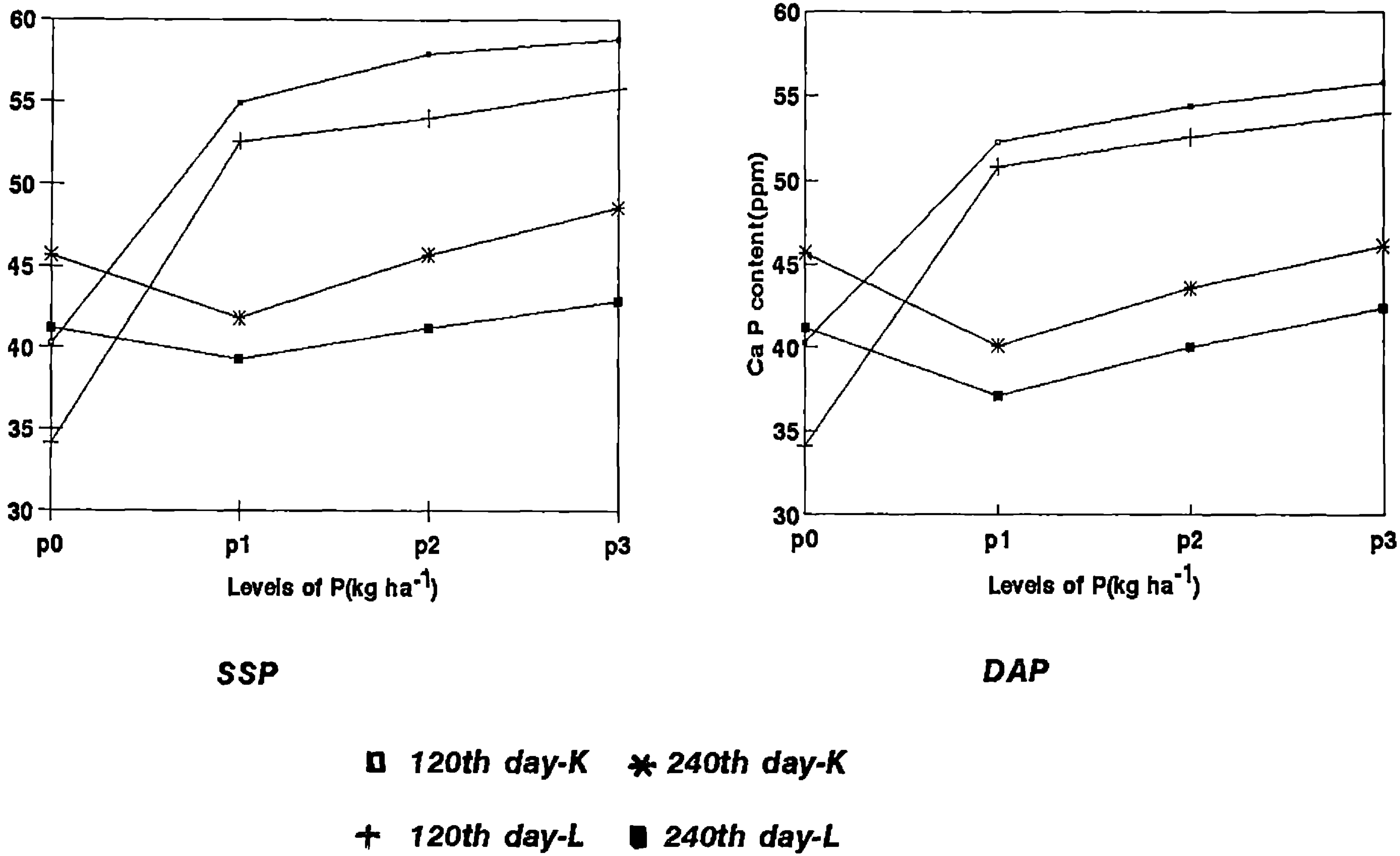



***Fig. 13 Fractions of Ca-P in Kuttanad alluvium & laterite soil as influenced by levels of P***

$P_3$ (356 4 ppm) followed by DAP $P_3$ (346 2 ppm) The rockphosphates recorded the lowest

The control treatment recorded the lowest value of 252 3 ppm while DAP $P_3$ registered the maximum (306 6 ppm) Again the rockphosphates recorded lower content of Al P as compared to water soluble sources The Ca P content was higher for rockphosphates followed by SSP treatments The interactions of DAP recorded the lowest The high Ca content in the sources of MTRP MRP and SSP may be the reason attribute for the increase The highest value was observed in MRP $P_3$ (44 3 ppm)

4 2 **Pot culture experiment**

4 2 1 Kuttanad alluvium

4 2 1 1 Nutrient release uptake and leaching loss of N different stages of crop growth

First crop

On perusal of the data presented in Table 18 it was observed that the values of available N ranged from 181 8 to 752 6 kg ha $^{1}$ the uptake values ranged from 0 19 to 0 75 g pot $^{1}$ and leaching loss varied from 3 27 to 19 60 ppm

Available N content was found to decrease with crop growth At all the stages of crop growth the control treatment recorded the lowest content of available N which decreased from 309 4 kg ha $^{1}$ at maximum tillering to 231 9 kg ha $^{1}$ at panicle initiation and at harvest the value was found to be 181 8 kg ha $^{1}$ Among the other treatments DAP $P_3$ (752 6 kg ha $^{1}$) recorded significantly higher content of available N at maximum tillering stage followed by DAP $P_2$ (746 3 kg ha $^{1}$) The same trend was observable at panicle initiation and harvest stages The $NH_4$ N

Table 18 Nutrient release uptake and leaching loss of N in the first crop of rice as influenced by treatments (Kuttanad alluvium)

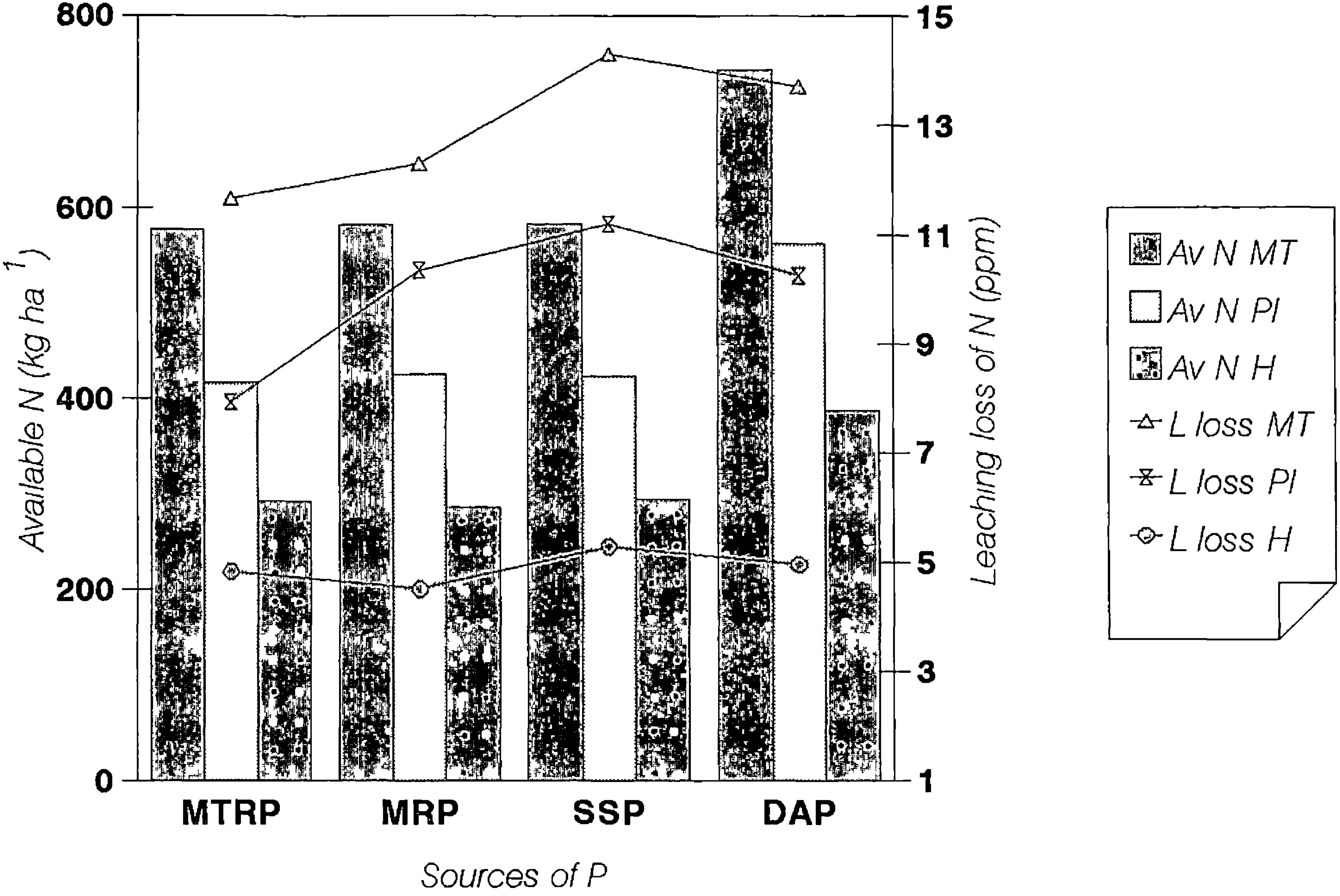
| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha 1 | Uptake g pot-1 | Leaching loss ppm | Avaialable kg ha 1 | Uptake g pot 1 | Leaching loss ppm | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm |
| 1 | MTRP $P_1$ | 568 6 | 0 28 | 11 20 | 403 4 | 0 34 | 8 87 | 278 9 | 0 49 | 4 20 |
| 2 | MTRP $P_2$ | 572 8 | 0 30 | 11 20 | 420 4 | 0 39 | 7 00 | 288 6 | 0 56 | 5 13 |
| 3 | MTRP $P_3$ | 589 5 | 0 32 | 12 60 | 426 4 | 0 45 | 7 93 | 307 3 | 0 60 | 5 13 |
| 4 | MRP $P_1$ | 570 7 | 0 28 | 11 20 | 415 7 | 0 37 | 9 80 | 272 5 | 0 49 | 3 27 |
| 5 | MRP $P_2$ | 581 2 | 0 30 | 11 67 | 422 3 | 0 42 | 11 20 | 288 6 | 0 59 | 4 67 |
| 6 | MRP $P_3$ | 593 6 | 0 35 | 14 00 | 436 9 | 0 48 | 10 07 | 295 3 | 0 62 | 5 60 |
| 7 | SSP $P_1$ | 583 2 | 0 30 | 12 60 | 411 8 | 0 42 | 9 80 | 275 9 | 0 55 | 3 73 |
| 8 | SSP $P_2$ | 576 9 | 0 35 | 14 00 | 426 4 | 0 48 | 11 20 | 298 9 | 0 59 | 6 07 |
| 9 | SSP $P_3$ | 589 5 | 0 39 | 16 53 | 432 7 | 0 50 | 12 60 | 307 3 | 0 65 | 6 07 |
| 10 | DAP $P_1$ | 730 8 | 0 34 | 8 87 | 533 1 | 0 54 | 7 00 | 295 0 | 0 61 | 3 73 |
| 11 | DAP $P_2$ | 746 3 | 0 39 | 12 60 | 564 4 | 0 58 | 10 73 | 422 3 | 0 68 | 5 13 |
| 12 | DAP $P_3$ | 752 6 | 0 41 | 19 60 | 589 5 | 0 60 | 13 07 | 445 3 | 0 75 | 6 03 |
| 13 | C | 309 4 | 0 19 | 9 33 | 231 9 | 0 25 | 7 47 | 181 8 | 0 40 | 6 0 |
| 14 | SSP $(P_2+P_2)$ | 572 8 | 0 33 | 12 4 | 422 3 | 0 48 | 11 60 | 288 6 | 0 60 | 6 0 |
| CD(0 05) | | 15 21 | | 4 73 | 17 68 | | 3 94 | 19 7 | | 2 01 |
| Source | | | | | | | | | | |
| MTRP | | 576 9 | 0 30 | 11 66 | 416 7 | 0 39 | 7 93 | 291 6 | 0 55 | 4 82 |
| MRP | | 581 8 | 0 31 | 12 29 | 424 9 | 0 42 | 10 36 | 285 4 | 0 57 | 4 51 |
| SSP | | 583 2 | 0 35 | 14 31 | 423 6 | 0 46 | 11 20 | 294 0 | 0 59 | 5 29 |
| DAP | | 743 2 | 0 38 | 13 69 | 562 3 | 0 57 | 10 26 | 387 5 | 0 68 | 4 96 |
| CD(0 05) | | 11 27 | | 2 73 | 8 18 | | 2 27 | 7 67 | | 1 16 |
| Level | | | | | | | | | | |
| $P_1$ | | 613 3 | 0 30 | 10 96 | 441 0 | 0 42 | 8 86 | 280 6 | 0 54 | 3 73 |
| $P_2$ | | 619 3 | 0 33 | 12 36 | 458 3 | 0 47 | 10 03 | 219 0 | 0 61 | 5 25 |
| $P_3$ | | 631 3 | 0 36 | 15 63 | 471 4 | 0 51 | 10 91 | 338 8 | 0 66 | 5 70 |
| CD(0 05) | | 7 60 | | 2 36 | 8 88 | | 1 97 | 9 34 | | 1 00 |

present in the fertiliser (Appendix II) might have been contributed towards the increased contents of available N at all these critical stages of crop growth

Regarding the uptake of N the control treatment registered the lowest content as there was not much increase in dry matter content The higher levels of DAP were superior in uptake at all the three stages of crop growth The values were 0 41 0 60 and 0 75 g pot $^{1}$ at maximum tillering panicle initiation and harvest stages In general the uptake value increased with crop growth

The leaching loss of N was found to be maximum for DAP $P_3$ followed by SSP $P_3$ at maximum tillering stage while at panicle initiation and harvest stages there was no significant difference in leaching loss This may be due to the high availability of the native N content of the soil

The nutrient release and leaching loss of N as influenced by different sources are illustrated in Fig 14 In general DAP was superior in available N release at the different stages of crop growth The release from other sources were found to be almost similar The leaching losses were higher for DAP followed by SSP MRP and MTRP It is clear that the difference in availability of N due to different sources also reflected in the uptake and leaching loss of the same element Compared to P and K the N loss may be more for paddy soils where N was applied as $NH_4$ N or urea form Reduction reactions in the waterlogged soil might have released ferrous and manganous ions which displace ammonium from the exchange complex to the soil solution where it is more subjected to removal An appreciable loss of ammonium ions by leaching from a submerged soil was detected by Ponnamperuma (1965) Moreover formation of nitrate in the deeper reductive soil layers subsequently undergo denitrification and loss from the soil




g 14 Nutrient release & leaching loss of N as influenced by sources of P at critical stages of

Second crop

The data pertaining to the release of available N in the soil uptake and leaching loss are presented in Table 19 The values of available N ranged from 108 7 to 884 6 kg ha $^{1}$ uptake from 0 20 to 0 80 g pot $^{1}$ and leaching loss from 1 87 to 11 20 ppm

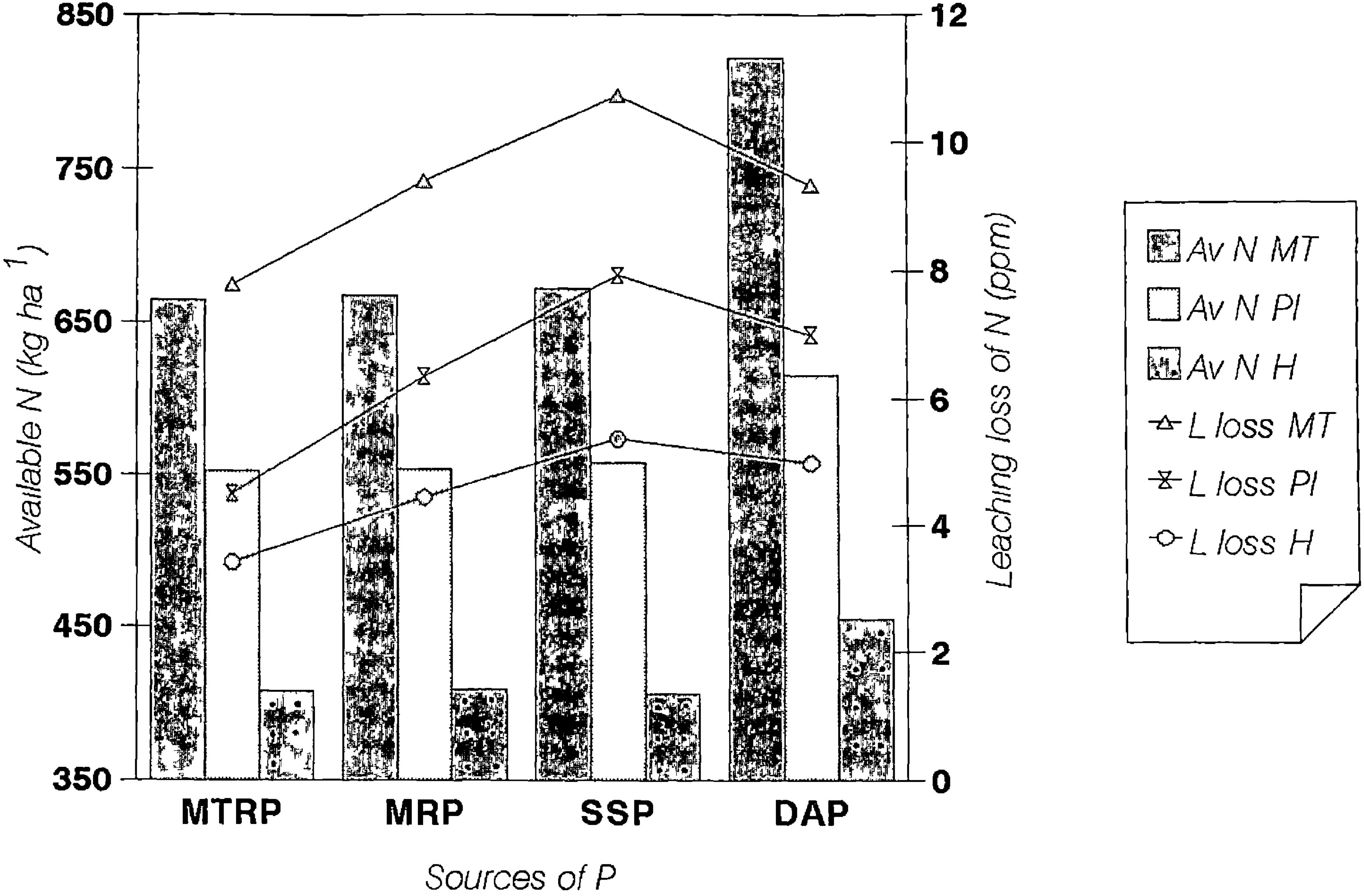
As there was continuous application of N to all the treatments under study the availability was found to be more pronounced at the second crop stage The uptake also showed increase with advancement of crop growth Compared to first crop the leaching loss of N was at a minimal rate during the second crop period due to the thick mat of roots formed in the pot culture study

Regarding the available N content of the soil the control treatment always registered the least amount It decreased from 320 6 kg ha $^{1}$ at maximum tillering to 108 7 kg ha $^{1}$ at harvest The triggering effect of P was necessary for the release of N from native organic matter of the soil Even for the microbial mineralisation of organic matter the additive source of P was necessary (Mengel and Kirkby 1978) As in the case of first crop the higher levels of DAP were superior in available N release at all the critical stages of crop growth In SSP ($P_2$+$P_2$) there was no significant increase in available N content as compared to other treatments

In the case of crop uptake of N the least values were registered by the control treatment which recorded 0 20 0 31 and 0 41 g pot $^{1}$ at maximum tillering panicle initiation and harvest stages respectively A decrease in the uptake of N in

Table 19 Nutrient release uptake and leaching of N in the second crop of rice as influenced by treatments (Kuttanad alluvium)

| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha 1 | Uptake g pot-1 | Leaching loss ppm | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm | Available kg ha-1 | Uptake g pot 1 | Leaching loss ppm |
| 1 | MTRP $P_1$ | 647 8 | 0 28 | 4 67 | 533 2 | 0 43 | 3 73 | 386 0 | 0 60 | 1 87 |
| 2 | MTRP $P_2$ | 660 6 | 0 35 | 8 87 | 551 9 | 0 47 | 4 67 | 411 8 | 0 75 | 3 73 |
| 3 | MTRP $P_3$ | 685 7 | 0 40 | 9 80 | 572 8 | 0 52 | 5 13 | 426 4 | 0 79 | 4 67 |
| 4 | MRP $P_1$ | 646 0 | 0 28 | 8 87 | 533 2 | 0 43 | 4 67 | 384 6 | 0 60 | 3 73 |
| 5 | MRP -$P_2$ | 664 0 | 0 36 | 8 87 | 547 7 | 0 49 | 6 47 | 409 7 | 0 75 | 4 67 |
| 6 | MRP $P_3$ | 693 5 | 0 39 | 10 73 | 581 2 | 0 50 | 7 93 | 432 7 | 0 79 | 4 93 |
| 7 | SSP $P_1$ | 656 4 | 0 28 | 9 80 | 541 5 | 0 45 | 7 47 | 395 2 | 0 60 | 5 13 |
| 8 | SSP $P_2$ | 673 2 | 0 36 | 11 20 | 556 8 | 0 47 | 7 93 | 405 5 | 0 73 | 5 13 |
| 9 | SSP $P_3$ | 686 8 | 0 40 | 11 20 | 576 9 | 0 52 | 8 40 | 418 0 | 0 79 | 5 87 |
| 10 | DAP $P_1$ | 777 7 | 0 27 | 8 87 | 589 5 | 0 47 | 6 07 | 439 0 | 0 63 | 4 67 |
| 11 | DAP $P_2$ | 802 8 | 0 37 | 9 80 | 610 4 | 0 52 | 7 93 | 451 0 | 0 75 | 5 13 |
| 12 | DAP $P_3$ | 884 6 | 0 43 | 9 33 | 646 0 | 0 55 | 7 00 | 476 6 | 0 80 | 5 13 |
| 13 | C | 320 6 | 0 20 | 8 87 | 252 2 | 0 31 | 6 77 | 108 7 | 0 41 | 4 8 |
| 14 | SSP ($P_2$+$P_2$) | 685 7 | 0 40 | 9 45 | 551 9 | 0 54 | 7 0 | 409 7 | 0 79 | 4 93 |
| CD(0 05) | | 19 53 | | 2 19 | 14 17 | | 1 58 | 14 96 | | 1 69 |
| Source | | | | | | | | | | |
| MTRP | | 664 7 | 0 34 | 7 78 | 552 6 | 0 47 | 4 51 | 408 0 | 0 71 | 4 32 |
| MRP | | 667 8 | 0 34 | 9 49 | 554 0 | 0 47 | 6 36 | 409 0 | 0 71 | 4 44 |
| SSP | | 672 1 | 0 35 | 10 73 | 558 4 | 0 48 | 7 93 | 406 2 | 0 71 | 5 38 |
| DAP | | 821 7 | 0 36 | 9 33 | 615 3 | 0 51 | 7 0 | 455 5 | 0 73 | 4 98 |
| CD(0 05) | | 11 27 | | 1 26 | 1 26 | | 0 9 | 8 18 | | 0 97 |
| Level | | | | | | | | | | |
| $P_1$ | | 681 9 | 0 28 | 8 05 | 549 3 | 0 45 | 5 48 | 401 2 | 0 60 | 3 85 |
| $P_2$ | | 700 2 | 0 36 | 9 7 | 566 7 | 0 48 | 6 75 | 419 5 | 0 74 | 4 66 |
| $P_3$ | | 737 6 | 0 41 | 10 26 | 594 2 | 0 52 | 7 12 | 438 4 | 0 79 | 5 5 |
| CD(0 05) | | 9 76 | | 1 09 | 1 08 | | 0 79 | 7 48 | | 0 84 |




15 Nutrient release & leaching loss of N as influenced by sources of P at critical stages of second crop of rice Kuttanad alluvium

the absence of added P was also reported by Ramanathan *et al* (1973) Among the treatment combinations DAP $P_3$ was superior in uptake followed by SSP $P_3$ and DAP $P_2$ at all the three stages of crop growth The uptake value of SSP ($P_2$+$P_2$) was slightly superior to SSP $P_2$ The immediate root proliferation by the water soluble sources of P might have enhanced more N uptake

With reference to the leaching loss of N the control treatment recorded the values of 8 87 ppm at tillering 6 77 ppm at panicle initiation and 4 8 ppm at harvest The loss was found to be at the minimum for the interaction MTRP $P_1$ throughout the cropping period In contrast to this SSP $P_2$ and SSP $P_3$ recorded the maximum loss at these critical stages of crop growth

The nutrient release and leaching loss of N as influenced by sources are provided in Fig 15 From this it is evident that DAP was superior while other sources were on par in N release In crop uptake and leaching loss also this trend was noticed

4 2 1 2 Nutrient release uptake and leaching loss of P at different stages of crop growth

First crop

The values with respect to nutrient release uptake and leaching loss of P (Bray 1) are provided in Table 20 and Table 22 Available P content using Bray 1 ranged from 7 27 to 26 96 kg ha $^{-1}$ while for Mathew s triacid it ranged from 10 93 to 49 30 kg ha $^{-1}$ the uptake varied from 0 003 to 0 138 g pot $^{-1}$ and the leaching loss from 0 03 to 0 16 ppm

Table 20 Nutrient release uptake and leaching loss of P in the first crop of rice as influenced by treatments Bray 1 (Kuttanad alluvium)



| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm |
| 1 | MTRP $P_1$ | 13 16 | 0 005 | 0 12 | 11 14 | 0 008 | 0 09 | 9 99 | 0 072 | 0 06 |
| 2 | MTRP $P_2$ | 15 54 | 0 006 | 0 13 | 13 69 | 0 009 | 0 10 | 11 42 | 0 082 | 0 07 |
| 3 | MTRP $P_3$ | 17 13 | 0 009 | 0 14 | 15 97 | 0 011 | 0 10 | 12 32 | 0 109 | 0 07 |
| 4 | MRP $P_1$ | 18 39 | 0 007 | 0 09 | 11 58 | 0 007 | 0 07 | 6 02 | 0 074 | 0 04 |
| 5 | MRP $P_2$ | 18 70 | 0 007 | 0 10 | 12 76 | 0 009 | 0 10 | 11 08 | 0 093 | 0 07 |
| 6 | MRP $P_3$ | 19 46 | 0 008 | 0 13 | 13 50 | 0 011 | 0 10 | 12 32 | 0 097 | 0 07 |
| 7 | SSP $P_1$ | 24 15 | 0 010 | 0 12 | 14 69 | 0 011 | 0 06 | 12 47 | 0 132 | 0 06 |
| 8 | SSP $P_2$ | 25 33 | 0 012 | 0 13 | 14 58 | 0 013 | 0 10 | 13 95 | 0 137 | 0 08 |
| 9 | SSP $P_3$ | 26 96 | 0 017 | 0 16 | 16 42 | 0 019 | 0 22 | 14 98 | 0 139 | 0 16 |
| 10 | DAP $P_1$ | 20 18 | 0 007 | 0 8 | 13 84 | 0 006 | 0 08 | 10 96 | 0 08 | 0 05 |
| 11 | DAP $P_2$ | 21 36 | 0 010 | 0 11 | 14 04 | 0 008 | 0 09 | 12 96 | 0 108 | 0 06 |
| 12 | DAP $P_3$ | 22 56 | 0 012 | 0 13 | 14 20 | 0 011 | 0 15 | 14 24 | 0 113 | 0 07 |
| 13 | C | 11 57 | 0 003 | 0 08 | 9 30 | 0 005 | 0 05 | 7 27 | 0 064 | 0 03 |
| 14 | SSP $(P_2+P_2)$ | 25 52 | 0 009 | 0 13 | 14 20 | 0 015 | 0 12 | 13 16 | 0 126 | 0 08 |
| CD(0 05) | | 0 27 | | 0 11 | 0 57 | | 0 13 | 0 35 | | 5 0 |
| Source | | | | | | | | | | |
| MTRP | | 15 27 | 0 007 | 0 13 | 13 60 | 0 009 | 0 097 | 11 24 | 0 09 | 0 07 |
| MRP | | 18 85 | 0 007 | 0 11 | 12 61 | 0 009 | 0 09 | 9 81 | 0 09 | 0 06 |
| SSP | | 25 48 | 0 013 | 0 14 | 15 23 | 0 014 | 0 13 | 13 8 | 0 14 | 0 10 |
| DAP | | 21 70 | 0 010 | 0 11 | 14 03 | 0 008 | 0 11 | 12 72 | 0 10 | 0 06 |
| CD(0 05) | | 0 32 | | 0 05 | 0 29 | | 0 06 | 1 17 | | 0 02 |
| Level | | | | | | | | | | |
| $P_1$ | | 18 97 | 0 007 | 0 10 | 12 81 | 0 008 | 0 07 | 9 86 | 0 08 | 0 05 |
| $P_2$ | | 20 23 | 0 008 | 0 11 | 13 76 | 0 009 | 0 09 | 13 25 | 0 10 | 0 07 |
| $P_3$ | | 21 52 | 0 011 | 0 14 | 15 02 | 0 013 | 0 14 | 13 46 | 0 11 | 0 09 |
| CD(0 05) | | 0 27 | | 0 05 | 0 29 | | 0 06 | 1 17 | | 0 02 |

Table 22 Nutrient release uptake and leaching loss of P in the first crop of rice as influenced by treatments Mathew s extractant (Kuttanad alluvium)

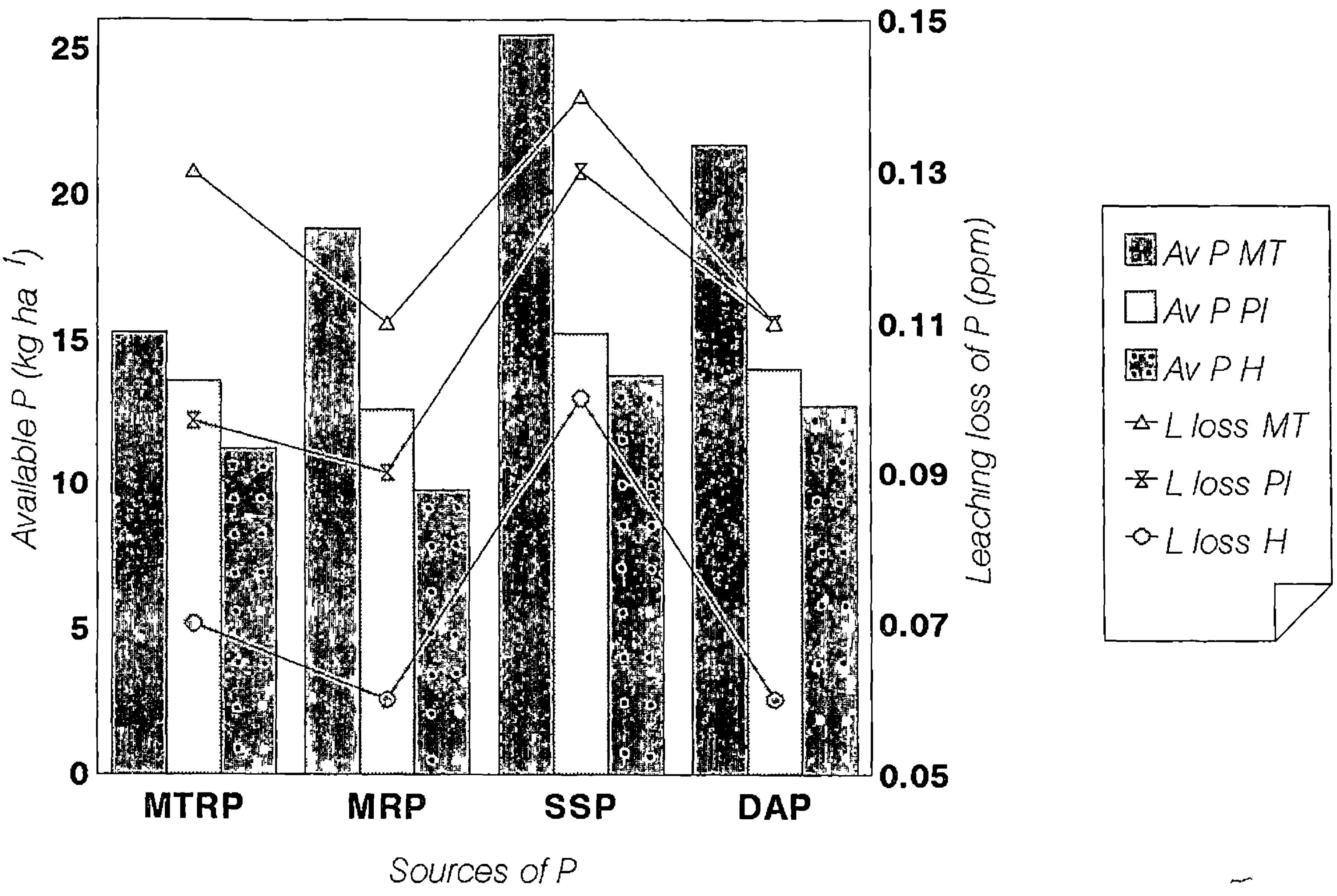
| Treatment No | Notation | Maximum tillering: Available kg ha $^{1}$ | Uptake g pot $^{1}$ | Leaching loss ppm | Panicle initiation: Available kg ha $^{1}$ | Uptake g pot $^{1}$ | Leaching loss ppm | Harvest: Available kg ha $^{-1}$ | Uptake g pot $^{1}$ | Leaching loss ppm |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MTRP $P_1$ | 30 28 | 0 005 | 0 12 | 27 80 | 0 008 | 0 09 | 25 37 | 0 072 | 0 06 |
| 2 | MTRP $P_2$ | 31 36 | 0 006 | 0 13 | 28 31 | 0 009 | 0 10 | 26 74 | 0 084 | 0 07 |
| 3 | MTRP $P_3$ | 32 63 | 0 009 | 0 14 | 29 50 | 0 011 | 0 10 | 27 30 | 0 109 | 0 07 |
| 4 | MRP $P_1$ | 31 48 | 0 007 | 0 9 | 30 30 | 0 007 | 0 07 | 26 12 | 0 074 | 0 04 |
| 5 | MRP $P_2$ | 32 48 | 0 007 | 0 10 | 27 60 | 0 009 | 0 10 | 25 26 | 0 093 | 0 07 |
| 6 | MRP $P_3$ | 34 14 | 0 008 | 0 13 | 31 80 | 0 011 | 0 10 | 25 32 | 0 097 | 0 07 |
| 7 | SSP -$P_1$ | 48 87 | 0 010 | 0 12 | 41 78 | 0 011 | 0 06 | 28 67 | 0 132 | 0 06 |
| 8 | SSP $P_2$ | 52 5 | 0 012 | 0 13 | 43 50 | 0 013 | 0 10 | 29 55 | 0 137 | 0 08 |
| 9 | SSP $P_3$ | 57 14 | 0 017 | 0 16 | 48 20 | 0 019 | 0 22 | 31 39 | 0 139 | 0 16 |
| 10 | DAP $P_1$ | 47 86 | 0 007 | 0 08 | 42 74 | 0 006 | 0 08 | 27 57 | 0 08 | 0 05 |
| 11 | DAP $P_2$ | 50 75 | 0 010 | 0 11 | 45 00 | 0 008 | 0 09 | 25 05 | 0 113 | 0 06 |
| 12 | DAP $P_3$ | 54 09 | 0 012 | 0 13 | 49 30 | 0 011 | 0 15 | 24 52 | 0 108 | 0 07 |
| 13 | C | 16 55 | 0 083 | 0 08 | 13 10 | 0 005 | 0 05 | 10 93 | 0 064 | 0 03 |
| 14 | SSP ($P_2$+$P_2$) | 49 66 | 0 010 | 0 13 | 44 90 | 0 005 | 0 12 | 25 05 | 0 082 | 0 08 |
| CD(0 05) | | 3 60 | | 0 11 | 0 67 | | 0 13 | 0 57 | | 5 0 |
| Source | | | | | | | | | | |
| MTRP | | 31 42 | 0 006 | 0 13 | 28 53 | 0 009 | 0 09 | 26 47 | 0 111 | 0 06 |
| MRP | | 32 70 | 0 007 | 0 11 | 29 90 | 0 009 | 0 09 | 25 56 | 0 088 | 0 06 |
| SSP | | 52 83 | 0 013 | 0 14 | 44 49 | 0 014 | 0 13 | 29 87 | 0 136 | 0 10 |
| DAP | | 50 9 | 0 009 | 0 11 | 45 68 | 0 008 | 0 11 | 25 71 | 0 100 | 0 06 |
| CD(0 05) | | 8 17 | | 0 06 | 0 39 | | 0 07 | 0 33 | | 0 02 |
| Level | | | | | | | | | | |
| $P_1$ | | 39 62 | 0 007 | 0 10 | 35 65 | 0 008 | 0 07 | 26 93 | 0 08 | 0 05 |
| $P_2$ | | 41 77 | 0 008 | 0 11 | 36 10 | 0 009 | 0 09 | 26 65 | 0 10 | 0 07 |
| $P_3$ | | 44 50 | 0 011 | 0 14 | 39 70 | 0 013 | 0 14 | 27 13 | 0 11 | 0 09 |
| CD(0 05) | | 7 08 | | 0 05 | | | 0 06 | | | 0 02 |

The control treatment registered 11 57 kg ha $^{1}$ as available P content of the native soil which was the lowest among the different treatments It is clear that available contents of P reduced in the soil as the rate of uptake increased which is evident from the decrease to 9 30 kg ha $^{1}$ at panicle initiation and 7 27 kg ha $^{1}$ at harvest stages for the control The highest P release was recorded by the treatment SSP $P_3$ In the case of SSP ($P_2$+$P_2$) the P release was on par with SSP $P_2$

The control treatment recorded the lowest uptake value of as P 0 003 0 005 and 0 0064 g pot $^{1}$ at maximum tillering panicle initiation and harvest stages respectively As in the case of available P release the other treatment combinations registered higher P uptake values The uptake of P by the treatment SSP ($P_2$+$P_2$) was same as that of SSP $P_2$ at all the critical stages of crop growth The treatments SSP $P_2$ and SSP $P_3$ were superior to the other treatments in all the stages of crop growth In general uptake was higher for SSP and DAP as compared to other sources

The control treatment recorded the lowest leaching loss In general the leaching loss was found to decrease with crop growth Maximum leaching loss was recorded by SSP $P_3$ in all the stages of crop growth The leachmg loss in SSP ($P_2$+$P_2$) was found to be similar to that of SSP $P_2$

Graphical illustration for available P and leachmg losses are provided in Fig 16 It is evident that the P availability in the soil was found to be maximum for the water soluble sources SSP and DAP throughout the crop period These results are in confirmation with that discussed in section 4 1 1 3 Leachmg losses were high for the source SSP as the availability was maximum




g 16 Nutrient release & leaching of P as influenced by sources of P at critical stages of first crop of rice Kuttanad alluvium

Irrespective of sources of P the increased levels of P application always resulted in an increase in available P content and leaching losses There was no significant change in leaching loss of P for the incremental levels of P

Second crop

The data corresponding to nutrient release uptake and leaching loss of P are presented in Table 21 and Table 23 Available P ranged from 3 26 to 11 38 kg ha $^{1}$ (Bray 1) and from 5 3 to 23 4 kg ha $^{1}$ (Mathew s triacid) whereas value of P uptake varied from 3 26 to 11 38 g pot $^{1}$ Leaching loss of P ranged from 0 02 to 0 12 ppm

As there was no P application except for the treatment SSP ($P_2$+$P_2$) P release was less for the second crop as compared to first crop This change also reflected in the value of P uptake Again the availability of P decreased with crop growth while the P uptake was maximum at the harvest stage As compared to first crop P uptake was high especially for the water insoluble sources which reflects their long term effect of P release

The lowest available P content was registered by the control treatment which recorded 6 13 4 40 and 3 26 kg ha $^{1}$ at maximum tillering panicle initiation and harvest stages respectively The treatments MTRP $P_3$ and MRP $P_3$ were on par and significantly superior to other treatments at maximum tillering and panicle initia tion stages While at harvest MTRP $P_3$ was significantly higher than others This is in confirmation with the results presented and discussed in section 4 1 1 3 The continuous application of P to the treatment SSP ($P_2$+$P_2$) resulted in available higher

Table 21 Nutrient release uptake and leaching loss of P in the second crop of rice as influenced by treatments Bray 1 (Kuttanad alluvium)

| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha $^{-1}$ | Uptake g pot $^{-1}$ | Leaching loss ppm | Available kg ha $^{-1}$ | Uptake g pot $^{-1}$ | Leaching loss ppm | Available kg ha $^{-1}$ | Uptake g pot $^{-1}$ | Leaching loss ppm |
| 1 | MTRP $P_1$ | 9 20 | 0 091 | 0 03 | 8 02 | 0 192 | 0 03 | 5 35 | 0 374 | 0 03 |
| 2 | MTRP $P_2$ | 10 18 | 0 064 | 0 05 | 9 20 | 0 218 | 0 04 | 6 22 | 0 425 | 0 04 |
| 3 | MTRP $P_3$ | 11 38 | 0 103 | 0 08 | 10 08 | 0 253 | 0 05 | 7 57 | 0 467 | 0 04 |
| 4 | MRP $P_1$ | 8 96 | 0 073 | 0 04 | 7 35 | 0 136 | 0 04 | 2 97 | 0 383 | 0 03 |
| 5 | MRP $P_2$ | 10 08 | 0 055 | 0 05 | 8 07 | 0 221 | 0 05 | 4 70 | 0 425 | 0 03 |
| 6 | MRP $P_3$ | 11 00 | 0 068 | 0 08 | 9 50 | 0 234 | 0 06 | 6 38 | 0 391 | 0 03 |
| 7 | SSP $P_1$ | 5 04 | 0 039 | 0 06 | 5 94 | 0 105 | 0 03 | 4 25 | 0 237 | 0 03 |
| 8 | SSP $P_2$ | 6 72 | 0 052 | 0 08 | 6 87 | 0 136 | 0 06 | 5 60 | 0 169 | 0 05 |
| 9 | SSP $P_3$ | 8 02 | 0 065 | 0 12 | 8 31 | 0 192 | 0 07 | 6 27 | 0 228 | 0 05 |
| 10 | DAP $P_1$ | 5 48 | 0 041 | 0 03 | 3 76 | 0 105 | 0 04 | 3 22 | 0 274 | 0 03 |
| 11 | DAP $P_2$ | 6 83 | 0 05 | 0 05 | 5 89 | 0 124 | 0 05 | 3 51 | 0 230 | 0 04 |
| 12 | DAP $P_3$ | 7 72 | 0 063 | 0 08 | 6 63 | 0 124 | 0 06 | 4 61 | 0 200 | 0 04 |
| 13 | C | 5 13 | 0 080 | 0 02 | 4 40 | 0 096 | 0 03 | 3 26 | 0 136 | 0 07 |
| 14 | SSP ($P_2$+$P_2$) | 6 27 | 0 063 | 0 08 | 4 78 | 0 192 | 0 06 | 5 14 | 0 228 | 0 04 |
| CD(0 05) | | 0 59 | | 5 01 | 0 78 | | 1 9 | 0 49 | | 1 9 |
| Source | | | | | | | | | | |
| MTRP | | 10 25 | 0 09 | 0 05 | 9 1 | 0 22 | 0 04 | 6 38 | 0 422 | 0 04 |
| MRP | | 10 04 | 0 07 | 0 06 | 8 3 | 0 19 | 0 05 | 4 68 | 0 399 | 0 03 |
| SSP | | 6 59 | 0 05 | 0 09 | 7 0 | 0 14 | 0 05 | 5 37 | 0 211 | 0 04 |
| DAP | | 6 67 | 0 05 | 0 05 | 5 4 | 0 12 | 0 05 | 3 58 | 0 244 | 0 04 |
| CD(0 05) | | 1 7 | | 0 005 | 0 37 | | 0 009 | 0 24 | | 0 009 |
| Level | | | | | | | | | | |
| $P_1$ | | 7 17 | 0 06 | 0 04 | 6 26 | 0 134 | 0 03 | 3 94 | 0 317 | 0 03 |
| $P_2$ | | 8 62 | 0 05 | 0 05 | 7 50 | 0 174 | 0 05 | 5 00 | 0 312 | 0 04 |
| $P_3$ | | 9 55 | 0 07 | 0 09 | 8 63 | 0 200 | 0 06 | 6 05 | 0 329 | 0 04 |
| CD(0 05) | | 0 28 | | 0 05 | 0 37 | | 0 009 | 0 24 | | 0 009 |

Table 23 Nutrient release uptake and leaching loss of P in the second crop of rice as influenced by treatments Mathew s extractant (Kuttanad alluvium)

| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha $^{1}$ | Uptake g pot $^{-1}$ | Leaching loss ppm | Available kg ha $^{-1}$ | Uptake g pot $^{1}$ | Leaching loss ppm | Available kg ha $^{1}$ | Uptake g pot $^{1}$ | Leaching loss pm |
| 1 | MTRP $P_1$ | 21 3 | 0 103 | 0 03 | 17 36 | 0 192 | 0 03 | 15 34 | 0 374 | 0 03 |
| 2 | MTRP $P_2$ | 23 3 | 0 064 | 0 05 | 18 65 | 0 218 | 0 04 | 14 53 | 0 425 | 0 04 |
| 3 | MTRP $P_3$ | 23 3 | 0 091 | 0 08 | 19 37 | 0 253 | 0 05 | 15 90 | 0 467 | 0 04 |
| 4 | MRP $P_1$ | 20 9 | 0 074 | 0 04 | 16 55 | 0 136 | 0 04 | 13 31 | 0 383 | 0 03 |
| 5 | MRP $P_2$ | 21 3 | 0 055 | 0 05 | 17 44 | 0 221 | 0 05 | 14 58 | 0 425 | 0 03 |
| 6 | MRP $P_3$ | 23 4 | 0 068 | 0 08 | 18 60 | 0 234 | 0 06 | 15 93 | 0 390 | 0 03 |
| 7 | SSP $P_1$ | 21 3 | 0 039 | 0 06 | 13 34 | 0 105 | 0 03 | 7 86 | 0 237 | 0 03 |
| 8 | SSP $P_2$ | 22 6 | 0 052 | 0 08 | 14 90 | 0 136 | 0 06 | 8 90 | 0 169 | 0 05 |
| 9 | SSP $P_3$ | 20 9 | 0 065 | 0 12 | 15 70 | 0 192 | 0 07 | 10 51 | 0 228 | 0 05 |
| 10 | DAP $P_1$ | 20 5 | 0 091 | 0 03 | 10 57 | 0 105 | 0 04 | 6 95 | 0 274 | 0 03 |
| 11 | DAP $P_2$ | 19 5 | 0 097 | 0 05 | 11 90 | 0 124 | 0 05 | 7 50 | 0 230 | 0 04 |
| 12 | DAP $P_3$ | 18 7 | 0 093 | 0 08 | 13 67 | 0 124 | 0 06 | 9 88 | 0 230 | 0 04 |
| 13 | C | 8 64 | 0 052 | 0 02 | 7 21 | 0 096 | 0 03 | 5 30 | 0 136 | 0 02 |
| 14 | SSP ($P_2$+$P_2$) | 23 5 | 0 063 | 0 08 | 12 60 | 0 192 | 0 06 | 8 41 | 0 228 | 0 04 |
| CD(0 05) | | 0 80 | | 5 01 | 1 64 | | 1 9 | 1 7 | | 1 9 |
| Source | | | | | | | | | | |
| MTRP | | 22 63 | 0 086 | 0 05 | 18 46 | 0 221 | 0 04 | 15 25 | 0 422 | 0 035 |
| MRP | | 21 86 | 0 065 | 0 05 | 17 53 | 0 197 | 0 04 | 14 60 | 0 399 | 0 03 |
| SSP | | 21 60 | 0 052 | 0 08 | 14 64 | 0 144 | 0 05 | 9 09 | 0 211 | 0 043 |
| DAP | | 19 56 | 0 093 | 0 05 | 12 04 | 0 117 | 0 05 | 8 11 | 0 244 | 0 035 |
| CD(0 05) | | 0 46 | | 0 05 | 2 99 | | 0 011 | 0 40 | 0 011 | 0 01 |
| Level | | | | | | | | | | |
| $P_1$ | | 21 0 | 0 06 | 0 04 | 14 45 | 0 134 | 0 03 | 10 86 | 0 317 | 0 03 |
| $P_2$ | | 21 67 | 0 05 | 0 05 | 15 72 | 0 174 | 0 05 | 11 37 | 0 312 | 0 04 |
| $P_3$ | | 21 57 | 0 07 | 0 09 | 16 83 | 0 200 | 0 06 | 13 05 | 0 329 | 0 04 |
| CD(0 05) | | 0 40 | | 0 005 | 4 32 | | 0 009 | 0 35 | | 0 009 |

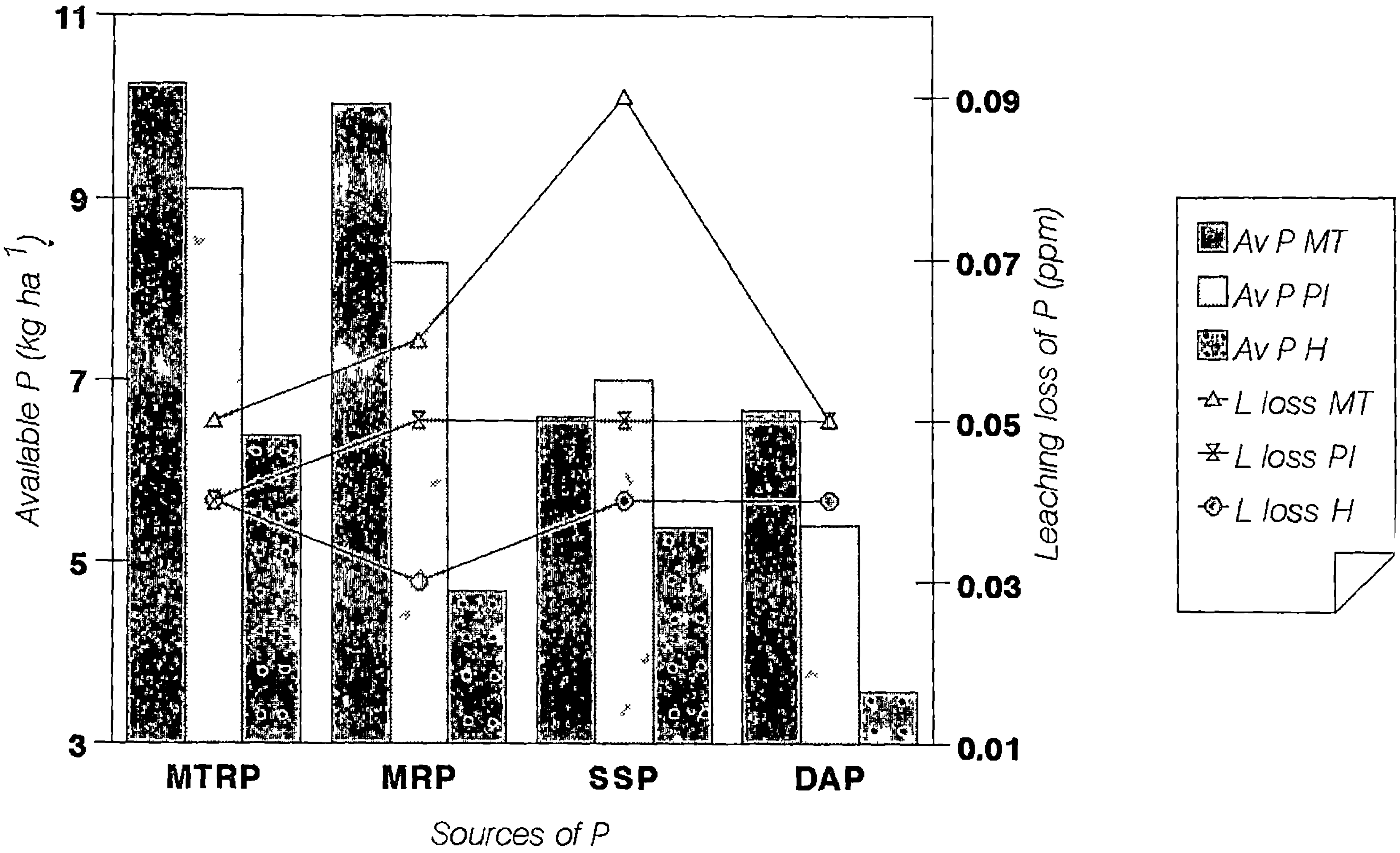



Fig 17 Nutrient release & leaching loss of P as influenced by sources of P at critical stages of second crop of rice Kuttanad alluvium

P content of the soil that was on par with that of SSP $P_2$ at maximum tillering while at panicle initiation there was significant increase in P content in the former that was on par with MTRP $P_1$ MRP $P_1$ MRP $P_2$ and SSP $P_3$

All the treatment combinations registered higher uptake as compared to control The highest P uptake was registered by MTRP $P_3$ at all the critical stages of crop growth This was closely followed by MRP $P_3$ The increased P uptake may be due to the relatively lower rate of fixation of gradually released P from rock phosphate As a result the slowly released P remained in available form for a longer time for succeeding crop The P uptake values of SSP ($P_2$+$P_2$) was similar to that of SSP $P_3$ However it was lower than that from rockphosphate From this it is clear that the continuous P application using a water soluble source may be substituted by the use of water insoluble source for the first crop as the removal was found to be better in the case of water insoluble source

The values of nutrient release and leaching losses are depicted in Fig 17 Both of the water insoluble sources MTRP and MRP maintained superiority over water soluble sources SSP and DAP in available P release by the soil There was no significant difference between the sources in leaching loss of P It was found that Mathew s extractant correlated better with P uptake as compared to Bray 1 extract ant (Appendix III)

4 2 1 3 Nutrient release uptake and leaching loss of K

First crop

The values for nutrient release uptake and leaching loss are provided in Table 24 The range was recorded as 102 6 to 539 72 kg $ha^{-1}$ for available K

Table 24 Nutrient release uptake and leaching loss of K in the first crop of rice as influenced by treatments (Kuttanad alluvium)

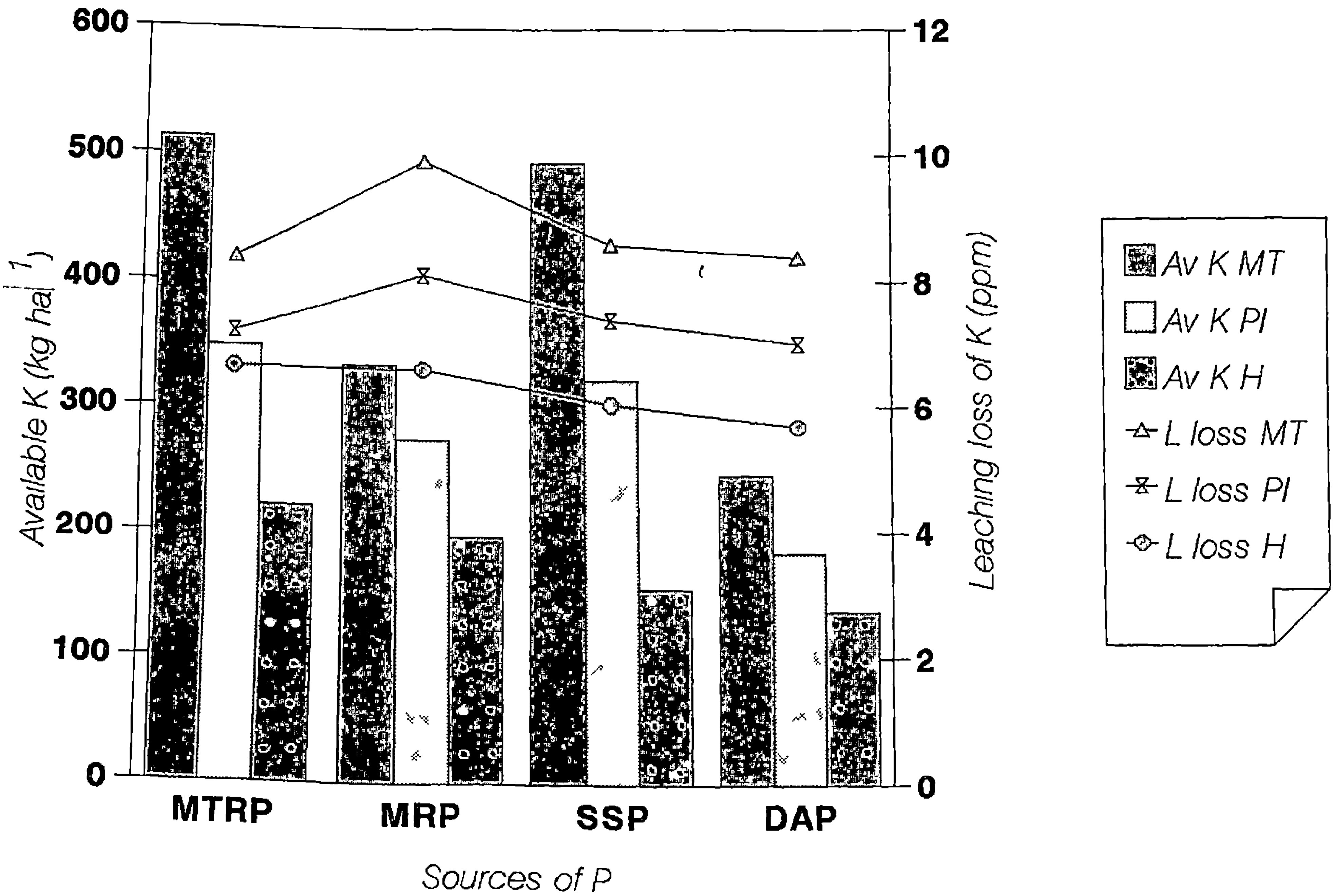


| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm |
| 1 | MTRP $P_1$ | 466 6 | 0 089 | 8 80 | 252 0 | 0 125 | 8 03 | 149 3 | 0 323 | 7 67 |
| 2 | MTRP $P_2$ | 513 3 | 0 095 | 7 33 | 364 0 | 0 054 | 7 33 | 233 3 | 0 373 | 7 43 |
| 3 | MTRP $P_3$ | 560 0 | 0 103 | 9 07 | 429 3 | 0 153 | 6 40 | 280 0 | 0 370 | 4 80 |
| 4 | MRP $P_1$ | 280 0 | 0 095 | 8 63 | 196 0 | 0 136 | 6 80 | 143 3 | 0 337 | 5 67 |
| 5 | MRP $P_2$ | 326 6 | 0 103 | 10 07 | 261 3 | 0 110 | 8 50 | 168 0 | 0 411 | 6 63 |
| 6 | MRP $P_3$ | 392 0 | 0 118 | 11 00 | 364 0 | 0 162 | 9 03 | 280 0 | 0 354 | 7 43 |
| 7 | SSP $P_1$ | 392 0 | 0 109 | 7 83 | 224 0 | 0 161 | 6 67 | 149 3 | 0 384 | 7 27 |
| 8 | SSP $P_2$ | 504 0 | 0 151 | 9 30 | 322 0 | 0 167 | 7 97 | 121 3 | 0 420 | 6 07 |
| 9 | SSP $P_3$ | 588 0 | 0 151 | 8 60 | 420 0 | 0 181 | 7 63 | 196 0 | 0 489 | 4 83 |
| 10 | DAP $P_1$ | 168 6 | 0 161 | 9 83 | 112 0 | 0 148 | 6 83 | 102 6 | 0 467 | 5 03 |
| 11 | DAP $P_2$ | 242 5 | 0 179 | 10 13 | 186 6 | 0 166 | 8 33 | 130 6 | 0 235 | 7 67 |
| 12 | DAP $P_3$ | 326 6 | 0 155 | 5 17 | 252 0 | 0 166 | 5 90 | 177 3 | 0 563 | 4 37 |
| 13 | C | 189 0 | 0 045 | 10 73 | 177 3 | 0 071 | 7 63 | 102 6 | 0 245 | 6 59 |
| 14 | SSP ($P_2$+$P_2$) | 401 31 | 0 144 | 10 53 | 280 0 | 0 217 | 7 26 | 168 0 | 0 401 | 6 07 |
| CD(0 05) | | 36 04 | | 2 26 | 42 85 | | 3 21 | 38 98 | | 1 94 |
| Source | | | | | | | | | | |
| MTRP | | 513 3 | 0 09 | 8 4 | 348 4 | 0 11 | 7 20 | 220 8 | 0 36 | 6 63 |
| MRP | | 332 8 | 0 11 | 9 9 | 273 7 | 0 14 | 8 10 | 197 1 | 0 37 | 6 60 |
| SSP | | 494 6 | 0 14 | 8 6 | 322 0 | 0 17 | 7 40 | 155 5 | 0 43 | 6 05 |
| DAP | | 245 9 | 0 17 | 8 4 | 183 6 | 0 16 | 7 02 | 136 8 | 0 42 | 5 69 |
| CD(0 05) | | 77 9 | | 1 30 | 24 7 | | 1 85 | 22 51 | | 1 12 |
| Level | | | | | | | | | | |
| $P_1$ | | 326 8 | 0 114 | 8 77 | 196 0 | 0 142 | 7 08 | 136 1 | 0 377 | 6 41 |
| $P_2$ | | 396 6 | 0 132 | 9 20 | 283 4 | 0 124 | 8 03 | 163 3 | 0 359 | 6 95 |
| $P_3$ | | 466 6 | 0 131 | 8 46 | 366 3 | 0 165 | 7 24 | 233 3 | 0 444 | 5 33 |
| CD(0 05) | | 67 51 | | 1 13 | 21 43 | | 1 61 | 19 49 | | 0 97 |

Uptake of K varied from 0 045 to 0 489 g pot $^{1}$ and leaching loss from 3 80 to 11 0 ppm

The control treatment recorded available K content of 189 0 kg ha $^{1}$ at maximum tillering which reduced to 177 3 kg ha $^{1}$ at panicle initiation and 102 6 kg ha $^{1}$ at harvest All the other treatments registered significantly higher amount of K content as compared to control Just like in the control a decreasing trend for available K content was observed from tillering to harvest stage This is due to the continuous removal of K as reflected by the values of K uptake The availability was found to be maximum for MTRP at $P_3$ level (560 0 kg ha $^{1}$) which was on par with SSP $P_3$ (588 0) The same trend was followed at panicle initiation but at harvest these treatments were on par with MRP $P_3$ This indicates that P sources rich in Ca may be able to release more exchangeable as well as available K from the soil The various treatment combinations of DAP released comparatively lesser quantities of K from the soil These results may be substantiated from the data provided in Appendix II on the elemental composition of fertilizers

For the control treatment uptake value at maximum tillering was 0 045 g pot $^{1}$ which increased to 0 071 g pot $^{1}$ at panicle initiation and to 0 401 g pot $^{1}$ at harvest respectively The control treatment recorded the lowest uptake The probable reason may be due to the slow diffusion of K from the soil as their uptake is very much dependent on the proximity of rooting surface It is not surprising therefore that depletion of P from the soil may affect the healthy root system in the upper layers These findings can be supported from the high uptake of DAP $P_2$ at maximum tillering SSP $P_2$ at panicle initiation and DAP $P_3$ at harvest It can be observed that the immediate release of P from water soluble sources resulted in more K uptake These findings are in line with that of Mathews and Jose (1984)




...elease and leaching loss of K as influenced by sources of P at critical stages of

Regarding the leaching loss of K the control treatment recorded 10 53 ppm at maximum tillering which reduced to 7 63 ppm at panicle initiation and 6 59 ppm at harvest There was no significant difference between the various treat ments in leachmg loss of K at all the three stages of crop growth

The nutrient release and leaching loss of K as influenced by sources are illustrated in Fig 18 This clearly indicates that availability of K was high for MTRP at all the three critical stages The least values were recorded by the source DAP The leaching losses were high in MRP treatment at maximum tillering stage while at harvest stage SSP and DAP were on par and significantly higher than MTRP and MRP There was no significant difference among the sources at panicle initiation stage In general loss of nutrient through leaching decreased with crop growth The basal application of K to the crop might have resulted m the immediate loss of the same from light textured Kuttanad alluvium

The mcreased level of P m general resulted in more K content in the soil This was due to the triggering mechanism of P in releasing more K content from the soil and so more loss from the soil as in the case of N which was discussed in section 4 2 1 1

Second crop

The results are presented in Table 25 Available K ranged from 42 5 to 195 6 kg ha $^{1}$ uptake varied from 0 16 to 0 77 g pot $^{1}$ Leaching loss ranged from 3 07 to 10 33 ppm

Table 25 Nutrient release uptake and leaching loss of K in the second crop of rice as influenced by treatments (Kuttanad allvuium)

| Treatment No | Notation | Maximum tillering Available kg ha$^{-1}$ | Maximum tillering Uptake g pot$^{-1}$ | Maximum tillering Leaching loss ppm | Panicle initiation Available kg ha$^{-1}$ | Panicle initiation Uptake g pot$^{-1}$ | Panicle initiation Leaching loss ppm | Harvest Available kg ha$^{-1}$ | Harvest Uptake g pot$^{-1}$ | Harvest Leaching loss ppm |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MTRP $P_1$ | 183 6 | 0 393 | 7 23 | 188 1 | 0 472 | 6 40 | 95 5 | 0 536 | 6 30 |
| 2 | MTRP $P_2$ | 182 6 | 0 376 | 5 53 | 183 6 | 0 513 | 4 57 | 88 0 | 0 572 | 4 03 |
| 3 | MTRP $P_3$ | 188 8 | 0 329 | 9 27 | 182 9 | 0 430 | 7 50 | 100 0 | 0 635 | 3 30 |
| 4 | MRP -$P_1$ | 180 7 | 0 274 | 9 70 | 172 4 | 0 308 | 7 10 | 85 1 | 0 582 | 3 17 |
| 5 | MRP $P_2$ | 185 9 | 0 279 | 10 33 | 111 1 | 0 416 | 6 20 | 89 6 | 0 663 | 4 00 |
| 6 | MRP $P_3$ | 195 6 | 0 323 | 9 63 | 174 7 | 0 345 | 6 10 | 86 6 | 0 587 | 3 97 |
| 7 | SSP $P_1$ | 169 5 | 0 438 | 9 23 | 140 3 | 0 387 | 5 17 | 109 7 | 0 691 | 4 23 |
| 8 | SSP $P_2$ | 165 7 | 0 433 | 10 20 | 182 1 | 0 358 | 7 50 | 104 5 | 0 707 | 3 97 |
| 9 | SSP $P_3$ | 182 1 | 0 448 | 8 23 | 175 4 | 0 386 | 6 43 | 94 0 | 0 589 | 3 07 |
| 10 | DAP $P_1$ | 154 5 | 0 280 | 6 27 | 91 8 | 0 555 | 6 03 | 71 6 | 0 605 | 3 40 |
| 11 | DAP $P_2$ | 163 5 | 0 319 | 8 97 | 91 8 | 0 559 | 5 50 | 78 4 | 0 608 | 4 23 |
| 12 | DAP $P_3$ | 164 2 | 0 375 | 5 33 | 98 5 | 0 624 | 4 60 | 85 1 | 0 595 | 4 00 |
| 13 | C | 89 6 | 0 160 | 9 00 | 60 4 | 0 393 | 5 80 | 42 5 | 0 318 | 4 06 |
| 14 | SSP ($P_2$+$P_2$) | 176 9 | 0 319 | 7 40 | 193 3 | 0 483 | 61 10 | 99 2 | 0 618 | 4 83 |
| CD(0 05) | | 3 86 | | 2 59 | 42 60 | | 0 85 | 5 31 | | 0 33 |
| Source | | | | | | | | | | |
| MTRP | | 185 0 | 0 532 | 7 34 | 184 9 | 0 48 | 6 2 | 94 5 | 0 581 | 4 54 |
| MRP | | 187 4 | 0 292 | 9 90 | 152 7 | 0 36 | 6 5 | 87 1 | 0 610 | 3 71 |
| SSP | | 172 4 | 0 439 | 9 22 | 165 9 | 0 38 | 6 4 | 102 7 | 0 663 | 3 80 |
| DAP | | 160 7 | 0 324 | 6 86 | 94 03 | 0 58 | 5 4 | 78 4 | 0 603 | 3 90 |
| CD(0 05) | | 22 3 | | 1 49 | 24 64 | | 0 49 | 3 06 | | 0 19 |
| Level | | | | | | | | | | |
| $P_1$ | | 172 07 | 0 346 | 8 10 | 148 1 | 0 430 | 6 17 | 90 4 | 0 603 | 4 27 |
| $P_2$ | | 174 42 | 0 351 | 8 75 | 142 1 | 0 461 | 5 94 | 90 1 | 0 637 | 4 05 |
| $P_3$ | | 182 67 | 0 365 | 8 11 | 157 8 | 0 446 | 6 15 | 91 4 | 0 601 | 3 58 |
| CD(0 05) | | 1 93 | | 1 29 | 21 34 | | 0 42 | 2 65 | - | 0 16 |

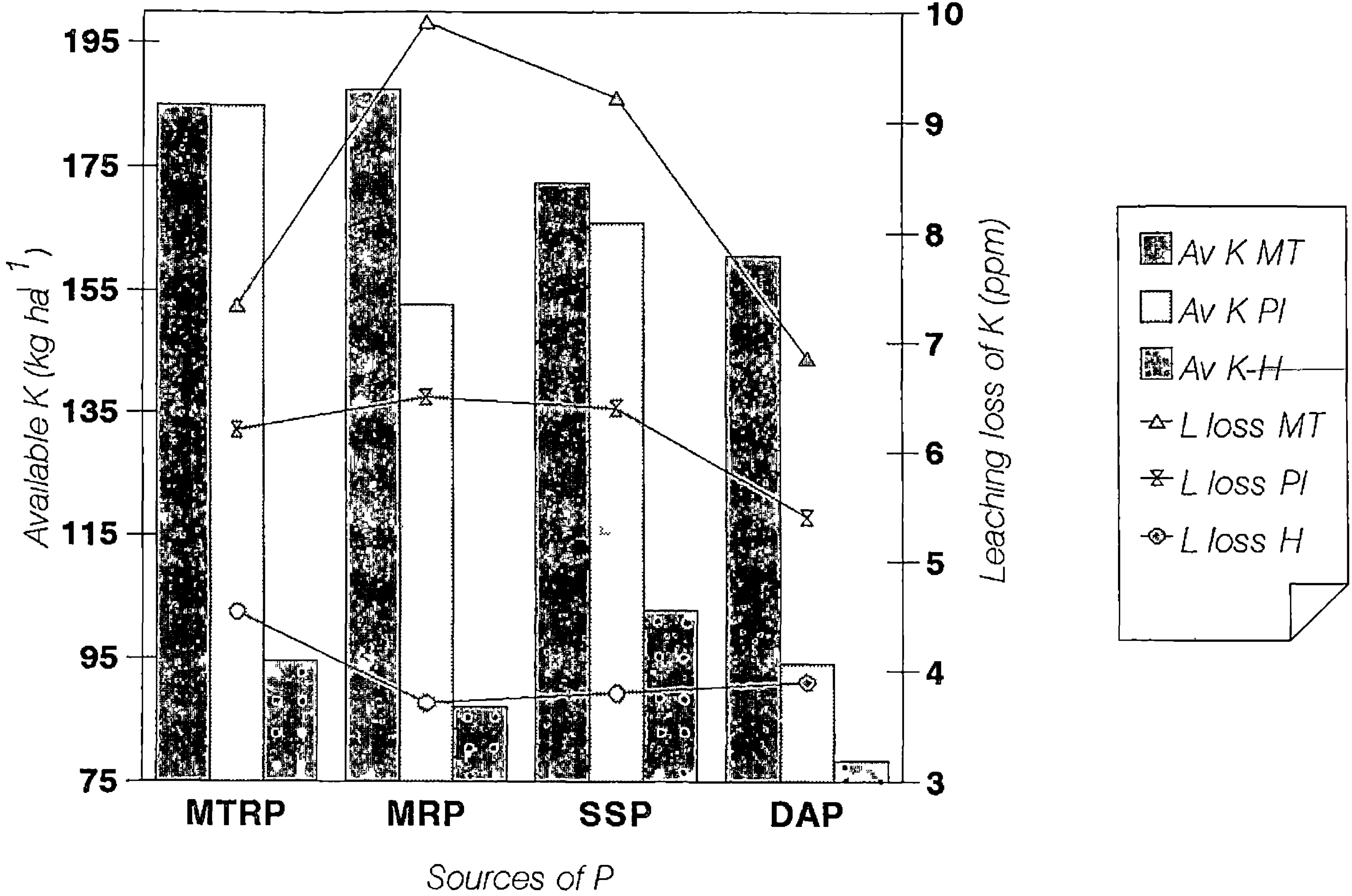



Fig 19 Nutrient release & leaching loss of K as influenced by sources of P at critical stages of second crop of rice-Kuttanad alluvium

As compared to first crop availability index was low for second crop This may be due to the less retention of K in the soil though there was continuous application of K for the second crop The uptake of K increased with crop growth while leaching loss was found to decrease with advancement of crop growth as reported for the first crop

The lowest value of available K in the soil was recorded by the control treatment which reduced from 89 6 to 60 45 kg ha $^{1}$ at panicle initiation and to 42 5 kg ha $^{1}$ at harvest As in the case of first crop roskphosphate tended to release more K from the soil at maximum tillering and panicle initiation while at harvest SSP $P_1$ and SSP $P_2$ were on par and recorded highest available K content in the soil This was closely followed by MTRP at $P_3$ level

The control treatment registered lowest uptake at all the stages of crop At maximum tillering stage MTRP was superior while at panicle initiation DAP recorded higher uptake At harvest stage MRP SSP and DAP were almost similar in K uptake

The graph illustrating nutrient release and leaching loss of K are provided in Fig 19 With reference to the influence of different sources of P on availability it is clear that water soluble sources had no remarkable influence on the release pattern as that of rockphosphate The leaching loss of K from DAP treat ments were comparatively low

4 2 1 4 Nutrient release and uptake of Ca

The data are presented in Table 26 The available Ca values ranged from 701 0 to 2672 9 kg ha $^{1}$ while uptake varied from 0 005 to 0 227 g pot $^{1}$

Table 26 Nutrient release and uptake of Ca in the first crop of rice as influenced by treatments (Kuttanad alluvium)

| Treatment | | Maximum tillering | | Panicle initiation | | Harvest | |
|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ |
| 1 | MTRP $P_1$ | 1732 2 | 0 015 | 1805 2 | 0 05 | 1478 4 | 0 124 |
| 2 | MTRP $P_2$ | 1836 8 | 0 015 | 1941 3 | 0 056 | 1657 6 | 0 131 |
| 3 | MTRP $P_3$ | 1971 2 | 0 012 | 2090 5 | 0 046 | 1702 4 | 0 175 |
| 4 | MRP $P_1$ | 2090 5 | 0 011 | 2254 9 | 0 039 | 1560 0 | 0 147 |
| 5 | MRP $P_2$ | 2180 2 | 0 013 | 2434 1 | 0 086 | 1657 6 | 0 227 |
| 6 | MRP $P_3$ | 2240 0 | 0 009 | 2672 9 | 0 089 | 1899 2 | 0 150 |
| 7 | SSP $P_1$ | 1358 9 | 0 010 | 1478 4 | 0 037 | 1164 8 | 0 127 |
| 8 | SSP $P_2$ | 1462 7 | 0 007 | 1657 6 | 0 033 | 1358 7 | 0 116 |
| 9 | SSP $P_3$ | 1568 0 | 0 012 | 1702 4 | 0 035 | 1462 7 | 0 124 |
| 10 | DAP $P_1$ | 940 8 | 0 011 | 866 6 | 0 024 | 763 0 | 0 085 |
| 11 | DAP $P_2$ | 940 8 | 0 010 | 896 0 | 0 028 | 716 8 | 0 081 |
| 12 | DAP $P_3$ | 970 6 | 0 015 | 896 0 | 0 030 | 785 0 | 0 101 |
| 13 | C | 985 6 | 0 050 | 896 0 | 0 13 | 701 0 | 0 091 |
| 14 | SSP ($P_2$+$P_2$) | 1805 2 | 0 010 | 971 4 | 0 032 | 970 6 | 0 120 |
| CD (0 05) | | 162 39 | | 142 61 | | 187 8 | |
| Source | | | | | | | |
| MTRP | | 1846 7 | 0 011 | 1945 6 | 0 071 | 1708 2 | 0 174 |
| MRP | | 2170 2 | 0 009 | 2453 9 | 0 035 | 1328 7 | 0 122 |
| SSP | | 1463 2 | 0 014 | 1612 8 | 0 051 | 1612 8 | 0 128 |
| DAP | | 950 7 | 0 012 | 886 2 | 0 027 | 754 9 | 0 089 |
| CD (0 05) | | 136 02 | | 142 61 | | 108 45 | |
| Level | | | | | | | |
| $P_1$ | | 1530 6 | 0 011 | 1601 2 | 0 037 | 1243 5 | 0 112 |
| $P_2$ | | 1605 1 | 0 011 | 1732 2 | 0 050 | 1347 6 | 0 136 |
| $P_3$ | | 1687 4 | 0 010 | 1840 4 | 0 050 | 1462 3 | 0 137 |
| CD (0 05) | | 31 19 | | 36 91 | | 93 92 | |

The available Ca content was found to be decreased with crop growth The control registered a maximum content at maximum tillering stage 985 6 kg ha $^{1}$ which decreased to 896 0 kg ha $^{1}$ at panicle initiation and 701 0 kg ha $^{1}$ at harvest Among the treatment combinations maximum Ca content was present in MRP $P_3$ at all the stages of crop growth This recorded 2240 0 kg ha $^{1}$ at maximum tillering 2672 9 kg ha $^{1}$ at panicle initiation and 1299 2 kg ha $^{1}$ at harvest respectively The source MRP was significantly higher as compared to others at tillering and panicle initiation while at harvest MTRP and SSP were significantly superior

The control treatment recorded the lowest uptake The Ca uptake by the crop was found to be gradually increasing with stages of crop growth as in the case of control treatment where it increased from 0 005 g pot $^{1}$ at maximum tillering to 0 013 g pot $^{1}$ at panicle initiation and 0 091 g pot $^{1}$ at harvest At maximum tiller ing stage almost the same uptake value of 0 01 g pot $^{1}$ was recorded by the various treatments At panicle initiation it increased to 0 089 g pot $^{1}$ and to 0 086 g pot $^{1}$ by the treatment MRP $P_3$ and MRP $P_2$ respectively At harvest MRP $P_3$ recorded 0 227 g pot $^{1}$ followed by MTRP $P_3$ (0 175 g pot $^{1}$)

In general available Ca content was higher for the sources MRP MTRP and SSP due to the contents of Ca as detailed in Appendix II while DAP registered the lowest This was followed in uptake also

Second crop

The data pertaining to nutrient release and uptake of Ca are provided in Table 27 Available Ca ranged from 164 2 (C) to 1806 0 kg ha $^{1}$ (MRP $P_3$) and uptake ranged from 0 014 to 0 187 g pot $^{1}$

Table 27 Nutrient release and uptake of Ca in the second crop of rice as influenced by treatments (Kuttanad alluvium)

| Treatment | | Maximum tillering | | Panicle initiation | | Harvest | |
|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ |
| 1 | MTRP $P_1$ | 792 0 | 0 015 | 1731 5 | 0 099 | 806 4 | 0 109 |
| 2 | MTRP $P_2$ | 881 6 | 0 049 | 1806 0 | 0 088 | 1030 4 | 0 112 |
| 3 | MTRP $P_3$ | 1056 3 | 0 025 | 1866 6 | 0 125 | 1254 4 | 0 112 |
| 4 | MRP $P_1$ | 1612 8 | 0 028 | 1585 2 | 0 081 | 896 0 | 0 091 |
| 5 | MRP $P_2$ | 1731 5 | 0 026 | 1612 4 | 0 131 | 970 6 | 0 131 |
| 6 | MRP $P_3$ | 1806 0 | 0 032 | 1731 5 | 0 085 | 1164 8 | 0 087 |
| 7 | SSP $P_1$ | 1358 9 | 0 045 | 1164 8 | 0 070 | 940 8 | 0 136 |
| 8 | SSP $P_2$ | 1478 0 | 0 027 | 1299 2 | 0 067 | 1164 8 | 0 090 |
| 9 | SSP $P_3$ | 1612 8 | 0 026 | 1478 4 | 0 068 | 1284 2 | 0 108 |
| 10 | DAP $P_1$ | 698 0 | 0 045 | 601 0 | 0 056 | 540 0 | 0 113 |
| 11 | DAP $P_2$ | 685 0 | 0 036 | 610 9 | 0 063 | 525 0 | 0 159 |
| 12 | DAP $P_3$ | 673 0 | 0 023 | 592 6 | 0 082 | 560 0 | 0 187 |
| 13 | C | 672 0 | 0 014 | 403 2 | 0 049 | 164 2 | 0 134 |
| 14 | SSP ($P_2$+$P_2$ | 1731 5 | 0 022 | 1612 8 | 0 062 | 806 4 | 0 108 |
| CD (0 05) | | 162 39 | | 164 42 | | 170 21 | |
| Source | | | | | | | |
| MTRP | | 943 3 | 0 029 | 1801 3 | 0 104 | 1030 4 | 0 111 |
| MRP | | 1716 7 | 0 028 | 1642 8 | 0 099 | 1010 4 | 0 103 |
| SSP | | 1483 2 | 0 032 | 1314 1 | 0 068 | 1129 9 | 0 111 |
| DAP | | 685 3 | 0 034 | 601 5 | 0 067 | 541 6 | 0 153 |
| CD (0 05) | | 136 01 | | 137 19 | | 140 53 | |
| Level | | | | | | | |
| $P_1$ | | 1115 4 | 0 033 | 1270 3 | 0 076 | 795 8 | 0 112 |
| $P_2$ | | 1219 0 | 0 034 | 1332 2 | 0 087 | 922 7 | 0 123 |
| $P_3$ | | 1287 0 | 0 026 | 1417 2 | 0 090 | 1065 8 | 0 123 |
| CD (0 05) | | 31 19 | | 32 21 | | 35 10 | |

The trend of results were same as in the case of first crop Available Ca content decreased with crop growth The control treatment recorded 0 014 g pot $^{1}$ at maximum tillering which increased to 0 049 g pot $^{1}$ at panicle initiation and 0 134 g pot $^{1}$ at harvest The interaction MRP $P_3$ recorded 1731 5 kg ha $^{1}$ at maximum tillering which decreased to 1584 2 kg ha $^{1}$ at panicle initiation and 1254 4 at harvest In SSP ($P_2$+$P_2$) there was numerical increase in Ca content but was not statistically significant

The Ca uptake as compared to that of control ranged from 0 014 to 0 091 g pot $^{1}$ The treatment MRP $P_3$ registered the highest uptake value for Ca at all the three stages (0 049 g pot $^{1}$ at maximum tillering 0 125 g pot $^{1}$ at panicle initiation and 0 187 g pot $^{1}$ at harvest)

4 2 1 5 Nutrient release and uptake of Mg

First crop

The data are presented in Table 28 Available Mg content ranged from 444 0 to 1298 5 kg ha $^{1}$ while uptake ranged from 0 01 to 0 351 g pot $^{1}$

Available Mg decreased with crop growth The control treatment recorded higher content of available Mg (1218 5 kg ha $^{1}$) at maximum tillering which was significantly higher than other treatments except DAP $P_3$ This may be attributed to the high Mg content in the original soil as indicated in Table 1 The levels of P did not have much influence on Mg availability

With respect to uptake there was increase with advancement of crop growth In general high uptake was noticed in DAP treatments The control treat ment registered the lowest uptake

Table 28 Nutrient release and uptake of Mg in the first crop of rice as influenced by treatments (Kuttanad alluvium)

| Treatment | | Maximum tillering | | Panicle initiation | | Harvest | |
|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha$^{1}$ | Uptake g pot$^{1}$ | Available kg ha$^{1}$ | Uptake g pot$^{1}$ | Available kg ha$^{1}$ | Uptake g pot$^{1}$ |
| 1 | MTRP $P_1$ | 1140 0 | 0 030 | 833 0 | 0 040 | 444 0 | 0 230 |
| 2 | MTRP $P_2$ | 1209 0 | 0 019 | 789 9 | 0 037 | 489 5 | 0 225 |
| 3 | MTRP $P_3$ | 1146 0 | 0 022 | 791 3 | 0 024 | 555 8 | 0 246 |
| 4 | MRP $P_1$ | 1173 0 | 0 018 | 985 6 | 0 039 | 582 4 | 0 219 |
| 5 | MRP $P_2$ | 1120 0 | 0 024 | 887 0 | 0 048 | 555 5 | 0 192 |
| 6 | MRP $P_3$ | 1059 2 | 0 024 | 789 6 | 0 029 | 600 3 | 0 202 |
| 7 | SSP $P_1$ | 1012 4 | 0 018 | 824 3 | 0 036 | 448 0 | 0 252 |
| 8 | SSP $P_2$ | 1184 5 | 0 032 | 976 6 | 0 025 | 563 8 | 0 286 |
| 9 | SSP $P_3$ | 1129 3 | 0 031 | 869 1 | 0 045 | 496 0 | 0 316 |
| 10 | DAP $P_1$ | 1080 3 | 0 032 | 806 0 | 0 065 | 582 4 | 0 297 |
| 11 | DAP $P_2$ | 1144 0 | 0 024 | 922 8 | 0 050 | 600 3 | 0 286 |
| 12 | DAP $P_3$ | 1298 6 | 0 028 | 763 4 | 0 058 | 600 3 | 0 351 |
| 13 | C | 1218 5 | 0 010 | 985 6 | 0 022 | 555 5 | 0 140 |
| 14 | SSP ($P_2$+$P_2$) | 1194 5 | 0 035 | 922 8 | 0 020 | 555 5 | 0 246 |
| CD (0 05) | | 70 58 | | 53 5 | | 50 66 | |
| Source | | | | | | | |
| MTRP | | 1165 0 | 0 023 | 804 7 | 0 033 | 496 3 | 0 233 |
| MRP | | 1116 7 | 0 022 | 887 4 | 0 038 | 579 4 | 0 204 |
| SSP | | 1112 0 | 0 027 | 890 0 | 0 035 | 502 6 | 0 284 |
| DAP | | 1174 2 | 0 028 | 830 7 | 0 057 | 594 3 | 0 311 |
| CD (0 05) | | 70 58 | | 31 5 | | 29 26 | |
| Level | | | | | | | |
| $P_1$ | | 1101 4 | 0 022 | 862 2 | 0 045 | 514 2 | 0 249 |
| $P_2$ | | 1166 8 | 0 024 | 894 0 | 0 040 | 552 2 | 0 247 |
| $P_3$ | | 1157 7 | 0 026 | 803 3 | 0 039 | 563 0 | 0 278 |
| CD (0 05) | | 61 12 | | 18 6 | | 25 34 | |

Second crop

The data pertaining to nutrient release and uptake are provided in Table 29

The available Mg content in second crop was comparatively low as compared to first crop This may be attributed to the continuous uptake by the crop The trend of results were same as that of first crop However the available Mg content of MTRP was low as compared to other sources

The uptake in second crop was higher than first crop This was relatively higher for DAP treatments

4 2 2 Laterite soil

4 2 2 1 Nutrient release uptake and leaching loss of nitrogen at different stages of crop growth

First crop

On perusal of the data presented in Table 30 it was found that available N ranged from 169 3 (DAP $P_1$) to 809 0 kg ha $^{1}$ (MTRP $P_3$) while uptake vaired from 0 143 (c) to 0 992 g pot $^{1}$ (MRP $P_3$) Leaching loss of N was considerably high and it ranged from 2 80 to 11 67 ppm

The control treatment recorded a maximum of 418 1 kg ha $^{1}$ as available N which reduced to 267 5 kg ha $^{1}$ at panicle initiation and to 188 2 kg ha $^{1}$ towards harvest Maximum content of available N for all treatments was observed at maximum tillering which decreased with crop growth This is due to the continuous

Table 29 Nutrient release and uptake of Mg in the second crop of rice as influenced by treatments (Kuttanad alluvium)

| Treatment No | Notation | Maximum tillering Available kg ha $^{-1}$ | Maximum tillering Uptake g pot $^{-1}$ | Panicle initiation Available kg ha $^{-1}$ | Panicle initiation Uptake g pot $^{-1}$ | Harvest Available kg ha $^{-1}$ | Harvest Uptake g pot $^{-1}$ |
|---|---|---|---|---|---|---|---|
| 1 | MTRP $P_1$ | 573 4 | 0 04 | 412 1 | 0 191 | 322 5 | 0 334 |
| 2 | MTRP $P_2$ | 501 3 | 0 064 | 448 0 | 0 218 | 367 3 | 0 391 |
| 3 | MTRP $P_3$ | 618 2 | 0 091 | 412 1 | 0 253 | 322 5 | 0 367 |
| 4 | MRP $P_1$ | 609 2 | 0 073 | 555 5 | 0 136 | 448 0 | 0 383 |
| 5 | MRP $P_2$ | 645 1 | 0 055 | 582 4 | 0 221 | 396 0 | 0 425 |
| 6 | MRP $P_3$ | 680 9 | 0 068 | 573 4 | 0 233 | 421 3 | 0 390 |
| 7 | SSP $P_1$ | 6003 | 0 039 | 412 1 | 0 237 | 322 5 | 0 386 |
| 8 | SSP $P_2$ | 680 9 | 0 052 | 512 6 | 0 168 | 412 1 | 0 408 |
| 9 | SSP $P_3$ | 591 0 | 0 065 | 582 4 | 0 228 | 367 3 | 0 412 |
| 10 | DAP $P_1$ | 618 2 | 0 091 | 355 5 | 0 274 | 396 0 | 0 403 |
| 11 | DAP $P_2$ | 645 1 | 0 097 | 573 4 | 0 230 | 412 1 | 0 451 |
| 12 | DAP $P_3$ | 618 2 | 0 093 | 573 4 | 0 230 | 423 2 | 0 473 |
| 13 | C | 645 1 | 0 052 | 582 4 | 0 166 | 412 1 | 0 278 |
| 14 | SSP ($P_2$+$P_2$) | 645 1 | 0 063 | 555 5 | 0 215 | 396 0 | 0 364 |
| CD (0 05) | | 33 6 | | 29 8 | | 15 9 | |
| Source | | | | | | | |
| MTRP | | 594 3 | 0 065 | 424 0 | 0 220 | 337 4 | 0 364 |
| MRP | | 546 0 | 0 065 | 570 4 | 0 196 | 421 7 | 0 399 |
| SSP | | 624 0 | 0 052 | 502 3 | 0 211 | 367 3 | 0 402 |
| DAP | | 627 1 | 0 093 | 567 4 | 0 244 | 410 4 | 0 442 |
| CD (0 05) | | 13 2 | | 20 6 | | 18 9 | |
| Level | | | | | | | |
| $P_1$ | | 600 2 | 0 060 | 483 8 | 0 209 | 372 2 | 0 376 |
| $P_2$ | | 640 6 | 0 067 | 529 1 | 0 209 | 396 8 | 0 418 |
| $P_3$ | | 642 5 | 0 079 | 535 3 | 0 236 | 383 5 | 0 410 |
| CD (0 05) | | 8 9 | | 17 6 | | 17 2 | |

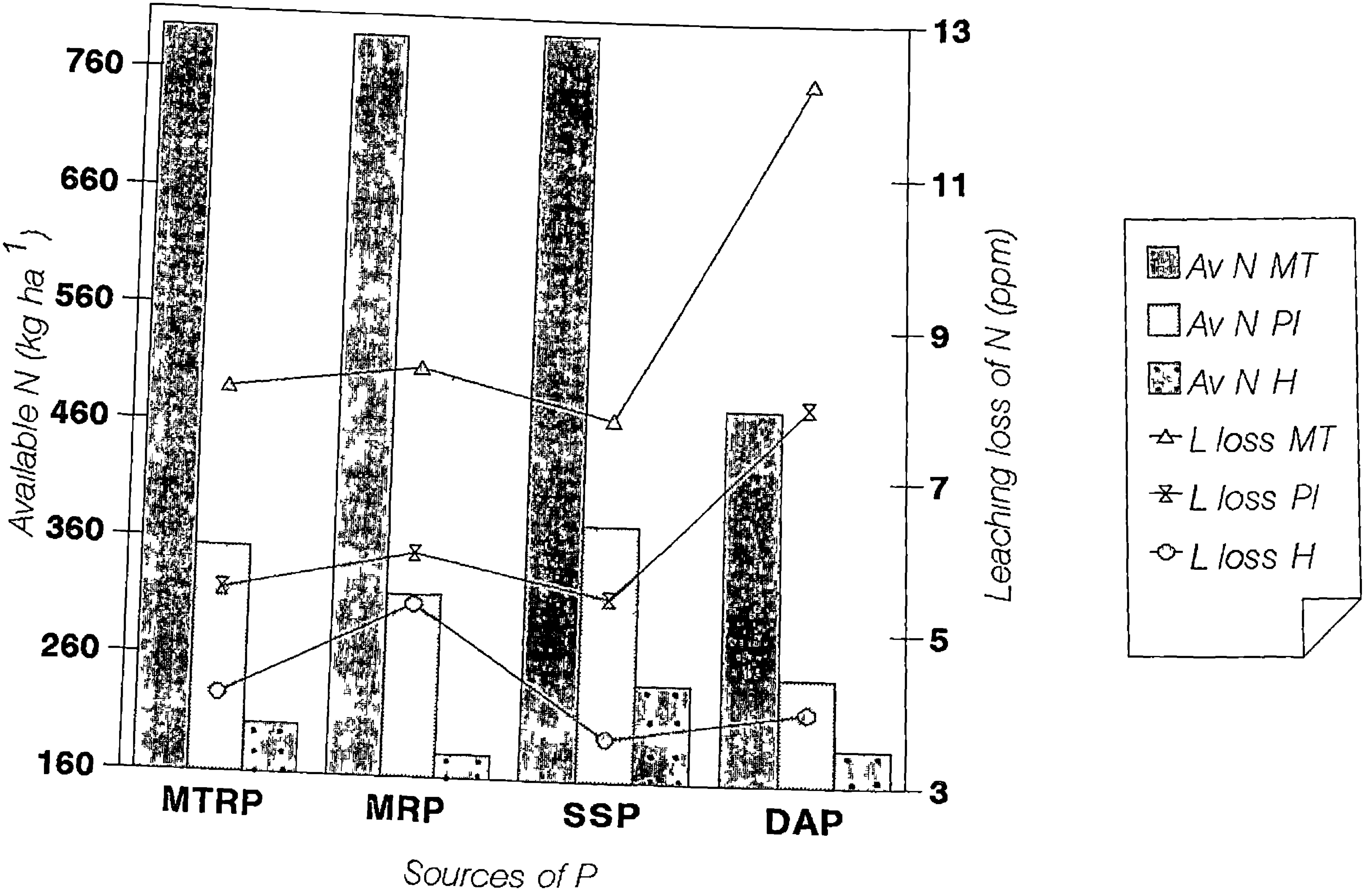
uptake by the crop Among the treatments MTRP $P_2$ MTRP $P_3$ MRP $P_3$ SSP $P_2$ and SSP $P_3$ were on par and significantly superior to other interactions at tillering stage of crop However at panicle initiation and harvest stages the interactions of SSP with different levels were singificantly higher in available N release In general SSP treatments were found to be the best in available N build up of the soil

The uptake of N was comparatively higher in laterite soil as compared to Kuttanad alluvium With reference to uptake the control treatment registered the lowest value in all the three critical stages of crop growth Absence of applied P may be the reason for the poor uptake of N These findings are in line with that of Ramanathan *et al* (1973) From the table it is evident that maximum uptake was registered at harvest stage The higher dry matter production resulted in higher uptake of N by the crop at this stage Maximum uptake was observed for SSP $P_3$ and MRP $P_3$ (0 40 g pot $^{1}$) which was closely followed by MTRP $P_3$ (0 360) and SSP $P_2$ (0 376) at maximum tillering The same trend was observed at harvest stage also with MRP $P_3$ (0 992 g pot $^{1}$) and SSP $P_3$ (0 958 g pot $^{1}$) At panicle initiation MTRP $P_3$ was superior (0 547 g) which was closely followed by MRP $P_3$ (0 482 g pot $^{1}$) From this it is evident that higher levels of rockphosphates and super phosphate utilised more N due to the higher utilization of N along with more P The relatively high uptake of N may be accounted for largely by the comparative ease with which $NO_3$ is translocated upward in the soil profile The $NO_3$ form of nitrogen is completely mobile and within limits moves largely with the soil water

The leaching loss of N in control treatment decreased from 9 30 ppm at tillering stage to 3 27 ppm at harvest The same trend was followed in other treatments also Maximum leaching loss was observed for DAP $P_3$ and DAP $P_2$

Table 30 Nutrient release uptake and leaching loss of N in the first crop of rice as influenced by treatments (laterite)

| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm |
| 1 | MTRP $P_1$ | 781 9 | 0 242 | 7 00 | 344 9 | 0 368 | 4 53 | 296 5 | 0 482 | 3 27 |
| 2 | MTRP $P_2$ | 796 5 | 0 352 | 8 34 | 351 2 | 0 437 | 5 20 | 200 7 | 0 802 | 3 73 |
| 3 | MTRP $P_3$ | 809 0 | 0 360 | 8 87 | 363 7 | 0 547 | 6 53 | 211 1 | 0 906 | 5 13 |
| 4 | MRP $P_1$ | 781 9 | 0 293 | 7 00 | 307 3 | 0 461 | 5 13 | 171 4 | 0 419 | 5 13 |
| 5 | MRP $P_2$ | 792 3 | 0 352 | 8 40 | 313 8 | 0 440 | 5 60 | 181 8 | 0 906 | 5 13 |
| 6 | MRP $P_3$ | 802 8 | 0 405 | 9 80 | 326 3 | 0 482 | 7 13 | 188 2 | 0 992 | 5 60 |
| 7 | SSP $P_1$ | 788 3 | 0 347 | 7 47 | 311 9 | 0 432 | 5 13 | 232 3 | 0 756 | 2 80 |
| 8 | SSP $P_2$ | 796 5 | 0 376 | 7 00 | 376 3 | 0 437 | 4 6 | 244 6 | 0 874 | 3 43 |
| 9 | SSP $P_3$ | 807 0 | 0 400 | 8 87 | 388 8 | 0 465 | 6 6 | 252 9 | 0 958 | 4 20 |
| 10 | DAP $P_1$ | 464 1 | 0 242 | 9 80 | 246 6 | 0 345 | 6 53 | 169 3 | 0 582 | 3 13 |
| 11 | DAP $P_2$ | 489 2 | 0 385 | 12 23 | 248 7 | 0 428 | 7 47 | 201 7 | 0 910 | 3 60 |
| 12 | DAP $P_3$ | 489 2 | 0 392 | 14 67 | 257 1 | 0 445 | 8 93 | 205 4 | 0 992 | 5 13 |
| 13 | C | 418 1 | 0 143 | 9 3 | 267 5 | 0 467 | 6 07 | 188 2 | 0 360 | 3 27 |
| 14 | SSP $(P_2+P_2)$ | 802 8 | 0 338 | 8 40 | 382 5 | 0 460 | 4 00 | 244 6 | 0 863 | 4 20 |
| CD(0 05) | | 13 27 | | 3 59 | 16 64 | | 3 59 | 12 95 | | 3 61 |
| Source | | | | | | | | | | |
| MTRP | | 795 8 | 0 32 | 8 07 | 353 2 | 0 45 | 5 42 | 202 7 | 0 73 | 4 04 |
| MRP | | 792 3 | 0 35 | 8 4 | 315 8 | 0 46 | 5 95 | 180 4 | 0 77 | 5 28 |
| SSP | | 797 2 | 0 37 | 7 78 | 379 1 | 0 44 | 5 40 | 243 2 | 0 87 | 3 58 |
| DAP | | 480 8 | 0 34 | 12 23 | 250 8 | 0 41 | 7 97 | 192 1 | 0 83 | 3 95 |
| CD(0 05) | | 7 66 | | 2 07 | 9 60 | | 2 07 | 7 47 | | 2 08 |
| Level | | | | | | | | | | |
| $P_1$ | | 704 05 | 0 281 | 7 81 | 317 6 | 0 421 | 5 33 | 192 3 | 0 559 | 3 58 |
| $P_2$ | | 718 62 | 0 366 | 8 99 | 322 5 | 0 435 | 5 71 | 207 1 | 0 873 | 4 04 |
| $P_3$ | | 727 0 | 0 389 | 10 55 | 333 9 | 0 484 | 7 54 | 216 9 | 0 962 | 5 01 |
| CD(0 05) | | 6 63 | | 1 79 | 8 32 | | 1 7 | 6 47 | | 1 80 |




& leaching loss of N as influenced by sources of P at critical followed by higher levels of rockphosphates and superphosphates at maximum tillering The higher leaching loss observed in treatments may be due to the more loss of $NH_4$ N immediately released from the same

At panicle initiation and harvest the leaching losses from different treat ments were on par

Nutrient release and leaching loss of N are depicted in Fig 20 When the effect of sources were compared it was observed that MTRP MRP and SSP were on par in N release at the maximum tillering stage However at panicle initiation and harvest SSP was significantly superior followed by MTRP MRP and DAP At all the stages DAP recorded the lowest available N content in the soil The leaching loss was significantly higher for DAP at tillering while at panicle initiation it was on par with MRP At harvest there was no difference between the sources for the leaching loss of N

Second crop

The availability uptake and leaching loss of N are furnished in Table 31 Available N values varied from 219 5 (c) to 903 1 kg ha $^{1}$ (SSP $P_3$) uptake from 0 237 (c) to 0 715 (SSP $P_3$) and leaching loss from 2 80 (SSP $P_1$) to 17 79 (DAP $P_3$)

As observed for the first crop there was a decrease in available N content and leaching loss with increase in crop growth In contrast to this the values for total N uptake indicated an increasing trend with advancement of crop growth On perusal of the data it is clear that both the availability and loss of N were less for the second crop as compared to the first crop

The available N content of control ranged from 219 5 to 505 9 kg ha $^{1}$ All the other treatments recorded a significantly higher content of available N as compared to control The interactions of SSP and higher level interaction of rock phosphates were on par and significantly superior to other combinations at maximum tillering and panicle initiation stages while at harvest MTRP $P_3$ was significantly superior The treatments of DAP recorded the least Second application of P did not lead to any additional increase in N content as compared to SSP $P_2$

The control treatment recorded an uptake of N as 0 237 g pot $^{1}$ at maximum tillering which increased slightly to 0 252 at panicle initiation and 0 356 g pot $^{1}$ at harvest stage In general SSP $P_3$ was superior in uptake followed by MRP $P_3$ The treatment SSP $(P_2+P_2)$ registered higher uptake of N as compared to SSP-$P_2$ at maximum tillering while at panicle initiation and harvest they were found to be recording almost same values

The leaching loss of N as 10 27 ppm was registered by the control treatment at maximum tillering which was later found to be decreased to 3 73 ppm at harvest For the loss of N there was no significant difference between the treatments and control

The illustration pertaining to N release and leaching losses are provided in Fig 21 The source SSP was superior to MTRP but par with MRP at tillering and panicle initiation stage while at harvest MTRP was superior followed by MRP SSP and DAP

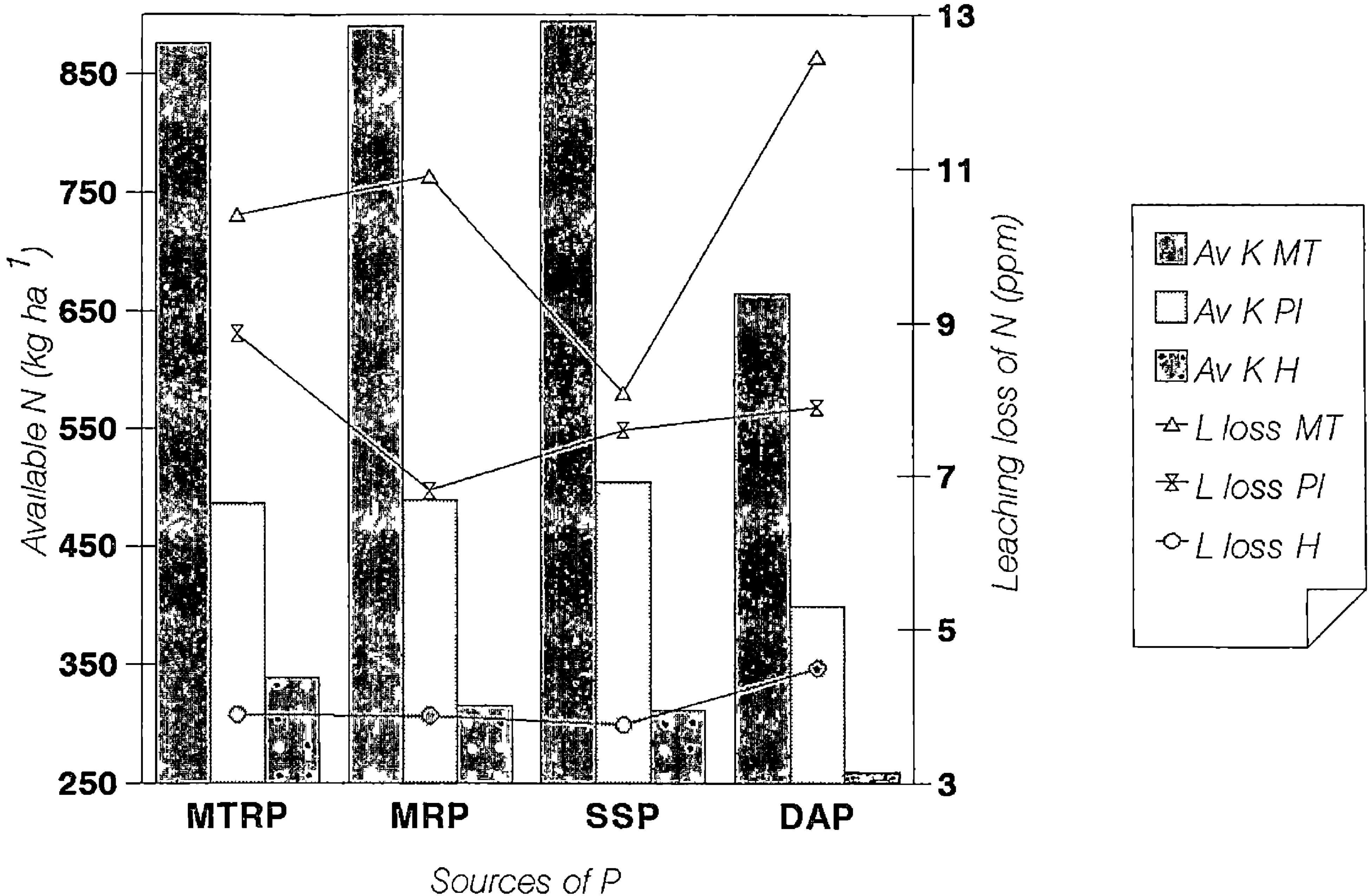



Fig 21 Nutrient release & leaching loss of N as influenced by sources of P at critical stages of second crop of rice laterite

The leaching loss was found to be at the same manner for the different sources at the different period of crop growth

4 2 2 2 Nutrient release uptake and leaching loss of P

From the data presented in Table 32 and Table 34 it was observed that available P using Bray 1 ranged from 6 15 to 24 84 kg ha $^{1}$ and for Mathew s extractant ranged from 22 40 to 50 80 kg ha $^{1}$ uptake ranged from 0 003 to 0 149 g pot $^{1}$ and leaching loss from 0 03 to 0 20 ppm at different stages of crop growth

All the treatment combinations were significantly higher than control in available P release which recorded a maximum of 11 08 kg ha $^{1}$ at maximum tiller ing For all the treatments there was decrease in available P content with crop growth It was found that SSP $P_3$ was the best releaser of available P in all the three stages followed by SSP $P_2$

The control treatment recorded uptake value of 0 002 g pot $^{1}$ at maximum tillering which gradually increased to 0 003 and 0 40 at panicle initiation and harvest stages respectively At maximum tillering stage on uptake value of 0 02 g pot $^{1}$ was recorded by higher levels of the different sources while at panicle intiation and harvest the treatment SSP $P_3$ recorded higher values of uptake as 0 040 and 0 169 g pot $^{1}$ The increased uptake of P in treatments of water soluble sources may be due to the ready availability of this nutrient from these sources

In general the leaching loss of P was considerably low as compared to that of N The high fixation of applied P resulted in low leaching The loss was found to be minimal towards harvest The leaching loss of P in the control treat ments was comparatively less This may be attributed to the lack of applied P The

Table 32 Nutrient release uptake and leaching loss of P in the first crop of rice as influenced by treatments Bray 1 (laterite)



| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm |
| 1 | MTRP $P_1$ | 15 14 | 0 09 | 0 08 | 13 35 | 0 015 | 0 05 | 11 58 | 0 102 | 0 04 |
| 2 | MTRP $P_2$ | 16 91 | 0 14 | 0 14 | 15 34 | 0 028 | 0 09 | 13 35 | 0 112 | 0 08 |
| 3 | MTRP $P_3$ | 18 30 | 0 19 | 0 20 | 16 32 | 0 030 | 0 10 | 14 53 | 0 136 | 0 09 |
| 4 | MRP $P_1$ | 15 28 | 0 08 | 0 11 | 13 78 | 0 019 | 0 09 | 11 60 | 0 084 | 0 06 |
| 5 | MRP $P_2$ | 16 96 | 0 15 | 0 11 | 15 58 | 0 022 | 0 11 | 12 78 | 0 109 | 0 08 |
| 6 | MRP $P_3$ | 17 53 | 0 18 | 0 13 | 16 85 | 0 029 | 0 12 | 14 96 | 0 128 | 0 09 |
| 7 | SSP $P_1$ | 19 89 | 0 10 | 0 11 | 17 51 | 0 024 | 0 05 | 14 62 | 0 130 | 0 04 |
| 8 | SSP $P_2$ | 22 84 | 0 18 | 0 15 | 19 89 | 0 034 | 0 09 | 16 70 | 0 147 | 0 08 |
| 9 | SSP $P_3$ | 24 84 | 0 20 | 0 20 | 21 97 | 0 040 | 0 12 | 19 36 | 0 169 | 0 09 |
| 10 | DAP $P_1$ | 18 14 | 0 12 | 0 20 | 14 16 | 0 024 | 0 09 | 9 40 | 0 135 | 0 07 |
| 11 | DAP $P_2$ | 19 91 | 0 17 | 0 19 | 16 53 | 0 020 | 0 06 | 12 16 | 0 143 | 0 04 |
| 12 | DAP $P_3$ | 22 39 | 0 2 | 0 20 | 18 71 | 0 037 | 0 12 | 13 75 | 0 150 | 0 10 |
| 13 | C | 11 08 | 0 002 | 0 06 | 9 98 | 0 003 | 0 04 | 6 15 | 0 042 | 0 03 |
| 14 | SSP ($P_2$+$P_3$) | 22 39 | 0 018 | 0 11 | 19 91 | 0 029 | 0 07 | 16 53 | 0 126 | 0 05 |
| CD(0 05) | | 0 85 | | 5 09 | 0 86 | | 0 04 | 0 65 | | 2 61 |
| Source | | | | | | | | | | |
| MTRP | | 16 7 | 0 02 | 0 14 | 15 0 | 0 14 | 0 08 | 13 15 | 0 12 | 0 07 |
| MRP | | 16 6 | 0 02 | 0 12 | 15 4 | 0 13 | 0 11 | 13 11 | 0 12 | 0 08 |
| SSP | | 22 5 | 0 03 | 0 15 | 19 8 | 0 16 | 0 09 | 16 89 | 0 15 | 0 07 |
| DAP | | 20 1 | 0 03 | 0 19 | 16 5 | 0 16 | 0 09 | 11 77 | 0 14 | 0 07 |
| CD(0 05) | | 0 48 | | 0 02 | 0 49 | | 0 02 | 0 39 | | 0 01 |
| Level | | | | | | | | | | |
| $P_1$ | | 17 11 | 0 09 | 0 13 | 14 7 | 0 02 | 0 07 | 11 8 | 0 11 | 0 05 |
| $P_2$ | | 19 75 | 0 16 | 0 16 | 16 84 | 0 03 | 0 09 | 13 74 | 0 13 | 0 07 |
| $P_3$ | | 20 76 | 0 19 | 0 18 | 18 46 | 0 03 | 0 12 | 15 65 | 0 15 | 0 09 |
| CD(0 05) | | 0 42 | | 0 02 | 0 43 | | 0 02 | 0 33 | | 0 01 |

Table 34 Nutrient release uptake and leaching loss of P in the first crop of rice as influenced by treatments Mathew s extractant (laterite)



| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm | Available Kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm |
| 1 | HTRP $P_1$ | 40 04 | 0 09 | 0 08 | 38 20 | 0 015 | 0 05 | 36 10 | 0 102 | 0 04 |
| 2 | HTRP $P_2$ | 42 90 | 0 14 | 0 14 | 40 10 | 0 028 | 0 09 | 38 90 | 0 112 | 0 08 |
| 3 | HTRP $P_3$ | 44 60 | 0 19 | 0 20 | 42 80 | 0 030 | 0 10 | 40 60 | 0 136 | 0 09 |
| 4 | MRP $P_1$ | 39 60 | 0 08 | 0 11 | 38 20 | 0 019 | 0 09 | 36 20 | 0 084 | 0 06 |
| 5 | MRP $P_2$ | 41 90 | 0 15 | 0 11 | 39 20 | 0 022 | 0 11 | 37 90 | 0 109 | 0 08 |
| 6 | MRP $P_3$ | 45 50 | 0 18 | 0 13 | 42 30 | 0 029 | 0 12 | 40 90 | 0 128 | 0 09 |
| 7 | SSP $P_1$ | 45 90 | 0 10 | 0 11 | 42 30 | 0 024 | 0 05 | 38 60 | 0 130 | 0 04 |
| 8 | SSP $P_2$ | 49 20 | 0 18 | 0 15 | 46 50 | 0 034 | 0 09 | 42 10 | 0 147 | 0 08 |
| 9 | SSP $P_3$ | 50 80 | 0 20 | 0 20 | 48 90 | 0 040 | 0 12 | 43 50 | 0 169 | 0 09 |
| 10 | DAP $P_1$ | 43 60 | 0 12 | 0 20 | 40 10 | 0 024 | 0 09 | 36 50 | 0 135 | 0 07 |
| 11 | DAP $P_2$ | 45 60 | 0 17 | 0 19 | 41 30 | 0 029 | 0 06 | 39 80 | 0 143 | 0 04 |
| 12 | DAP -$P_3$ | 49 60 | 0 20 | 0 20 | 43 40 | 0 037 | 0 12 | 41 20 | 0 150 | 0 10 |
| 13 | C | 29 50 | 0 002 | 0 06 | 25 60 | 0 003 | 0 04 | 22 40 | 0 042 | 0 03 |
| 14 | SSP ($P_2$+$P_2$) | 49 60 | 0 18 | 0 11 | 45 90 | 0 029 | 0 07 | 42 90 | 0 126 | 0 05 |
| CD (0 05) | | 1 12 | | 5 09 | 0 98 | | 0 04 | 1 01 | | 2 61 |
| Source | | | | | | | | | | |
| HTRP | | 42 51 | 0 02 | 0 14 | 40 36 | 0 14 | 0 08 | 38 53 | 0 12 | 0 07 |
| MRP | | 42 33 | 0 02 | 0 12 | 39 90 | 0 13 | 0 11 | 38 33 | 0 12 | 0 08 |
| SSP | | 48 63 | 0 03 | 0 15 | 45 90 | 0 16 | 0 09 | 41 40 | 0 15 | 0 07 |
| DAP | | 46 26 | 0 03 | 0 19 | 41 60 | 0 16 | 0 09 | 39 16 | 0 14 | 0 07 |
| CD (0 05) | | 1 30 | | 0 02 | 1 40 | | 0 02 | 0 98 | | 0 01 |
| Level | | | | | | | | | | |
| $P_1$ | | 42 28 | 0 09 | 0 13 | 39 70 | 0 02 | 0 07 | 36 85 | 0 11 | 0 05 |
| $P_2$ | | 44 9 | 0 16 | 0 16 | 41 77 | 0 03 | 0 09 | 39 67 | 0 13 | 0 07 |
| $P_3$ | | 47 62 | 0 19 | 0 18 | 44 35 | 0 03 | 0 12 | 41 55 | 0 15 | 0 09 |
| CD (0 05) | | 1 05 | | 0 02 | 1 15 | | 0 02 | 0 90 | | 0 01 |

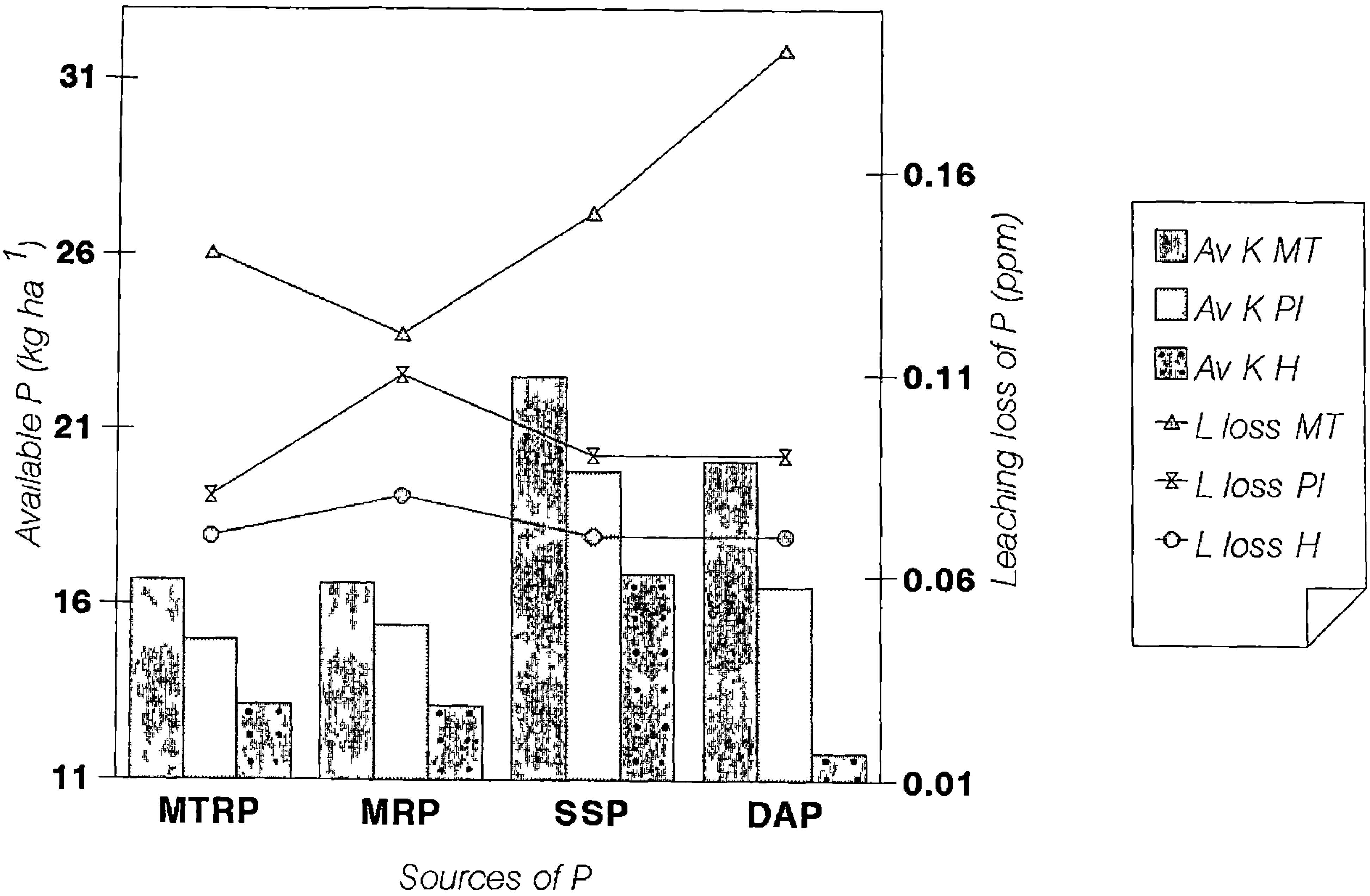



Fig 22 Nutrient release & leaching loss of P as influenced by sources of P at critical stages of first crop of rice laterite

highest leaching loss was observed in SSP $P_3$ and DAP $P_3$ treatments which recorded 0 2 0 12 and 0 09 ppm at maximum tillering panicle initiation and harvest stages However there was no significant difference between the various treatment combinations in leaching loss of P

The nutrient release and leaching loss of P in the first crop are presented in Fig 22 From this it is clear that SSP was superior in available P release and leaching loss closely followed by DAP In all the cases the two rockphosphates followed a similar trend These results are in line with that obtained in section 4 1 2 3 The quantity of P extracted by Mathew s triacid extractant was relatively higher It was found that Mathew s triacid extracted P correlated with P uptake only at harvest stage (r = 0 700*) as provided in Appendix III while Bray 1 correlated at panicle initiation (r – 0 500*) and harvest stages (r = 0 700*)

Second crop

The data pertaining to the release uptake and leaching loss are furnished in Table 33 and Table 35 The available P content ranged from 4 80 to 16 70 kg ha $^{1}$ using Bray 1 and 13 20 to 39 90 kg ha $^{1}$ for Mathew s extractant while uptake varied from 0 011 to 0 149 g pot $^{1}$ and leaching loss from 0 02 to 0 09 ppm

The availability of P was lower in the second crop Since P was not applied in the second season and was continuously taken up by the crop this decrease occurred It is interesting to note that though availability of P was higher from water soluble sources in the first crop and in the initial stages of second crop and towards the harvest stage there was higher content in rockphosphate especially MTRP From

Table 33 Nutrient release uptake and leaching loss of P in the second crop of rice as influenced by treatments Bray 1 (laterite)

| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha $^{1}$ | Uptake g pot $^{1}$ | Leaching loss ppm | Available kg ha $^{1}$ | Uptake g pot $^{1}$ | Leaching loss ppm | Available kg ha $^{1}$ | Uptake g pot $^{1}$ | Leaching loss ppm |
| 1 | MTRP $P_1$ | 10 39 | 0 035 | 0 04 | 9 20 | 0 050 | 0 04 | 8 40 | 0 130 | 0 03 |
| 2 | MTRP $P_2$ | 12 16 | 0 038 | 0 04 | 11 58 | 0 061 | 0 03 | 10 10 | 0 142 | 0 03 |
| 2 | MTRP $P_3$ | 13 35 | 0 044 | 0 04 | 12 16 | 0 077 | 0 03 | 11 17 | 0 146 | 0 03 |
| 4 | MRP $P_1$ | 10 41 | 0 038 | 0 04 | 9 22 | 0 053 | 0 03 | 7 53 | 0 129 | 0 03 |
| 5 | MRP $P_2$ | 12 40 | 0 039 | 0 03 | 10 32 | 0 065 | 0 04 | 8 72 | 0 136 | 0 03 |
| 6 | MRP $P_3$ | 13 39 | 0 049 | 0 04 | 12 80 | 0 070 | 0 04 | 10 39 | 0 149 | 0 03 |
| 7 | SSP $P_1$ | 12 53 | 0 044 | 0 04 | 9 58 | 0 054 | 0 04 | 6 12 | 0 130 | 0 03 |
| 8 | SSP $P_2$ | 14 32 | 0 489 | 0 04 | 11 58 | 0 066 | 0 04 | 7 53 | 0 141 | 0 03 |
| 9 | SSP $P_3$ | 16 70 | 0 056 | 0 05 | 12 16 | 0 070 | 0 03 | 9 90 | 0 149 | 0 02 |
| 10 | DAP $P_1$ | 9 40 | 0 018 | 0 03 | 6 12 | 0 040 | 0 03 | 5 35 | 0 088 | 0 03 |
| 11 | DAP $P_2$ | 10 32 | 0 021 | 0 05 | 7 58 | 0 048 | 0 03 | 7 02 | 0 110 | 0 02 |
| 12 | DAP -$P_3$ | 12 80 | 0 023 | 0 04 | 10 10 | 0 053 | 0 02 | 8 10 | 0 179 | 0 02 |
| 13 | C | 6 15 | 0 011 | 0 02 | 5 50 | 0 039 | 0 03 | 4 80 | 0 083 | 0 03 |
| 14 | SSP ($P_2$+$P_2$) | 14 49 | 0 054 | 0 09 | 10 48 | 0 064 | 0 05 | 6 13 | 0 140 | 0 04 |
| CD(0 05) | | 0 65 | | 2 20 | 1 11 | | 3 31 | 0 72 | - | 2 30 |
| Source | | | | | | | | | | |
| MTRP | | 11 96 | 0 04 | 0 06 | 10 98 | 0 06 | 0 03 | 9 89 | 0 14 | 0 03 |
| MRP | | 12 06 | 0 04 | 0 04 | 10 78 | 0 06 | 0 04 | 8 88 | 0 14 | 0 03 |
| SSP | | 14 5 | 0 05 | 0 04 | 11 11 | 0 06 | 0 04 | 7 87 | 0 14 | 0 03 |
| DAP | | 10 8 | 0 02 | 0 04 | 7 93 | 0 05 | 0 03 | 6 8 | 0 10 | 0 02 |
| CD(0 05) | | 0 37 | | 0 01 | 0 64 | | 0 01 | 0 60 | | 0 01 |
| Level | | | | | | | | | | |
| $P_1$ | | 10 68 | 0 03 | 0 04 | 8 53 | 0 05 | 0 04 | 6 85 | 0 12 | 0 03 |
| $P_2$ | | 12 3 | 0 04 | 0 04 | 10 26 | 0 06 | 0 04 | 8 35 | 0 132 | 0 03 |
| $P_3$ | | 14 06 | 0 04 | 0 05 | 11 80 | 0 07 | 0 03 | 9 89 | 0 141 | 0 03 |
| CD(0 050 | | 0 32 | | 0 01 | 0 55 | | 0 01 | 0 53 | | 0 01 |

Table 35 Nutrient release uptake and leaching loss of P in the second crop of rice as influenced by treatments Mathew s extractant (laterite)

| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha 1 | Uptake g pot$^{-1}$ | Leaching loss ppm | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm | Available kg ha 1 | Uptake g pot 1 | Leaching loss ppm |
| 1 | MTRP $P_1$ | 35 10 | 0 035 | 0 04 | 32 80 | 0 064 | 0 04 | 30 26 | 0 130 | 0 03 |
| 2 | MTRP $P_2$ | 36 20 | 0 038 | 0 04 | 34 10 | 0 061 | 0 03 | 31 80 | 0 142 | 0 03 |
| 3 | MTRP $P_3$ | 38 80 | 0 044 | 0 04 | 35 90 | 0 047 | 0 03 | 33 20 | 0 146 | 0 03 |
| 4 | MRP -$P_1$ | 34 90 | 0 038 | 0 04 | 31 90 | 0 063 | 0 03 | 28 30 | 0 129 | 0 03 |
| 5 | MRP $P_2$ | 35 80 | 0 039 | 0 03 | 33 20 | 0 039 | 0 04 | 29 90 | 0 136 | 0 03 |
| 6 | MRP $P_3$ | 38 60 | 0 049 | 0 04 | 34 90 | 0 060 | 0 05 | 30 50 | 0 149 | 0 03 |
| 7 | SSP $P_1$ | 35 90 | 0 044 | 0 04 | 32 80 | 0 044 | 0 04 | 26 90 | 0 130 | 0 03 |
| 8 | SSP $P_2$ | 38 70 | 0 049 | 0 04 | 34 60 | 0 046 | 0 04 | 27 20 | 0 141 | 0 03 |
| 9 | SSP $P_3$ | 39 90 | 0 056 | 0 05 | 35 20 | 0 051 | 0 03 | 28 30 | 0 149 | 0 02 |
| 10 | DAP $P_1$ | 32 90 | 0 018 | 0 03 | 29 60 | 0 053 | 0 03 | 23 20 | 0 08 | 0 03 |
| 11 | DAP $P_2$ | 33 20 | 0 021 | 0 05 | 30 20 | 0 048 | 0 03 | 25 60 | 0 10 | 0 02 |
| 12 | DAP $P_2$ | 34 60 | 0 023 | 0 04 | 31 40 | 0 063 | 0 02 | 26 90 | 0 143 | 0 02 |
| 13 | C | 19 70 | 0 011 | 0 02 | 17 60 | 0 039 | 0 03 | 13 20 | 0 083 | 0 03 |
| 14 | SSP ($P_2$+$P_2$) | 38 60 | 0 054 | 0 09 | 35 40 | 0 054 | 0 05 | 30 26 | 0 140 | 0 04 |
| CD (0 05) | | 0 83 | | 2 20 | 1 20 | - | 3 31 | 1 6 | | 2 30 |
| Source | | | | | | | | | | |
| MTRP | | 36 70 | 0 04 | 0 06 | 34 26 | 0 06 | 0 03 | 31 75 | 0 14 | 0 03 |
| MRP | | 36 43 | 0 04 | 0 04 | 33 33 | 0 06 | 0 04 | 29 56 | 0 14 | 0 03 |
| SSP | | 38 16 | 0 05 | 0 04 | 34 20 | 0 06 | 0 04 | 27 36 | 0 14 | 0 03 |
| DAP | | 33 56 | 0 02 | 0 04 | 30 40 | 0 05 | 0 03 | 25 23 | 0 10 | 0 02 |
| CD (0 05) | 0 90 | | 0 01 | 0 85 | | 0 01 | 1 13 | | 0 01 | |
| Level | | | | | | | | | | |
| $P_1$ | | 34 70 | 0 03 | 0 04 | 31 77 | 0 05 | 0 04 | 27 16 | 0 12 | 0 03 |
| $P_2$ | | 35 97 | 0 04 | 0 04 | 33 02 | 0 06 | 0 04 | 28 62 | 0 13 | 0 03 |
| $P_3$ | | 37 97 | 0 04 | 0 05 | 34 35 | 0 07 | 0 03 | 29 72 | 0 14 | 0 03 |
| CD(0 05) | | 0 78 | | 0 01 | 1 12 | | 0 01 | 1 05 | | 0 01 |

this it is clear that considerable amount of P was left in the rockphosphate applied treatments even after growing rice for two seasons and hence it is likely that their residual effect could be obtained subsequent crops also These findings are in line with those of Mathews (1985) As in the case of previous crop the uptake of P increased with crop growth The leaching loss of P reached almost a steady state in second crop

All the treatments were significantly higher than control in P release The control treatment registered a maximum value of 6 15 kg ha $^{1}$ at tillering stage which reduced to 5 50 kg ha $^{1}$ at panicle initiation and 2 80 kg ha $^{1}$ at harvest stage This drastic decrease may be due to the high fixation process occurring in the soil Among the treatment combinations SSP $P_3$ was significantly superior at maximum tillering while at panicle initiation the higher levels of SSP MRP and MTRP were on par At harvest MTRP $P_3$ was superior closely followed by MRP $P_3$ The drastic reduction of SSP and DAP treatment in N release may be due to the high fixation of P from these sources Whereas in the case of rockphosphates there was a slow and steady dissolution with time of submergence In the case of SSP $(P_2+P_2)$ there was significant increase in available P as compared to SSP $P_2$ while at panicle initiation it was found to be on par with SSP $P_2$ and MTRP $P_2$ At harvest the treatment SSP $(P_2+P_2)$ was on par with MRP $P_1$ It can be inferred that continuous P application as in SSP $(P_2+P_2)$ did not release much residual P in the soil In fact the left over P after the first crop from rockphosphates were found to be superior The results tend to conclude the economic use of rockphosphates for the continuous rice cropping system

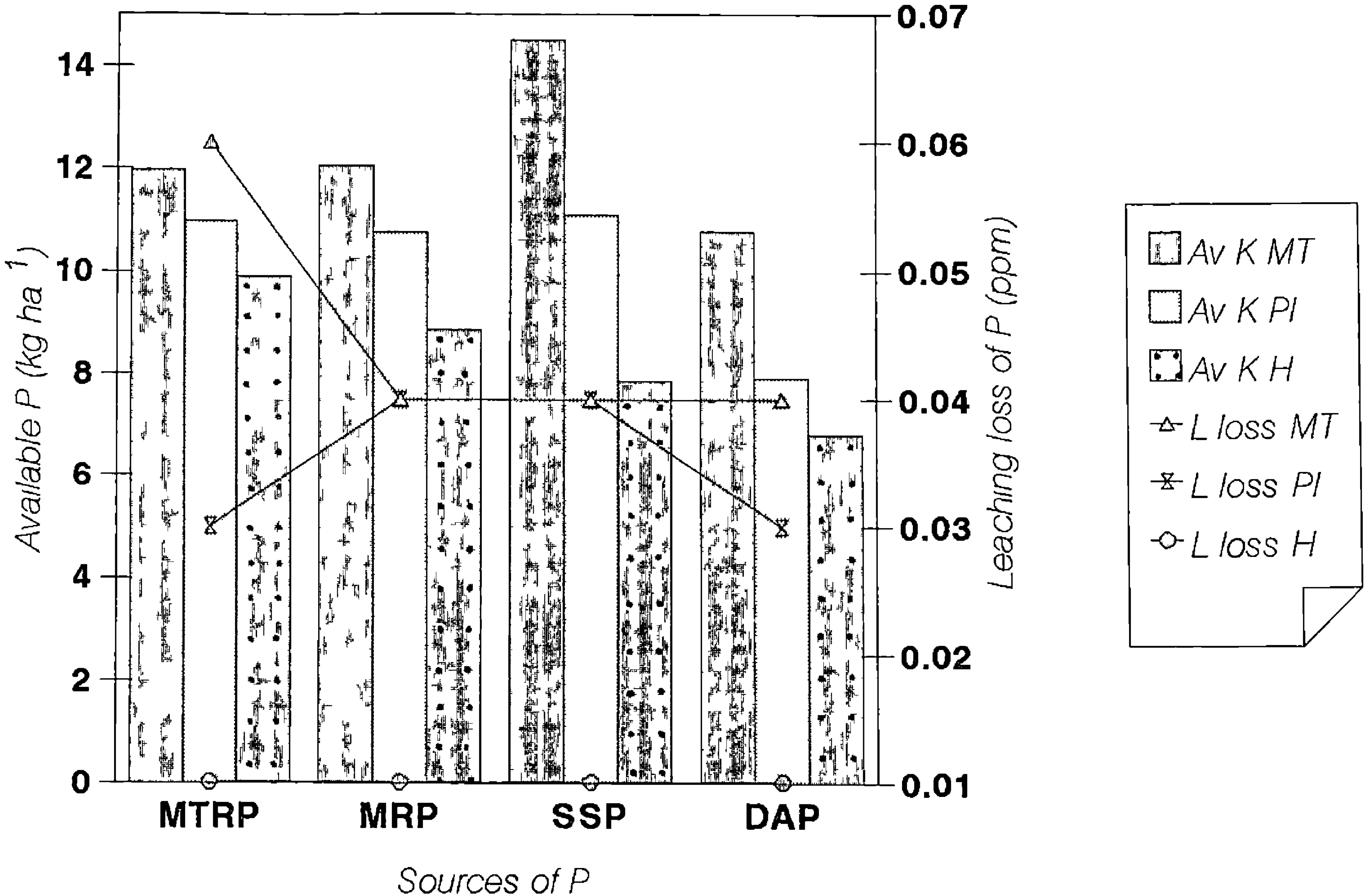



Fig 23 Nutrient release & leaching loss of P as influenced by sources of P at critical stages of second crop of rice laterite

The control treatment recorded the lowest P uptake which ranged from 0 011 at tillering stage to 0 083 at harvest The high availability of P from SSP $P_3$ at tillering stage lead to its higher uptake of 0 056 g pot $^{1}$ while at panicle initiation the highest levels of MTRP MRP and SSP recorded 0 07 g pot $^{1}$ as uptake At harvest also these treatments were superior in uptake and they registered 0 149 g pot $^{1}$ as P uptake

There was no significant difference between treatments and with control in leaching loss of P at all the critical stages of crop growth The loss was at a steady rate ranging from 0 03 to 0 04 ppm of P

The illustration regarding nutrient release and leaching loss of P in second crop are provided in Fig 23 when the effect of sources was pooled together it was evident that SSP was superior in available P at tillering stage followed by MRP and MTRP which were on par At panicle initiation SSP MTRP and MRP were on par and at harvest MTRP was superior followed by MRP SSP DAP In all the stages DAP recorded the lowest available P The uptake of N was comparatively poor by the source of DAP All the sources registered the same content of leaching loss Both the extractants failed to register positive correlation with crop uptake of P by the second crop

With increase in levels of P there was significant increase in P release There was also increased uptake with increase in levels of P

4 2 2 3 Nutrient release uptake and leaching loss of K

First crop

The data are presented in Table 36 Available K ranged from 90 6 to

Table 36 Nutrient release uptake and leaching loss of K in the first crop of rice as influenced by treatments (laterite)

| Treatment | | Maximum tillering | | | Panicle initiation | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Leaching loss ppm |
| 1 | MTRP $P_1$ | 149 3 | 0 139 | 6 0 | 123 3 | 0 205 | 4 70 | 112 0 | 0 298 | 2 60 |
| 2 | MTRP $P_2$ | 224 0 | 0 169 | 10 33 | 168 0 | 0 253 | 5 73 | 121 3 | 0 326 | 2 93 |
| 3 | MTRP $P_3$ | 280 0 | 0 227 | 11 00 | 177 3 | 0 269 | 6 50 | 158 6 | 0 419 | 3 87 |
| 4 | MRP $P_1$ | 224 0 | 0 149 | 7 0 | 177 3 | 0 235 | 5 20 | 149 3 | 0 354 | 3 53 |
| 5 | MRP $P_2$ | 272 5 | 0 194 | 10 0 | 252 0 | 0 269 | 6 10 | 233 3 | 0 469 | 3 56 |
| 6 | MRP $P_3$ | 298 3 | 0 229 | 14 0 | 280 0 | 0 275 | 8 10 | 252 0 | 0 489 | 3 27 |
| 7 | SSP $P_1$ | 121 3 | 0 134 | 10 10 | 112 0 | 0 154 | 2 90 | 93 3 | 0 278 | 3 27 |
| 8 | SSP $P_2$ | 194 0 | 0 156 | 9 20 | 177 3 | 0 172 | 2 77 | 121 3 | 0 388 | 2 70 |
| 9 | SSP $P_3$ | 224 0 | 0 219 | 9 20 | 196 0 | 0 205 | 3 90 | 186 6 | 0 409 | 3 97 |
| 10 | DAP $P_1$ | 112 0 | 0 130 | 7 83 | 102 6 | 0 183 | 4 17 | 93 3 | 0 257 | 3 93 |
| 11 | DAP $P_2$ | 130 6 | 0 139 | 7 87 | 112 0 | 0 213 | 3 23 | 102 6 | 0 354 | 2 60 |
| 12 | DAP $P_3$ | 177 3 | 0 196 | 7 40 | 121 3 | 0 213 | 3 8 | 107 9 | 0 388 | 3 87 |
| 13 | C | 102 6 | 0 127 | 7 17 | 98 5 | 0 156 | 5 1 | 90 6 | 0 194 | 2 93 |
| 14 | SSP ($P_2$+$P_2$) | 220 0 | 0 150 | 7 27 | 168 0 | 0 169 | 3 90 | 119 5 | 0 380 | 2 90 |
| CD (0 05) | | 49 32 | | 3 12 | 37 6 | | 1 4 | 40 26 | | 3 12 |
| Source | | | | | | | | | | |
| MTRP | | 217 7 | 0 17 | 9 11 | 156 2 | 0 24 | 5 64 | 130 6 | 0 35 | 3 13 |
| MRP | | 264 9 | 0 19 | 10 33 | 236 4 | 0 26 | 6 50 | 211 5 | 0 44 | 3 45 |
| SSP | | 180 4 | 0 17 | 9 5 | 161 7 | 0 18 | 3 25 | 133 7 | 0 39 | 3 31 |
| DAP | | 139 9 | 0 15 | 7 7 | 111 9 | 0 20 | 3 73 | 101 2 | 0 33 | 3 50 |
| CD (0 05) | | 28 47 | | 1 80 | 21 74 | | 0 83 | 23 24 | | 0 97 |
| Level | | | | | | | | | | |
| $P_1$ | | 151 60 | 0 14 | 7 73 | 128 8 | 0 194 | 4 24 | 111 9 | 0 290 | 3 23 |
| $P_2$ | | 205 70 | 0 16 | 9 35 | 177 3 | 0 226 | 4 45 | 144 6 | 0 384 | 2 94 |
| $P_3$ | | 244 90 | 0 22 | 10 40 | 193 6 | 0 255 | 5 57 | 129 5 | 0 426 | 3 82 |
| CD (0 05) | | 24 66 | | 1 56 | 18 83 | | 0 72 | 20 13 | | 1 12 |

298 3 kg ha $^{1}$ and uptake varied from 0 127 to 0 489 g pot $^{1}$ Leaching loss of K ranged from 2 60 to 14 0 ppm

The control treatment of registered 102 6 kg/ha of available K at maximum tillering which reduced to 98 5 at panicle initiation and 90 6 kg ha $^{1}$ at harvest stages of crop As in the case of control there was decrease in available K content towards harvest The treatment MRP $P_3$ recorded higher content of available K m all the stages followed by MRP $P_2$ and MTRP $P_3$ But was not statistically significant The increase availability of K due to different sources of P can be accounted to mcreased dissolution of Ca along with P Monovalent $K^+$ consequently get replaced from the clay lattuce by the mass action of more divalent $Ca^{2+}$ (Tisdale 1975)

The control treatment recorded an uptake value of 0 127 g pot $^{1}$ at tiller ing stage which increased to 0 194 g pot $^{1}$ at harvest stage The uptake of K was very low by the control treatment which may be due to the absence of P These findings are in line with those of Venkatramaiah (1979) Higher uptake of K was observed in SSP $P_3$ (0 227 g pot $^{1}$) followed by DAP $P_3$ (0 217 g pot $^{1}$) although its availability was low as compared to rockphosphates This may be attributed to the enhanced effect of available P from water soluble sources on K uptake

Leachmg loss of K decreased with crop growth There was no significant difference in leaching loss of K among the various treatments and with control in all the stages of crop growth Clay minerals of the kaolinite type do not absorb $K^+$ selectively High rates of K loss by leachmg therefore has been observed in kaolinitic soils (Mengel and Kirky 1978)

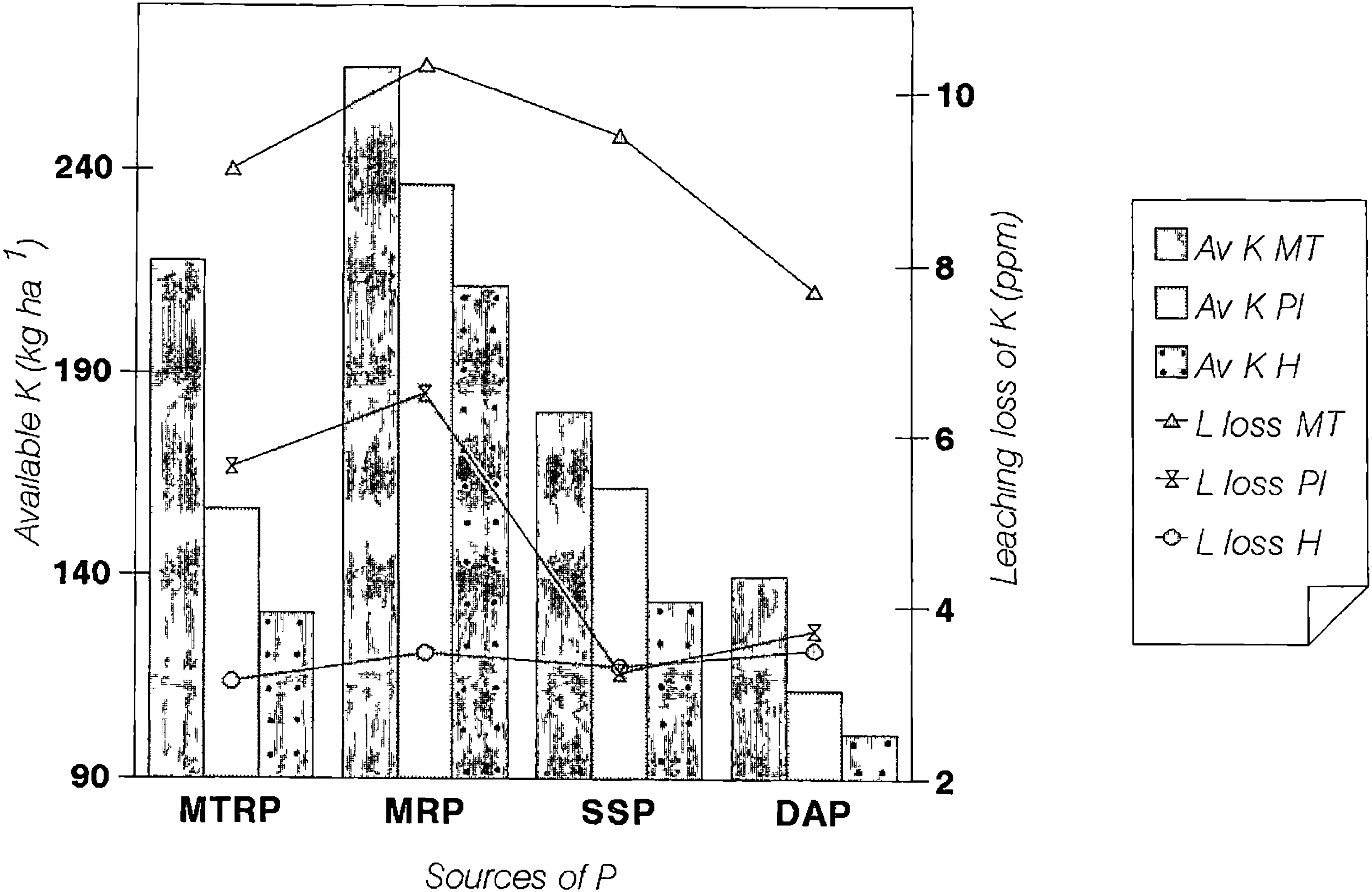



Fig 24 Nutrient release & leaching loss of K as influenced by sources of P at critical stages of first crop of rice laterite

The nutrient release and leaching loss of K are illustrated in Fig 24 In the case of available K it was more or less uniform in all the sources The uptake values were higher for water soluble sources in all the stages of crop growth Although there was slight increase in K with increase in levels of P the increase was not statistically significant

Second crop

The data are presented in Table 37 Available K ranged from 15 7 to 134 9 kg ha $^{1}$ while uptake varied from 0 262 to 0 759 g pot $^{1}$ Leaching loss ranged from 1 27 to 7 10 ppm

The control treatment registered the lowest content of available K which ranged from 70 4 at maximum tillering to 20 9 kg ha $^{1}$ at harvest stage The treatments MTRP $P_3$ MRP $P_3$ and SSP $P_3$ were superior which registered 188 10 193 30 and 194 10 respectively but were on par The same trend was seen at panicle initiation and harvest The second application of P resulted in significantly higher availability of K at maximum tillering but at panicle initiation and harvest it was on par with SSP $P_2$

Uptake of K increased with crop growth The control treatment recorded an uptake value of 0 262 at tillering which increased to 0 297 at panicle initiation and 0 312 ppm at harvest stage Among the treatments SSP $P_3$ was superior in K uptake closely followed by MRP $P_3$ and MTRP $P_3$ All the treatment combinations of DAP registered lower uptake The uptake value of SSP ($P_2$+$P_2$) was same as that of SSP $P_3$ at maximum tillering

Table 37 Nutrient release uptake and leaching loss of K in the second crop of rice as influenced by treatments (laterite)

| Treatment No | Notation | Maximum tillering Available kg ha⁻¹ | Maximum tillering Uptake g pot⁻¹ | Maximum tillering Leaching loss ppm | Panicle initiation Available kg ha⁻¹ | Panicle initiation Uptake g pot⁻¹ | Panicle initiation Leaching loss ppm | Harvest Available kg ha⁻¹ | Harvest Uptake g pot⁻¹ | Harvest Leaching loss pm |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MTRP $P_1$ | 88 2 | 0 286 | 6 77 | 67 2 | 0 691 | 3 27 | 21 6 | 0 361 | 1 80 |
| 2 | MTRP $P_2$ | 103 6 | 0 351 | 6 90 | 73 9 | 0 759 | 3 30 | 22 4 | 0 383 | 2 77 |
| 3 | MTRP $P_3$ | 112 0 | 0 344 | 6 23 | 70 2 | 0 390 | 3 23 | 26 8 | 0 413 | 2 33 |
| 4 | MRP $P_1$ | 93 12 | 0 327 | 6 03 | 89 6 | 0 478 | 3 37 | 20 2 | 0 368 | 1 30 |
| 5 | MRP $P_2$ | 126 5 | 0 356 | 4 67 | 96 3 | 0 531 | 3 03 | 26 8 | 0 392 | 1 27 |
| 6 | MRP $P_3$ | 134 9 | 0 392 | 6 73 | 100 8 | 0 478 | 3 03 | 29 1 | 0 363 | 1 60 |
| 7 | SSP $P_1$ | 81 7 | 0 374 | 7 00 | 62 7 | 0 541 | 3 60 | 17 9 | 0 336 | 1 77 |
| 8 | SSP $P_2$ | 109 5 | 0 380 | 7 10 | 67 9 | 0 513 | 3 03 | 20 1 | 0 343 | 1 97 |
| 9 | SSP $P_3$ | 122 3 | 0 413 | 7 07 | 71 7 | 0 557 | 2 87 | 25 3 | 0 354 | 2 57 |
| 10 | DAP $P_1$ | 74 3 | 0 364 | 6 23 | 56 0 | 0 361 | 2 80 | 15 7 | 0 437 | 1 89 |
| 11 | DAP $P_2$ | 81 4 | 0 385 | 7 00 | 60 5 | 0 341 | 4 27 | 19 4 | 0 478 | 1 60 |
| 12 | DAP $P_3$ | 93 12 | 0 369 | 7 00 | 62 7 | 0 218 | 4 23 | 24 6 | 0 499 | 1 80 |
| 13 | C | 70 4 | 0 262 | 7 00 | 51 5 | 0 420 | 3 9 | 20 9 | 0 312 | 1 70 |
| 14 | SSP $(P_2+P_2)$ | 126 5 | 0 357 | 7 10 | 64 9 | 0 513 | 4 03 | 22 4 | 0 384 | 1 24 |
| CD (0 05) | | 4 76 | | 1 94 | 8 07 | | 1 47 | 4 0 | | 1 40 |
| Source | | | | | | | | | | |
| MTRP | | 101 2 | 0 33 | 6 6 | 70 4 | 0 61 | 3 26 | 23 6 | 0 39 | 2 3 |
| MRP | | 118 2 | 0 35 | 5 8 | 95 5 | 0 49 | 3 14 | 25 4 | 0 37 | 1 4 |
| SSP | | 104 5 | 0 39 | 7 0 | 67 4 | 0 54 | 3 16 | 21 1 | 0 34 | 2 10 |
| DAP | | 82 9 | 0 37 | 6 7 | 59 7 | 0 31 | 3 76 | 19 9 | 0 47 | 1 76 |
| CD (0 05) | | 4 66 | | 1 12 | 2 75 | | 0 85 | 2 33 | | 0 81 |
| Level | | | | | | | | | | |
| $P_1$ | | 84 30 | 0 34 | 6 51 | 68 87 | 0 52 | 3 26 | 18 85 | 0 38 | 1 69 |
| $P_2$ | | 105 25 | 0 37 | 6 42 | 74 65 | 0 54 | 3 36 | 22 17 | 0 39 | 1 90 |
| $P_3$ | | 115 58 | 0 38 | 6 76 | 76 35 | 0 41 | 3 39 | 26 45 | 0 41 | 2 07 |
| CD (0 05) | | 4 03 | | 0 97 | 2 38 | | 0 74 | 2 02 | | 0 70 |

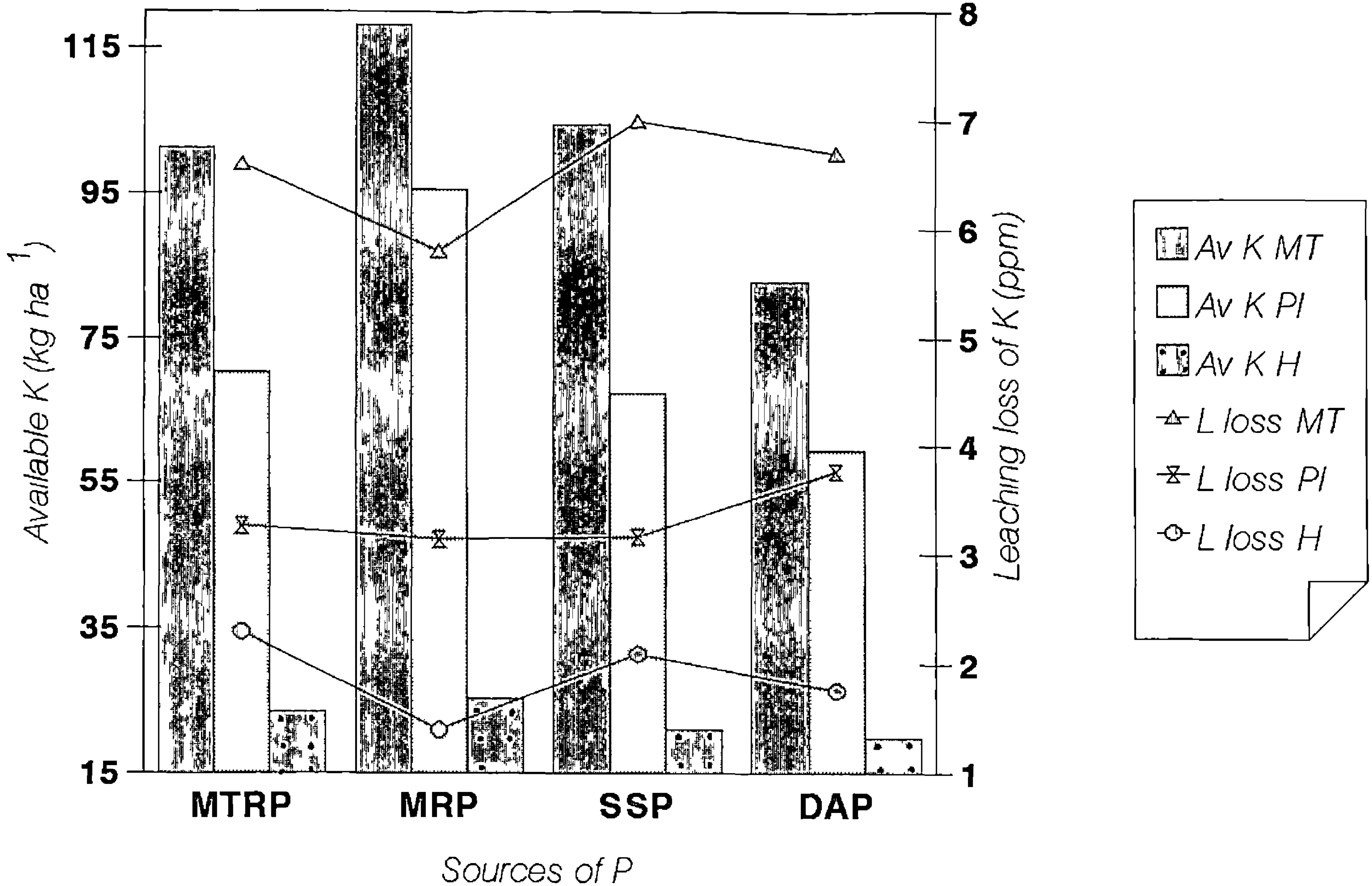



Fig 25 Nutrient release & leaching loss of K as influenced by sources of P at critical stages of second crop of rice laterite

Leaching loss of control treatment ranged from 7 0 at maximum tillering to 1 27 ppm at harvest stage There was no significant difference among the various treatments in leaching loss of K

The nutrient release and leaching of K are illustrated in Fig 25 Among the sources MRP MTRP and SSP were superior in available K content and DAP recorded the lowest in all the stages The leaching loss of K was lower for MRP at different stages of crop growth

4 2 2 4 Nutrient release and uptake of Ca at different stages of crop growth

First crop

The data are provided in Table 38 Available Ca ranged from 238 7 kg ha $^{-1}$ to 969 9 kg ha $^{-1}$ and uptake varied from 0 026 to 0 150 g pot $^{-1}$

The control treatment registered the lowest content of available Ca It recorded 612 8 kg ha $^{-1}$ at maximum tillering which decreased to 238 7 kg ha $^{-1}$ at harvest Among the treatments MRP $P_3$ was significantly superior to others and recorded 969 9 kg ha $^{-1}$ followed by MRP $P_2$ (876 6 kg ha $^{-1}$) at maximum tillering stage In the other two stages also this trend was observed In general MTRP and MRP were on par followed by SSP The lowest content of available Ca was recorded by DAP

The control treatment recorded uptake value of 0 026 at maximum tiller ing stage which increased to 0 048 at panicle initiation and 0 077 g pot $^{-1}$ at harvest As in the case of control there was gradual increase in uptake towards harvest in all the other treatments All the treatments of MTRP SSP and MAP registered an average uptake value of 0 03 0 09 and 0 150 g pot $^{-1}$ at maximum tillering panicle

Table 38 Nutrient release and uptake of Ca in the first crop of rice as influenced by treatments (laterite)

| Treatment | | Maximum tillering | | Panicle initiation | | Harvest | |
|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha$^{1}$ | Uptake g pot$^{1}$ | Available kg ha$^{1}$ | Uptake g pot$^{1}$ | Available kg ha$^{1}$ | Uptake g pot$^{1}$ |
| 1 | MTRP $P_1$ | 822 5 | 0 010 | 544 0 | 0 07 | 216 8 | 0 14 |
| 2 | MTRP $P_2$ | 858 4 | 0 030 | 554 4 | 0 09 | 285 6 | 0 16 |
| 3 | MTRP $P_3$ | 861 4 | 0 035 | 568 0 | 0 10 | 373 2 | 0 17 |
| 4 | MRP $P_1$ | 851 2 | 0 010 | 532 9 | 0 07 | 294 1 | 0 13 |
| 5 | MRP $P_2$ | 876 3 | 0 020 | 573 9 | 0 10 | 313 6 | 0 16 |
| 6 | MRP $P_2$ | 969 9 | 0 030 | 582 4 | 0 10 | 403 2 | 0 18 |
| 7 | SSP $P_1$ | 752 0 | 0 017 | 448 0 | 0 07 | 208 5 | 0 14 |
| 8 | SSP $P_2$ | 798 0 | 0 028 | 492 8 | 0 09 | 285 3 | 0 15 |
| 9 | SSP $P_3$ | 821 0 | 0 038 | 524 0 | 0 10 | 343 3 | 0 17 |
| 10 | DAP $P_1$ | 618 5 | 0 010 | 432 9 | 0 04 | 796 0 | 0 09 |
| 11 | DAP $P_2$ | 652 9 | 0 015 | 492 8 | 0 07 | 238 7 | 0 12 |
| 12 | DAP $P_3$ | 696 3 | 0 028 | 432 9 | 0 08 | 283 7 | 0 13 |
| 13 | C | 612 8 | 0 010 | 537 0 | 0 04 | 238 7 | 0 07 |
| 14 | SSP ($P_2$+$P_2$) | 797 7 | 0 026 | 472 0 | 0 09 | 367 3 | 0 16 |
| CD (0 05) | | 5 65 | | 4 93 | | 4 50 | |
| Source | | | | | | | |
| MTRP | | 847 4 | 0 025 | 555 4 | 0 086 | 291 8 | 0 156 |
| MRP | | 899 1 | 0 020 | 562 8 | 0 09 | 336 9 | 0 156 |
| SSP | | 790 3 | 0 027 | 488 2 | 0 08 | 278 9 | 0 153 |
| DAP | | 655 9 | 0 017 | 452 8 | 0 06 | 239 4 | 0 113 |
| CD (0 05) | | 5 13 | | 4 26 | | 4 01 | |
| Level | | | | | | | |
| $P_1$ | | 761 05 | 0 056 | 489 40 | 0 062 | 228 7 | 0 125 |
| $P_2$ | | 796 40 | 0 023 | 528 27 | 0 087 | 280 8 | 0 147 |
| $P_3$ | | 837 15 | 0 033 | 526 82 | 0 095 | 350 8 | 0 162 |
| CD (0 05) | | 4 20 | | 4 0 | | 3 96 | |

Table 39 Nutrient release and uptake of Ca in the second crop of rice as influenced by treatments (laterite)

| Treatment | | Maximum tillering | | Panicle initiation | | Harvest | |
|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ | Available kg ha$^{-1}$ | Uptake g pot$^{-1}$ |
| 1 | MTRP $P_1$ | 205 0 | 0 037 | 190 2 | 0 063 | 180 9 | 0 093 |
| 2 | MTRP $P_2$ | 265 9 | 0 063 | 245 1 | 0 085 | 192 8 | 0 150 |
| 3 | MTRP $P_3$ | 315 3 | 0 072 | 251 2 | 0 092 | 230 2 | 0 180 |
| 4 | MRP $P_1$ | 265 8 | 0 039 | 256 9 | 0 064 | 176 3 | 0 100 |
| 5 | MRP $P_2$ | 296 0 | 0 063 | 265 9 | 0 071 | 201 7 | 0 124 |
| 6 | MRP $P_3$ | 340 8 | 0 080 | 286 7 | 0 100 | 230 2 | 0 157 |
| 7 | SSP $P_1$ | 205 0 | 0 028 | 140 2 | 0 09 | 167 4 | 0 146 |
| 8 | SSP $P_2$ | 265 9 | 0 065 | 201 7 | 0 09 | 192 8 | 0 169 |
| 9 | SSP $P_3$ | 296 3 | 0 049 | 245 1 | 0 095 | 117 4 | 0 183 |
| 10 | DAP $P_1$ | 192 0 | 0 042 | 146 1 | 0 066 | 104 5 | 0 050 |
| 11 | DAP $P_2$ | 198 5 | 0 046 | 166 1 | 0 065 | 110 7 | 0 080 |
| 12 | DAP $P_3$ | 205 6 | 0 054 | 190 2 | 0 065 | 131 7 | 0 092 |
| 13 | C | 192 0 | 0 040 | 166 1 | 0 060 | 104 5 | 0 076 |
| 14 | SSP ($P_2$+$P_2$) | 280 0 | 0 03 | 272 0 | 0 052 | 265 0 | 0 107 |
| CD(0 05) | | 6 60 | | 7 70 | | 8 80 | |
| Source | | | | | | | |
| MTRP | | 262 1 | 0 057 | 228 8 | 0 080 | 201 3 | 0 141 |
| MRP | | 300 9 | 0 060 | 269 8 | 0 078 | 202 7 | 0 127 |
| SSP | | 255 7 | 0 057 | 212 3 | 0 091 | 159 2 | 0 166 |
| DAP | | 198 7 | 0 047 | 167 4 | 0 060 | 115 6 | 0 074 |
| CD(0 05) | | 6 12 | | 5 95 | | 5 13 | |
| Level | | | | | | | |
| $P_1$ | | 216 9 | 0 036 | 195 9 | 0 072 | 157 3 | 0 097 |
| $P_2$ | | 256 5 | 0 059 | 219 7 | 0 078 | 174 5 | 0 130 |
| $P_3$ | | 289 6 | 0 069 | 243 3 | 0 088 | 197 3 | 0 153 |
| CD(0 05) | | 4 6 | | 4 9 | | 5 1 | |

ınıtıatıon and harvest while DAP recorded 0 02 0 06 and 0 11 g pot $^{1}$ The sources MTRP MRP and SSP are Ca rıch sources and so they regıstered hıgher avaılabılıty and uptake (Appendıx II)

Second crop

The data pertaınıng to thıs are provıded ın Table 39 Sınce P was not applıed ın the second crop season and laterıte soıl beıng basıcally low ın Ca content the release of Ca was lower than the first crop It ranged from 192 0 to 280 9 kg ha $^{1}$ whıle uptake ranged from 0 042 to 0 179 g pot $^{1}$

The control treatment was found to be on par wıth the DAP treatments It recorded avaılable Ca content of 192 0 kg ha $^{1}$ at maxımum tıllerıng whıch decreased to 166 1 at panıcle ınıtıatıon and 104 5 kg ha $^{1}$ at harvest The doses of SSP sıgnıficantly ıncreased the Ca content over the other combınatıons Thıs was followed by the hıghest level ınteractıon of MTRP and MRP whıch were on par at all the 3 stages

All the treatments regıstered more or less same uptake value However control and DAP treatments recorded an average of 0 04 0 06 and 0 07 g pot $^{1}$ whıle SSP MTRP and MRP recorded 0 06 0 08 and 0 14 g pot $^{1}$ at maxımum tıllerıng panıcle ınıtıatıon and harvest stages respectıvely

4 2 2 5 Nutrıent release and uptake of Mg at dıfferent growth stages

Fırst crop

The results are presented ın Table 40 The avaılable Mg content varıed from 241 9 to 473 0 kg ha $^{1}$ whıle uptake ranged from 0 01 to 0 298 g pot $^{1}$

Table 40 Nutrient release and uptake of Mg in the first crop of rice as influenced by treatments (laterite)

| Treatment | | Maximum tillering | | Panicle initiation | | Harvest | |
|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha⁻¹ | Uptake g pot⁻¹ | Available kg ha⁻¹ | Uptake g pot⁻¹ | Available kg ha⁻¹ | Uptake g pot⁻¹ |
| 1 | MTRP $P_1$ | 672 0 | 0 103 | 672 0 | 0 192 | 439 0 | 0 334 |
| 2 | MTRP $P_2$ | 421 0 | 0 064 | 716 0 | 0 218 | 250 0 | 0 391 |
| 3 | MTRP $P_3$ | 739 0 | 0 095 | 734 7 | 0 253 | 439 0 | 0 367 |
| 4 | MRP $P_1$ | 976 6 | 0 073 | 573 0 | 0 136 | 403 0 | 0 383 |
| 5 | MRP $P_2$ | 985 6 | 0 055 | 376 3 | 0 221 | 358 0 | 0 425 |
| 6 | MRP $P_3$ | 734 7 | 0 068 | 385 3 | 0 234 | 367 3 | 0 390 |
| 7 | SSP $P_1$ | 546 5 | 0 039 | 618 0 | 0 237 | 501 7 | 0 386 |
| 8 | SSP $P_2$ | 528 6 | 0 052 | 654 0 | 0 169 | 591 3 | 0 412 |
| 9 | SSP $P_3$ | 439 0 | 0 065 | 645 0 | 0 229 | 627 2 | 0 408 |
| 10 | DAP $P_1$ | 367 3 | 0 091 | 322 0 | 0 274 | 241 9 | 0 451 |
| 11 | DAP $P_2$ | 349 4 | 0 097 | 152 3 | 0 230 | 80 6 | 0 473 |
| 12 | DAP $P_3$ | 582 4 | 0 094 | 116 4 | 0 230 | 62 7 | 0 403 |
| 13 | C | 367 3 | 0 052 | 300 0 | 0 166 | 246 4 | 0 278 |
| 14 | SSP ($P_2$+$P_2$) | 600 3 | 0 063 | 720 0 | 0 215 | 582 4 | 0 364 |
| CD (0 05) | | 70 9 | | 216 36 | | 50 66 | |
| Source | | | | | | | |
| MTRP | | 610 6 | 0 087 | 707 5 | 0 221 | 376 0 | 0 364 |
| MRP | | 674 2 | 0 065 | 443 8 | 0 197 | 376 1 | 0 399 |
| SSP | | 504 7 | 0 052 | 639 0 | 0 212 | 573 4 | 0 402 |
| DAP | | 433 0 | 0 094 | 196 9 | 0 245 | 128 4 | 0 442 |
| CD (0 05) | | 70 5 | | 124 90 | | 29 26 | |
| Level | | | | | | | |
| $P_1$ | | 640 6 | 0 076 | 546 2 | 0 209 | 396 4 | 0 388 |
| $P_2$ | | 571 0 | 0 067 | 474 6 | 0 209 | 319 9 | 0 425 |
| $P_3$ | | 831 7 | 0 081 | 470 3 | 0 236 | 374 05 | 0 392 |
| CD (0 05) | | 61 2 | | 108 1 | | 25 34 | |

In general available Mg content decreased with crop growth The control treatment registered 448 0 kg ha $^{1}$ at maximum tillering which gradually reduced to 250 0 kg ha $^{1}$ at harvest The status of Mg was generally low in laterite soil as compared to Kuttanad alluvium (Table 1) It was observed that there was no significant difference between the various sources in all the stages of crop growth The P sources did not have any influence on Mg availability

Uptake of the nutrient increased with crop growth The increase being drastic towards the harvest as high amount was taken by the grains The control treatment recorded the lowest uptake (0 01 g pot $^{1}$ at maximum tillering 0 040 g pot $^{1}$ at panicle initiation and 0 094 g pot $^{1}$ at harvest period) All the treatment combinations had more or less same uptake and was higher than control From this it may be inferred that P has influence on Mg uptake by the crop

Second crop

The data pertaining to Mg availability and uptake are presented in Table 41 The available Mg ranged from 124 0 to 232 9 kg ha $^{1}$ and uptake from 0 040 to 0 473 g pot $^{1}$

The availability of Mg further decreased in second crop season As in the case of first crop there was no significant variation between the various sources in available Mg

With respect to uptake the values were higher in second crop as compared to the first The higher rooting intensity in the second crop season might have attributed to this increase In all the three stages a slight depression in Mg

Table 41 Nutrient release and uptake of Mg in the second crop of rice as influenced by treatments (laterite)

| Treatment | | Maximum tillering | | Panicle initiation | | Harvest | |
|---|---|---|---|---|---|---|---|
| No | Notation | Available kg ha⁻¹ | Uptake g pot⁻¹ | Available kg ha⁻¹ | Uptake g pot⁻¹ | Available kg ha⁻¹ | Uptake g pot⁻¹ |
| 1 | MTRP $P_1$ | 206 1 | 0 064 | 179 2 | 0 192 | 152 3 | 0 425 |
| 2 | MTRP $P_2$ | 206 1 | 0 068 | 188 2 | 0 218 | 134 4 | 0 391 |
| 3 | MTRP $P_3$ | 224 0 | 0 075 | 179 2 | 0 253 | 127 5 | 0 473 |
| 4 | MRP $P_1$ | 215 0 | 0 073 | 196 9 | 0 192 | 143 4 | 0 412 |
| 5 | MRP $P_2$ | 224 0 | 0 065 | 179 2 | 0 221 | 143 4 | 0 408 |
| 6 | MRP $P_3$ | 206 1 | 0 064 | 188 2 | 0 234 | 127 5 | 0 403 |
| 7 | SSP $P_1$ | 215 0 | 0 065 | 172 6 | 0 237 | 152 3 | 0 412 |
| 8 | SSP $P_2$ | 215 0 | 0 063 | 172 6 | 0 169 | 152 3 | 0 451 |
| 9 | SSP $P_3$ | 232 9 | 0 063 | 179 2 | 0 229 | 143 4 | 0 408 |
| 10 | DAP $P_1$ | 206 0 | 0 071 | 188 2 | 0 276 | 134 4 | 0 391 |
| 11 | DAP $P_2$ | 206 1 | 0 063 | 188 2 | 0 179 | 139 6 | 0 367 |
| 12 | DAP $P_3$ | 215 0 | 0 055 | 172 6 | 0 184 | 152 3 | 0 383 |
| 13 | C | 215 0 | 0 040 | 152 3 | 0 152 | 124 0 | 0 278 |
| 14 | SSP ($P_2$+$P_2$) | 215 0 | 0 065 | 179 2 | 0 172 | 134 4 | 0 451 |
| CD (0 05) | | 7 50 | | 12 76 | | 18 6 | |
| Source | | | | | | | |
| MTRP | | 212 06 | 0 069 | 182 2 | 0 221 | 138 0 | 0 429 |
| MRP | | 215 03 | 0 067 | 188 1 | 0 215 | 138 1 | 0 407 |
| SSP | | 220 9 | 0 064 | 168 1 | 0 211 | 149 3 | 0 423 |
| DAP | | 209 06 | 0 063 | 183 0 | 0 179 | 139 1 | 0 380 |
| CD (0 05) | | 3 60 | | 6 80 | | 10 56 | |
| Level | | | | | | | |
| $P_1$ | | 210 5 | 0 068 | 184 2 | 0 224 | 145 6 | 0 410 |
| $P_2$ | | 212 8 | 0 064 | 182 0 | 0 196 | 142 4 | 0 404 |
| $P_3$ | | 219 5 | 0 064 | 179 8 | 0 225 | 137 6 | 0 416 |
| CD (0 05) | | 3 10 | | 5 66 | | 5 59 | |

availability was observed for the DAP treatments The low availability of P from DAP in the corresponding season might have retarded the uptake of the same

**Effect of different treatment combinations on grain and straw yield of rice**

Kuttanad alluvium

First crop

The results are provided in Table 42 In the control treatment where the application of P was deleted the grain and straw yields were minimum as indicated by the values 30 50 g pot $^{1}$ and 19 58 g pot $^{1}$ respectively The highest grain yield was recorded by SSP $P_3$ (58 53 g pot $^{1}$) MTRP $P_3$ (50 47 g pot $^{1}$)) and DAP $P_3$ (51 97 g pot $^{1}$) which were on par and superior to other treatments In the case of straw yield DAP $P_3$ (36 20 g pot $^{1}$) SSP $P_3$ (36 27 g pot $^{1}$) and DAP $P_2$ (34 43 g pot $^{1}$) were on par and significantly higher than other combinations In SSP ($P_2$+$P_2$) the grain and straw yield were on par with that of SSP $P_2$

The grain and straw yield was influenced by different sources of P in comparison to control and SSP ($P_2$+$P_2$) and are illustrated in Fig 26 It is evident that the water soluble sources fared well both in the case of grain and straw yield as compared to water insoluble sources The source DAP was superior to SSP while MTRP was superior to MRP in the case of grain yield While for straw both MTRP and MRP were similar so were DAP and SSP With incremental doses of P applied there was significant increase in yield of grain and straw as illustrated in Fig 27

The data provided and discussed in section 4 2 established that the uptake of nutrient such as N P K were maximum for the sources SSP and DAP during the first crop season All these might have contributed to the increased yield of grain and straw recorded by these phosphatic fertilizers

Table 42 Grain and straw yield (g pot $^{1}$) as influenced by treatments in the first and second crop of rice (Kuttanad alluvium and laterite)

| Treatment | | Kuttanad alluvium | | | | Laterite | | | |
|---|---|---|---|---|---|---|---|---|---|
| No | Notation | First crop | | Second crop | | First crop | | Second crop | |
| | | Grain yield | Straw yield | Grain yield | Straw yield | Grain yield | Straw yield | Grain yield | Straw yield |
| 1 | MTRP $P_1$ | 41 87 | 24 13 | 40 37 | 32 53 | 39 37 | 26 50 | 35 27 | 23 90 |
| 2 | MTRP $P_2$ | 45 13 | 26 97 | 43 67 | 37 80 | 42 33 | 28 60 | 40 51 | 24 50 |
| 3 | MTRP $P_3$ | 50 47 | 28 87 | 48 50 | 39 20 | 47 30 | 31 30 | 44 70 | 27 60 |
| 4 | MRP $P_1$ | 40 30 | 26 07 | 39 04 | 31 00 | 37 97 | 27 83 | 35 54 | 22 60 |
| 5 | MRP $P_2$ | 42 53 | 24 03 | 43 45 | 35 00 | 43 20 | 26 63 | 43 78 | 24 0 |
| 6 | MRP $P_3$ | 46 27 | 29 67 | 45 99 | 40 33 | 46 77 | 29 97 | 44 02 | 25 50 |
| 7 | SSP $P_1$ | 43 73 | 30 40 | 37 62 | 32 94 | 49 53 | 30 80 | 43 53 | 24 30 |
| 8 | SSP $P_2$ | 47 60 | 32 50 | 40 97 | 34 80 | 52 33 | 33 21 | 44 80 | 28 43 |
| 9 | SSP $P_3$ | 53 53 | 36 27 | 43 19 | 36 21 | 56 17 | 35 43 | 47 87 | 31 37 |
| 10 | DAP $P_1$ | 46 30 | 32 27 | 38 47 | 35 20 | 41 57 | 31 37 | 32 67 | 27 57 |
| 11 | DAP $P_2$ | 49 33 | 34 43 | 41 80 | 37 33 | 44 92 | 35 47 | 37 93 | 29 85 |
| 12 | DAP $P_3$ | 51 97 | 36 20 | 43 47 | 40 80 | 46 92 | 38 59 | 38 0 | 34 50 |
| 13 | C | 30 50 | 19 58 | 26 50 | 21 09 | 35 06 | 22 6 | 29 40 | 20 67 |
| 14 | SSP ($P_2$+$P_2$) | 47 90 | 35 00 | 43 61 | 34 5 | 52 56 | 33 2 | 44 90 | 27 0 |
| CD(0 05) | | 1 89 | 2 66 | 2 14 | 3 05 | 1 58 | 2 50 | 2 17 | 2 39 |
| Source | | | | | | | | | |
| MTRP | | 45 82 | 26 60 | 44 18 | 36 50 | 43 00 | 28 80 | 40 16 | 25 30 |
| MRP | | 43 03 | 26 50 | 42 83 | 35 40 | 42 71 | 28 10 | 41 10 | 24 03 |
| SSP | | 48 17 | 33 03 | 40 59 | 32 70 | 52 68 | 33 13 | 45 40 | 28 00 |
| DAP | | 49 20 | 34 20 | 41 24 | 37 70 | 44 47 | 34 40 | 36 20 | 30 64 |
| CD (0 05) | | 1 09 | 1 53 | 1 23 | 1 76 | 0 91 | 1 45 | 1 25 | 1 38 |
| Levels | | | | | | | | | |
| $P_1$ | | 42 96 | 28 10 | 38 87 | 32 90 | 42 11 | 29 12 | 36 75 | 25 30 |
| $P_2$ | | 46 15 | 29 40 | 42 57 | 35 70 | 45 69 | 30 40 | 41 75 | 27 40 |
| $P_3$ | | 50 56 | 32 70 | 45 53 | 38 20 | 49 29 | 33 82 | 43 64 | 30 40 |
| CD (0 05) | | 0 95 | 1 33 | 1 07 | 1 52 | 0 79 | 1 25 | 1 08 | 1 19 |

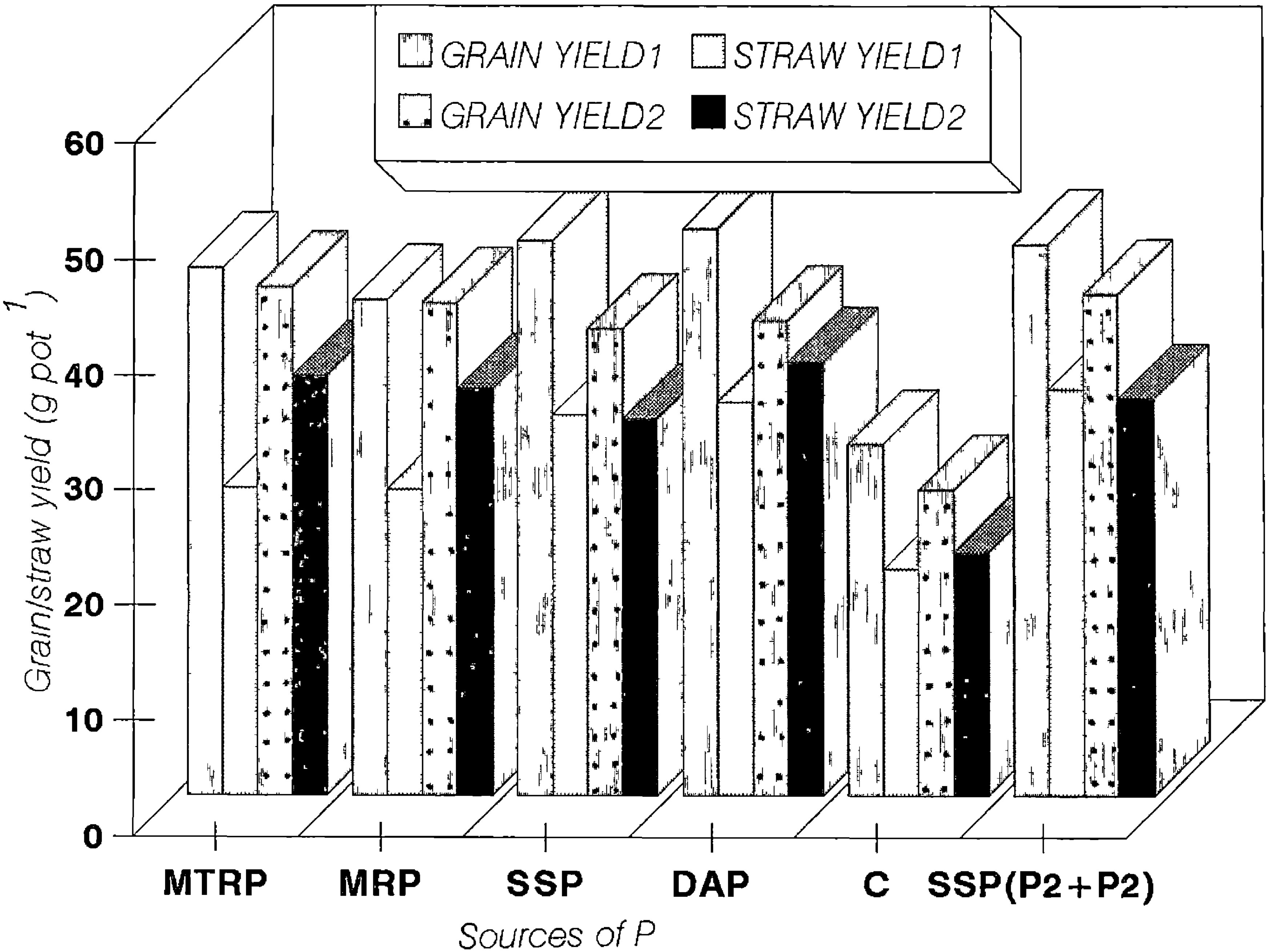



Fig 26 Grain & straw yield of first & second crop of rice as influenced by sources of P (Kuttanad alluvium)

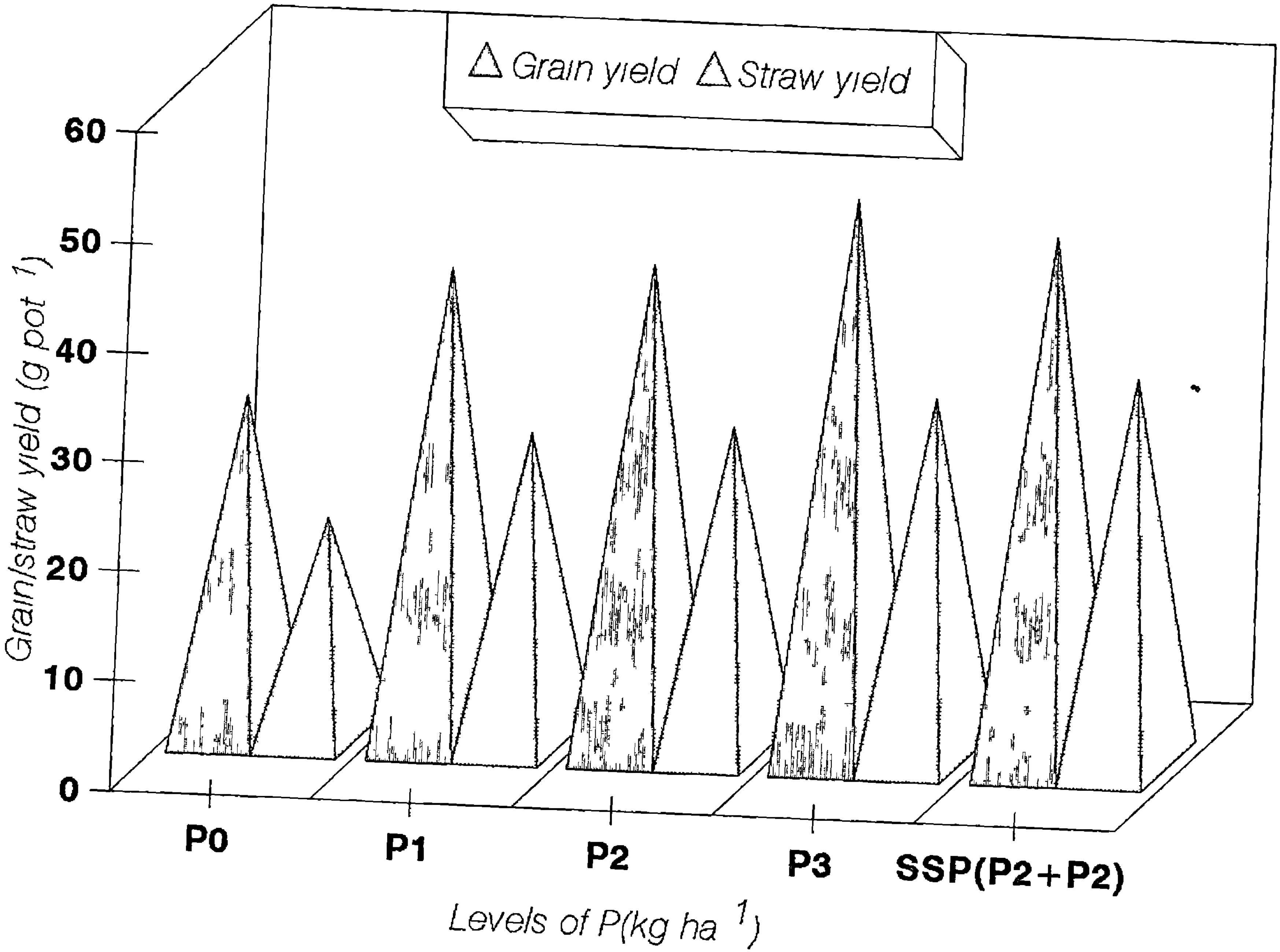



Fig 27 Grain & straw yield of first crop of rice as influenced by levels of P (Kuttanad alluvium)

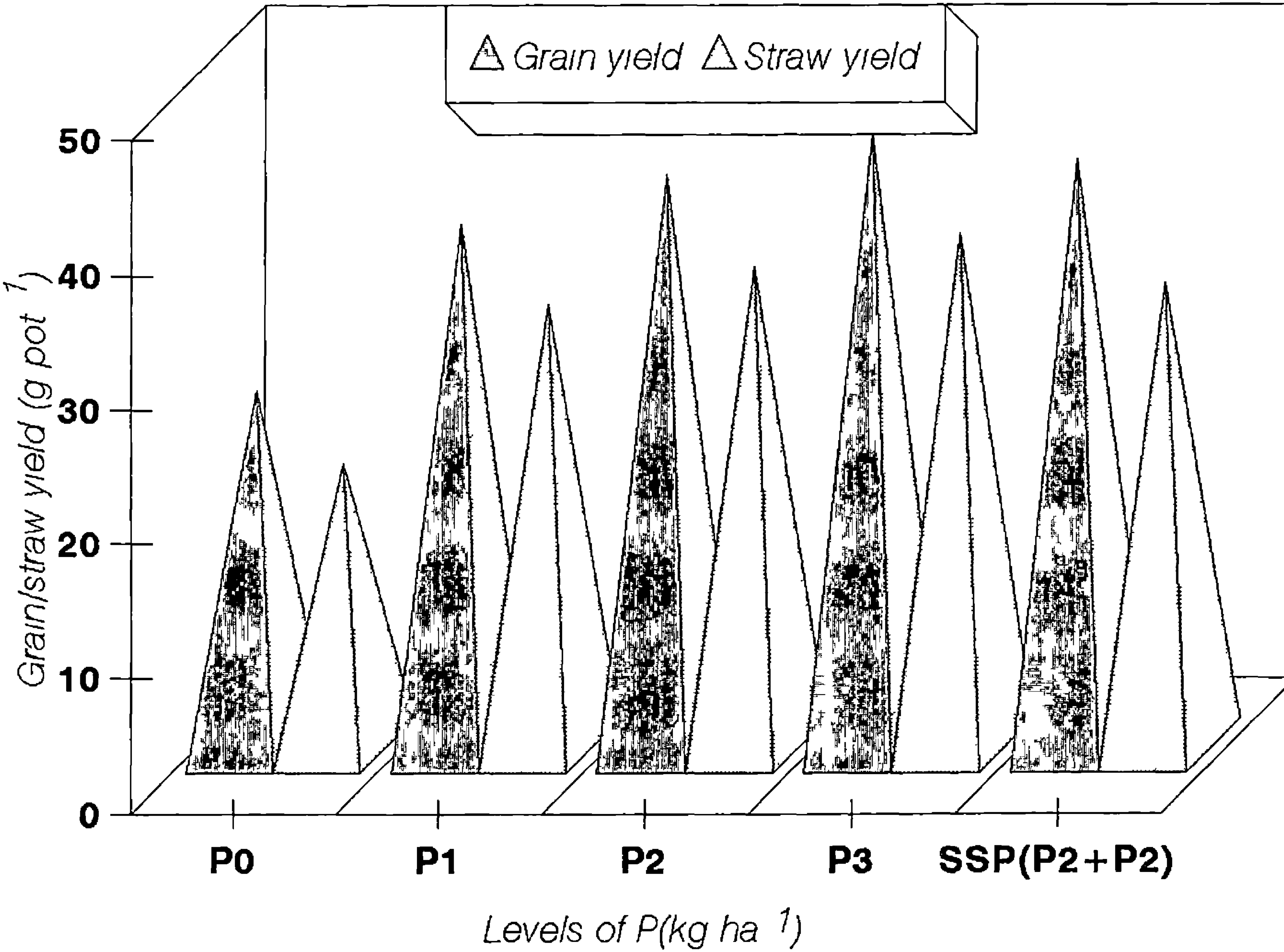



Fig 28 Grain & straw yield of second crop of rice as influenced by levels of P (Kuttanad alluvium)

Second crop

From the table it is evident that control treatment recorded the lowest grain yield (26 50 g pot $^{1}$) and straw yield (21 09 g pot $^{1}$) as compared to other treatments The MTRP $P_3$ treatment was found to be the best and significantly higher than others in grain yield This was followed by the treatments MRP $P_3$ DAP $P_3$ and SSP $P_3$ In the case of straw yield DAP $P_3$ MRP $P_3$ and MTRP $P_3$ were on par and significantly superior to others In the case of SSP ($P_2$+$P_2$) the grain yield were found to be on par with SSP $P_3$ DAP $P_3$ MTRP $P_2$ and MRP $P_2$ while MTRP $P_3$ and MRP $P_3$ registered was significantly higher values Straw yield recorded by the same treatments was on par with interactions of SSP

From Fig 26 it is clear that MTRP was superior in grain yield followed by MRP SSP and DAP The water soluble sources SSP and DAP recorded similar grain yield In the case of straw yield DAP and MTRP were similar followed by MRP and SSP The residual effect of phosphate added to a previous crop is much more apparent for rice than other crops The availability of rice crop to utilize the residual P has been well documented (Patrick and Mahapatra 1968)

As in the case of first crop with increase in levels of applied P the yield of both grain and straw were found to be increased (Fig 28)

Laterite soil

The grain and straw yield of first and second crop as influenced by treatments are provided in Table 42

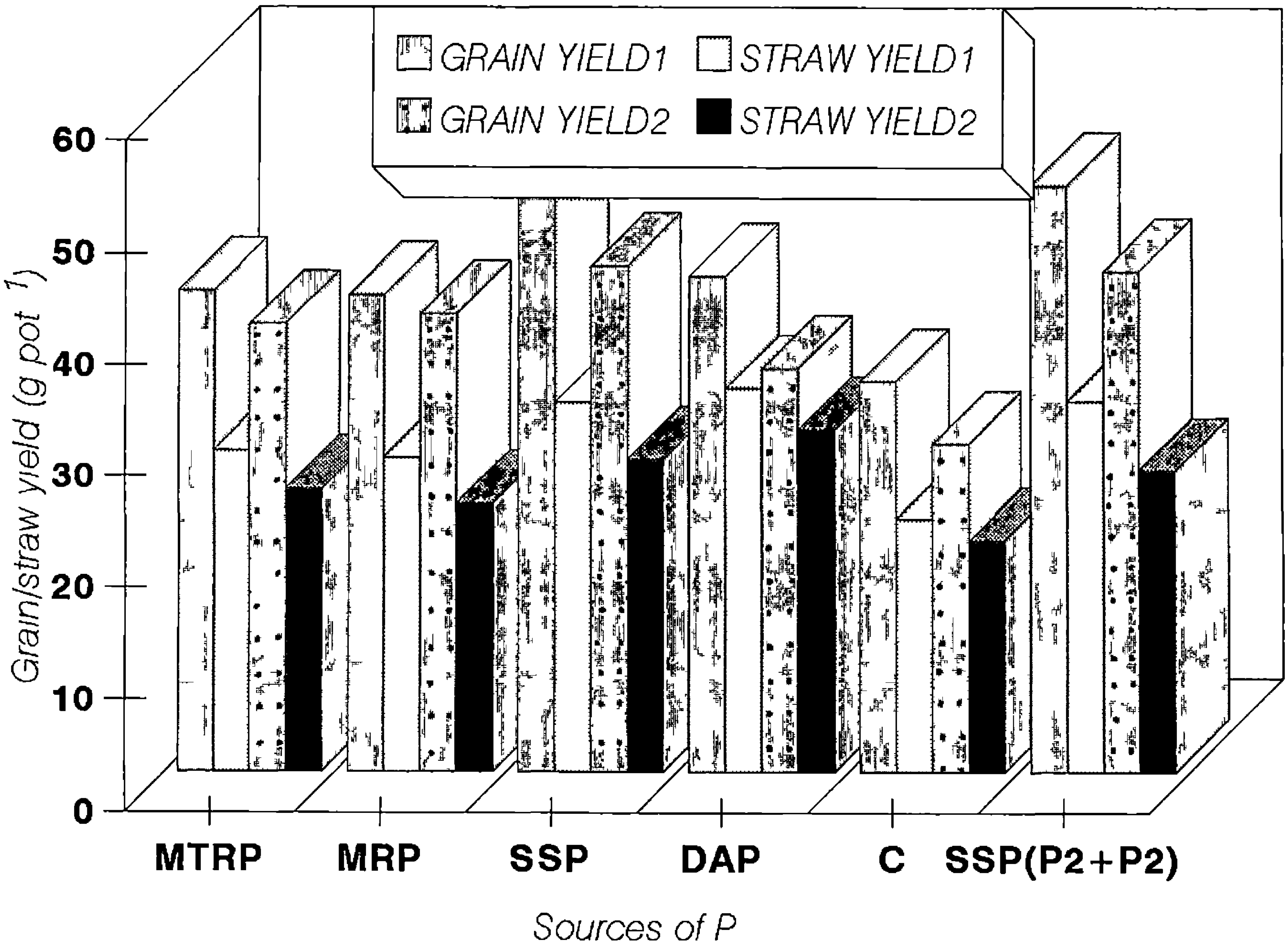



Fig 29 Grain & straw yield of first & second crop of rice as influenced by sources of P (laterite)

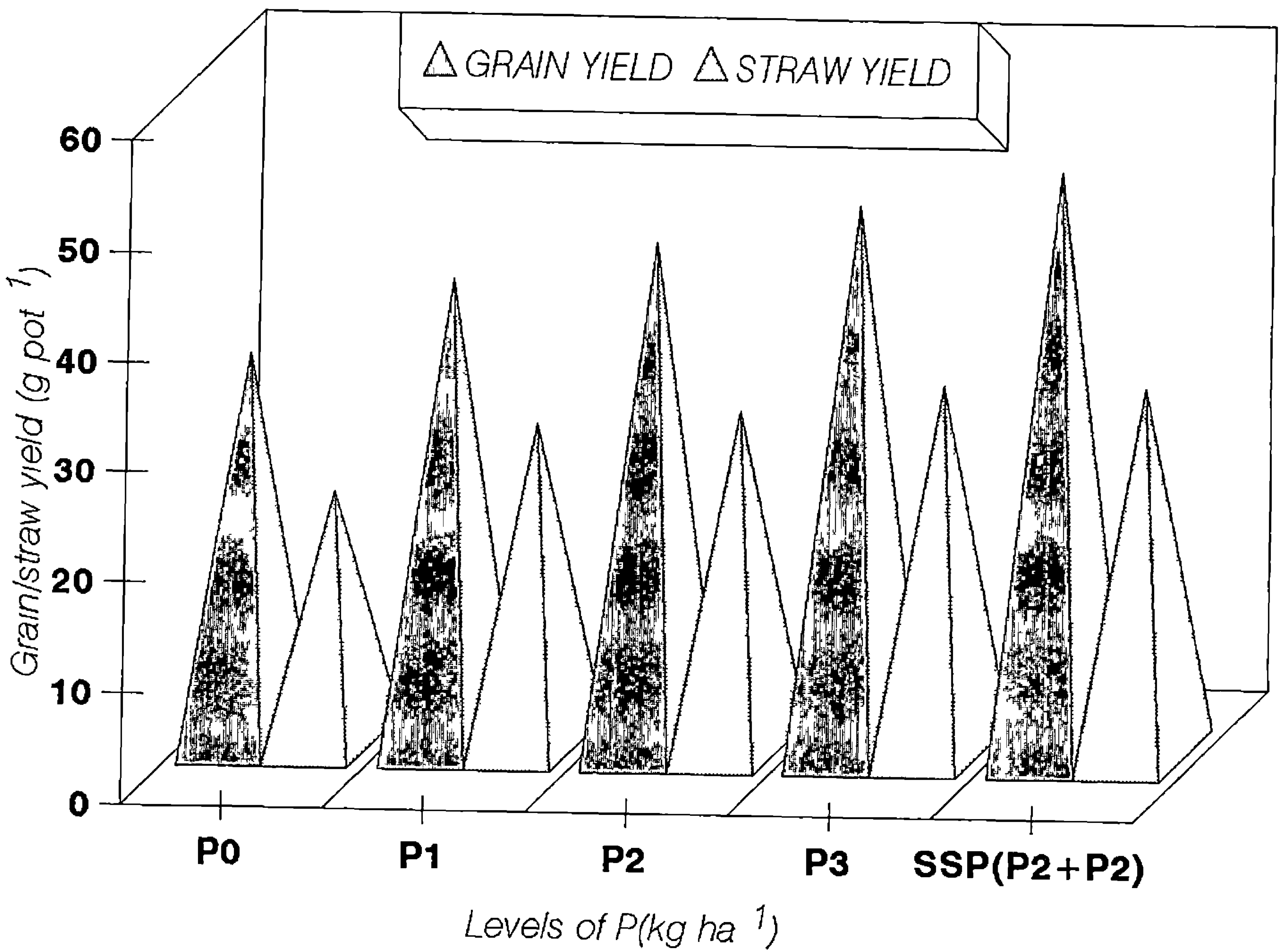



Fig 30 Grain & straw yield of first crop of rice as influenced by levels of P (laterite)

First crop

The control treatment registered the lowest grain yield (35 06 g pot $^{1}$) and straw yield (22 67 g pot $^{1}$) among the various treatment combinations The absence of P along with poor uptake of other nutrients might have contributed for this drastic decrease in yield Among the P applied treatments SSP $P_3$ showed the best performance (56 17 g pot $^{1}$) The treatments MTRP $P_3$ MRP $P_3$ and SSP $P_3$ were on par and were next to SSP $P_3$ in grain yield With respect to straw yield DAP $P_3$ was superior followed by SSP $P_3$ The treatment SSP ($P_2$+$P_2$) recorded almost the same yield as that of SSP $P_2$

Mean values of grain and straw yield as influenced by sources in comparison to SSP ($P_2$+$P_2$) and control are provided in Fig 29 In general SSP was superior in grain yield followed by the sources DAP MTRP and MRP While in straw yield both SSP and DAP were on par and so were MTRP and MRP

With increase in levels of P applied there was significant increase in grain and straw yield (Fig 31) The higher availability and uptake of P along with other nutrients might have increased the yield

Second crop

From the data presented in Table 42 it was recognised that in general there was decrease in both grain and straw yield of the second crop as compared to first However this decrease was more prominent with water soluble sources

The control treatment recorded 29 40 and 20 67 g pot $^{1}$ as grain and straw yield respectively The other treatments were significantly higher than control

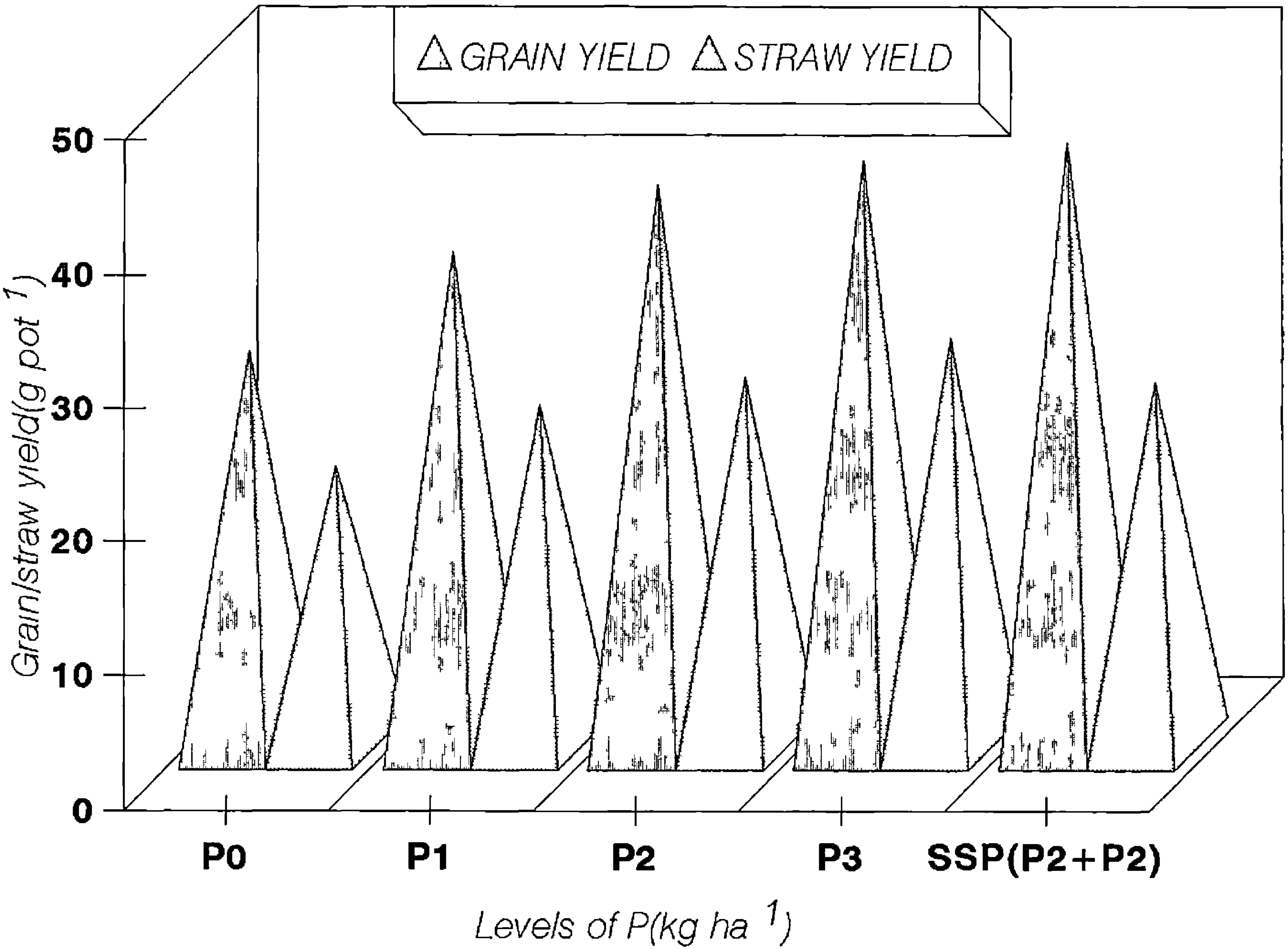



Fig 31 Grain & straw yield of second crop of rice as influenced by levels of P (laterite)

Among the treatments SSP $P_3$ was significantly superior (47 87 g pot $^{1}$) followed by MTRP (44 70 g pot $^{1}$) and MRP (44 02 g pot $^{1}$) which were on par Though the SSP was on par with other sources in available P at panicle initiation and harvest stages it was significantly higher than other sources This may be the reason for increased yield registered by the same treatment The crop uptake of P was maximum at the tillering stage and the P absorbed might have efficiently utilised for grain production Phosphorus taken up beyond panicle initiation tended to accumulate in the grain straw and root with no advantage to the grain yield (Patnaik *et al* 1965) With regard to straw yield the treatment DAP $P_3$ was superior followed by SSP $P_3$ The second addition of SSP ($P_2+P_2$) failed to give any additional yield as compared to SSP $P_2$

From Fig 29 it is evident that SSP was superior followed by MTRP MRP and DAP for the grain yield of rice In the case of straw yield DAP was superior followed by SSP MTRP and MRP Both the grain and straw yield indicated by the sources MTRP and MRP were almost similar

With incremental dose of P there was increase in grain and straw yield (Fig 32)

**Relative yield of rice as influenced by different treatments in Kuttanad alluvium and laterite soil types**

Fertilisers form a significant input in intensive agriculture but they are energy and money exhaustive Phosphorus occupies a key place in balanced fertiliser programmes and India s current $P_2O_5$ consumption is 2 88 million tonnes (Anon 1996) Conventional P sources like SSP and complex fertilisers like DAP are becoming costly and so alternate cheap sources of P for increased efficiency merit significant importance Any factor which can increase crop yields at a given level of input application will automatically increase fertiliser efficiency and in this process the cost of production per unit crop will be reduced

In this context the fertiliser use efficiency of different P sources may be assessed based on relative yield Since relative yield represents the per cent increase in yield over the conventional practice the observed variation in relative yield values are explainable in the light of yield contributed by different phosphatic fertilisers The yield an important criteria to determine the efficiency of any fertiliser practice is the ultimate reflectant of all the factors influencing the effective utilisation of nutrients

Values based on relative yield for the first and second crop of rice in both the soil types are given in Table 43 Irrespective of the soil types the control treatment recorded the lowest value for the first and second crop under study On comparison of the treatments it was observed that SSP $P_3$ DAP $P_2$ MTRP $P_3$ and DAP $P_3$ were superior to standard practise in the yield production of first crop under Kuttanad alluvium However the increase was more pronounced in SSP $P_3$ (111 7) and DAP $P_3$ (108 49) In the second crop of rice MTRP $P_2$ MTRP $P_3$ and MRP $P_3$ were found to be superior to standard practice In the laterite soil SSP $P_3$ registered higher relative yield for both the first (106 86) and second crop (106 67) of rice

The higher relative yield of water soluble P sources may be attributed to the high availability and uptake of major nutrients especially P during the first crop season The increased availability of P must have enhanced the higher uptake of other nutrients as detailed in section 4 2 1 The poor relative yield of control may be due to the low uptake of nutrients owing to absence of P In general performance of

Table 43 Relative yield of rice as influenced by different treatments for the first and second crop season in Kuttanad alluvium and laterite

| Treatment | | Kuttanad allvium | | laterite | |
|---|---|---|---|---|---|
| No | Notation | First crop | Second crop | First crop | Second crop |
| 1 | MTRP $P_1$ | 87 41 | 92 57 | 74 90 | 78 55 |
| 2 | MTRP $P_2$ | 94 21 | 100 13 | 80 53 | 90 22 |
| 3 | MTRP $P_3$ | 105 36 | 111 21 | 83 99 | 99 55 |
| 4 | MRP $P_1$ | 84 13 | 89 52 | 72 24 | 79 15 |
| 5 | MRP $P_2$ | 88 78 | 99 63 | 82 19 | 97 50 |
| 6 | MRP $P_3$ | 96 57 | 105 45 | 88 98 | 98 04 |
| 7 | SSP $P_1$ | 90 54 | 86 26 | 94 23 | 96 95 |
| 8 | SSP $P_2$ | 99 37 | 93 94 | 99 56 | 99 77 |
| 9 | SSP $P_3$ | 111 70 | 99 03 | 106 86 | 106 67 |
| 10 | DAP $P_1$ | 96 56 | 88 21 | 79 09 | 72 76 |
| 11 | DAP $P_2$ | 102 98 | 95 84 | 85 46 | 84 47 |
| 12 | DAP $P_3$ | 108 49 | 99 67 | 89 26 | 84 63 |
| 13 | C | 63 67 | 60 76 | 66 76 | 65 47 |

rockphosphates were better in Kuttanad alluvium as compared to laterite This may be attributed to the high liming effect of these sources (section 4 1 1 5) and consequent better maintenance of higher concentration of P in the rhizosphere and subsequent less loss of nutrients through leaching

The capability of laterite soil to buffer the P concentration of the soil solution might have governed the prolonged residual effect showed by the treatment SSP $P_3$ Nutrient availability depends not only on the concentration of soil solution present at any given time but also on the ability of the soil to maintain the nutrient concentration (Mengel and Kirkby 1978) This is particularly evident in the case of laterite with a good reserve of Fe P and Al P fraction (Table 17) All these fractions of P might have resulted in substantial replenishment of P in the soil solution from the solid phase of the soil Due to the same reason skipping of P for one or two seasons of rice may be possible for wetlands of laterite soil In order to provide a satisfactory P concentration in the soil solution even after the harvest of first crop the phosphate adsorption capacity should be higher as in the case of laterites

These observations tend to conclude that rock phosphate especially MTRP is a better alternative to costly SSP and DAP for the wet land rice of Kuttanad alluvium and laterite The performance of the crop was found to be much better for more acidic soils of Kuttanad alluvium Almost all the sources of P provided an extended residual effect when the level of application was enhanced from 45 to 67 5 kg $P_2O_5$ $ha^{-1}$ during the first crop season of rice There is a considerable residual effect from large applications of P fertilizer to high P sorbing soils like laterite The efficiency of fertilizer P as well as soil P is increased when soils are limed with the use of rock phosphates

# Summary

# SUMMARY

Study on the "Evaluation of Maton rockphosphate for the acid rice soils of Kerala was conducted at the College of Horticulture during the period 1994 96 to evaluate the effectiveness of MTRP as a source of P compared to SSP DAP and indegenous rockphosphate in acid rice soils of Kerala and to study the pattern of release of P from all the above sources The investigation consisted of mainly two parts an incubation study and a continuous pot culture experiment for two seasons In order to ascertain the pattern of release of P under two typical rice soils of Kerala Kuttanad alluvium and laterite an incubation study was conducted for a period of eight months The most important sources of phosphatic fertilisers used in the study were also compared with two treatments i e no P treatment (native source) and continuous application of SSP (conventional practice) The pot culture experiment using Jaya variety of rice was conducted during Mundakan and Punja season so as to draw conclusions on the residual nature of P sources The salient features of the results are summarised below

1 The soil pH of Kuttanad alluvium and laterites were found to be gradually increased with periods of waterlogging irrespective of the treatments including the control The pH of Kuttanad alluvium ranged from 3 90 to 5 08 and laterite from 4 90 to 5 65 In raising the pH of both the soil types rockphosphates MTRP and MRP fared well as compared to water soluble phosphates SSP and DAP

2 Available nitrogen contents of the soil decreased with period of incubation irrespective of the treatments and it varied from 357 5 to 1122 60 kg ha$^{1}$ in Kuttanad alluvium and from 302 40 to 740 10 kg ha$^{1}$ in laterite soil

3 Available P slightly increased with periods of incubation reached a maximum and then decreased The peak content of available P in the water soluble phosphates was recorded on 120th day while for rockphosphates on 150th 180th day irrespective of the soil types

4 Between the two extracting agents Bray 1 (0 03 N $NH_4F$ + 0 025 N HCl) and Mathew s triacid (0 06 N $H_2SO_4$ + 0 05 N oxalic aic + 0 06 N HCl) more available P was extracted by Mathew s triacid which was found to be following the same trend for both the soils under study

5 At 120th day of incubation maximum release of P was with SSP while at 240th day MTRP was superior for both the soil types

6 The release of available P increased with incremental doses of applied P from 22 5 to 67 5 kg $P_2O_5$ ha $^{1}$

7 Available K decreased with periods of incubation In Kuttanad alluvium it ranged from 459 2 to 683 20 kg ha $^{1}$ while in laterite ranged from 110 4 to 185 9 kg ha $^{1}$

8 In general maximum Ca release was registered at the 5th and 6th month of incubation after which it declined

9 In the case of Mg higher release was observed at the 1st two months of incuba tion and there was a gradual decrease towards the later periods

10 Higher content of available N K Ca and Mg were recorded in Kuttanad alluvium as compared to laterite soil

11 The most dominant P fraction was found to be Fe P followed by Al P and Ca P in both the soil types There was increase in Fe P and Al P from 120th to 240th day while Ca P decreased With application of different sources of P Fe P and Al P was maximum with water soluble P at both 120th and 240th day while Ca P was maximum for rockphosphates followed by SSP

12 With advancement of crop growth available N P K Ca and Mg decreased in both the soil types whereas the uptake of these nutrients increased and the leachate losses were found to be decreased

13 Uptake of P was higher in SSP and DAP treatments in first crop for both the soil types

14 With respect to second crop MTRP recorded relatively higher uptake in Kuttanad alluvium while in the case of laterite soil SSP was superior in the initial stages but rockphosphates were found to be equally effective in the later periods

15 There was no significant difference in leaching losses between the various sources irrespective of the soil types The second crop recorded lower leaching loss of P as compared to first crop in both the soil types

16 Among the nutrients maximum leachate loss was recorded for N followed by K and P throughout the period of crop growth

17 The grain yield in first crop in Kuttanad alluvium was higher for water soluble sources followed by MTRP and MRP while in the case of laterite SSP was superior followed by DAP MTRP and MRP The sources MTRP and MRP were on par

18 The grain yield in second crop of Kuttanad alluvium was significantly superior to MTRP followed by MRP SSP and DAP The sources SSP and DAP were on par In the case of laterite SSP was significantly higher followed by rock phosphates and DAP recorded the lowest yield The gram yield of SSP ($P_2$+$P_2$) was found to be on par with MTRP $P_2$ and SSP $P_3$ while in laterite the yield was same as that of SSP $P_2$

19 With regard to straw yield in the first crop of both the soil types SSP and DAP were on par and were superior to rockphosphates

20 In the second crop in Kuttanad alluvium DAP and MTRP were on par while in laterite DAP was superior to other sources Straw yield in SSP ($P_2$+$P_2$) was found to be on par with SSP $P_2$

21 With increase in levels of P applied there was significant increase in the grain and straw yield

22 The relative yield was higher for SSP $P_3$ in the first crop of both soil types In the second crop MTRP $P_2$ and MTRP $P_3$ and MRP $P_3$ registered higher rela tive yield in Kuttanad alluvium while in laterite soil SSP $P_3$ was superior

Plate 1 Crop stand in MTRP $P_1$ as compared to C and SSP $P_1$ in Kuttanad alluvium

Plate 2 Crop stand in MTRP $P_2$ as compared to C and MRP $P_2$ in Kuttanad alluvium

Plate 3 Crop stand in MTRP $P_3$ as compared toC and DAP $P_3$ in Kuttanad alluvium

1


2


3

Plate 4. Crop stand in MTRP-$P_2$ as compared to C and SSP ($P_2$+$P_2$) in Kuttanad alluvium

Plate 5. Crop stand in MTRP-$P_1$ as compared to DAP-$P_1$ in laterite

Plate 6. Crop stand in MTRP-$P_2$ as compared to SSP-$P_2$ in laterite

4


5


6

Plate 7. Crop stand in MTRP-$P_3$ as compared to MRP-$P_3$ in laterite

Plate 8. Crop stand in MTRP-$P_2$ as compared to SSP ($P_2$+$P_2$) in laterite

Plate 9. Influence of MTRP-$P_2$ over C, MRP-$P_2$, SSP-$P_2$ and DAP-$P_2$ on panicle characteristics in Kuttanad alluvium

7


MTRP
MRP
CONTROL

8


CONTROL
MTRP
SSP

9

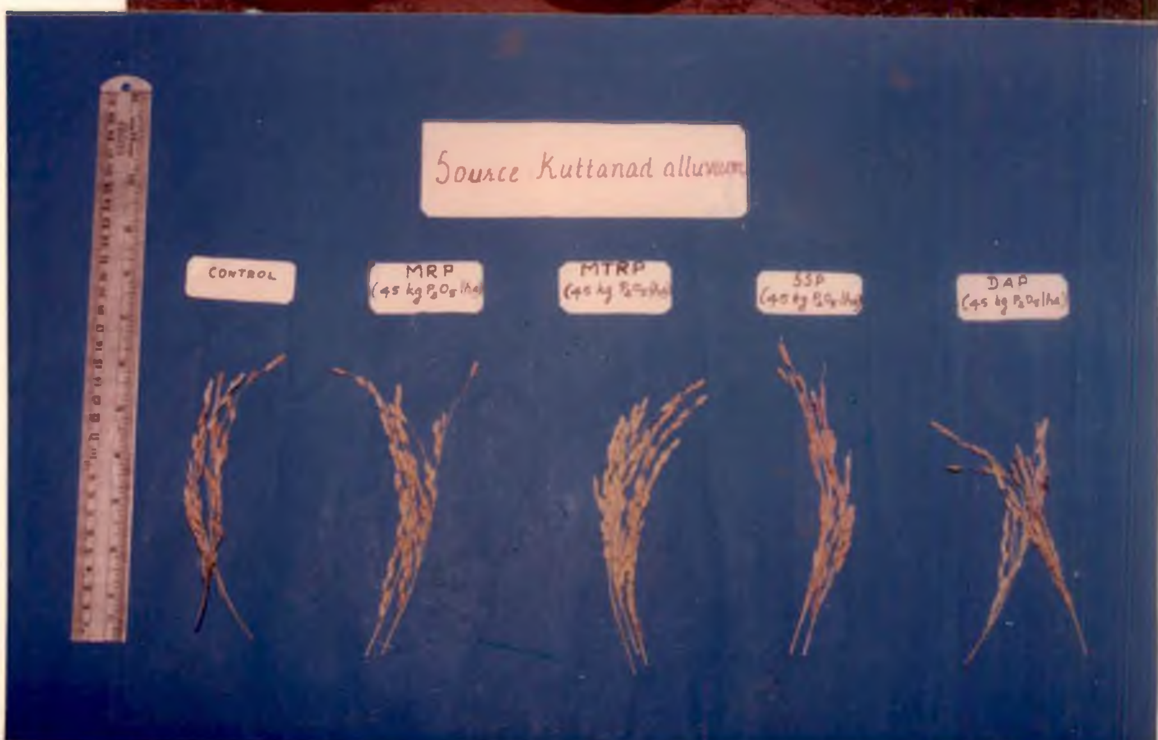

Source Kuttanad alluvium
CONTROL
MRP
MTRP
SSP
DAP

Plate 10. Influence of MTRP-$P_3$ over C, MRP-$P_3$, SSP-$P_3$ and DAP-$P_3$ in Kuttanad alluvium

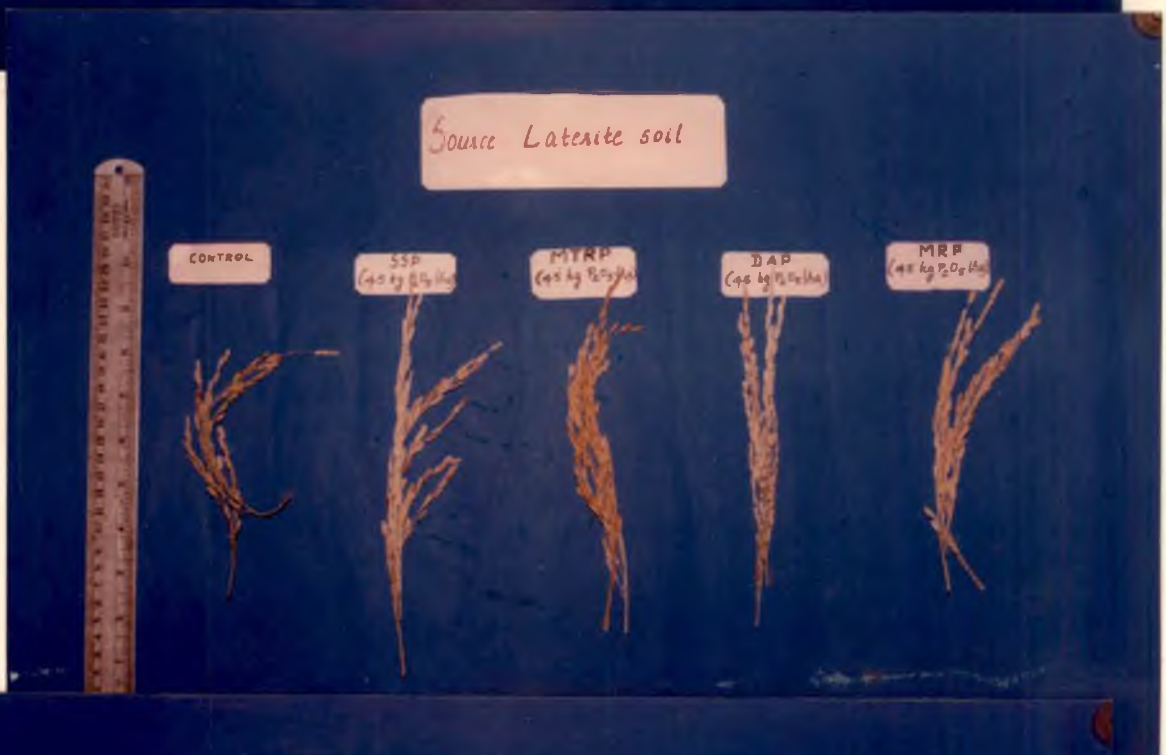
Plate 11. Influence of MTRP-$P_2$ over C, MRP-$P_2$, SSP-$P_2$ and DAP-$P_2$ on panicle characteristics in laterite

Plate 12. Influence of MTRP-$P_3$ over C, MRP-$P_3$, SSP-$P_3$ and DAP-$P_3$ on panicle characteristics in laterite

10


Source Kuttanad alluvium
CONTROL
MRP
MTRP
SSP
DAP

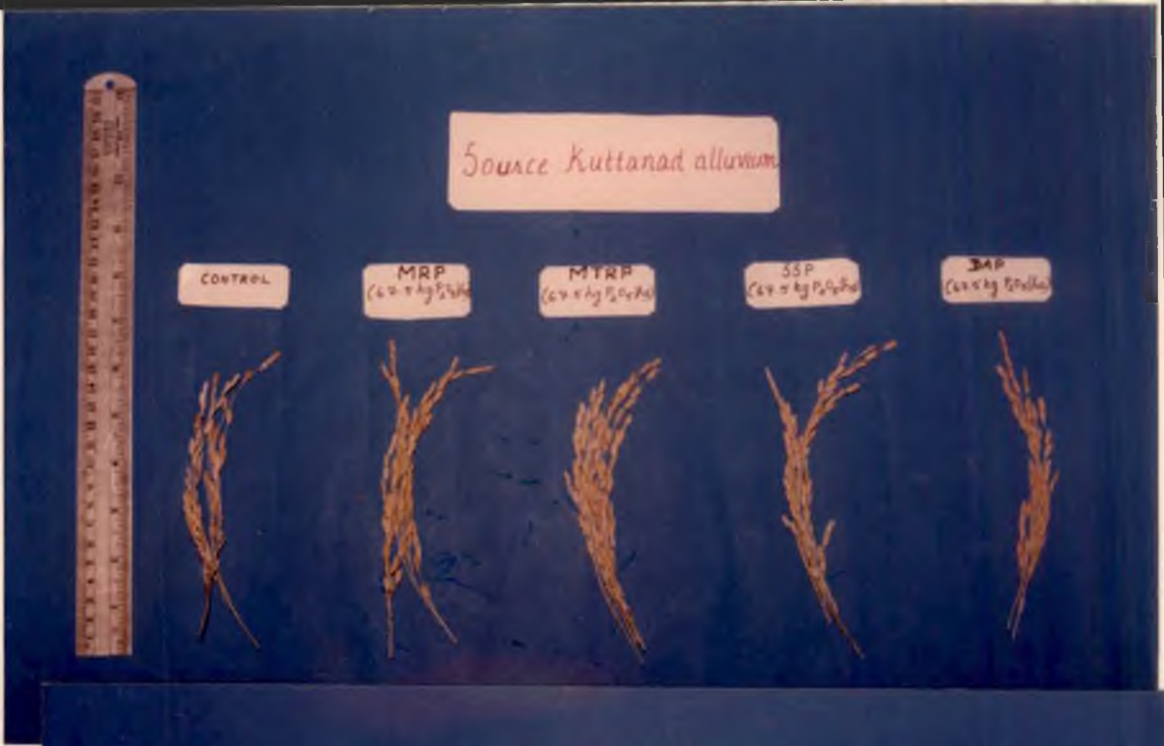
11


Source Laterite soil
CONTROL
SSP
MTRP
DAP
MRP

12

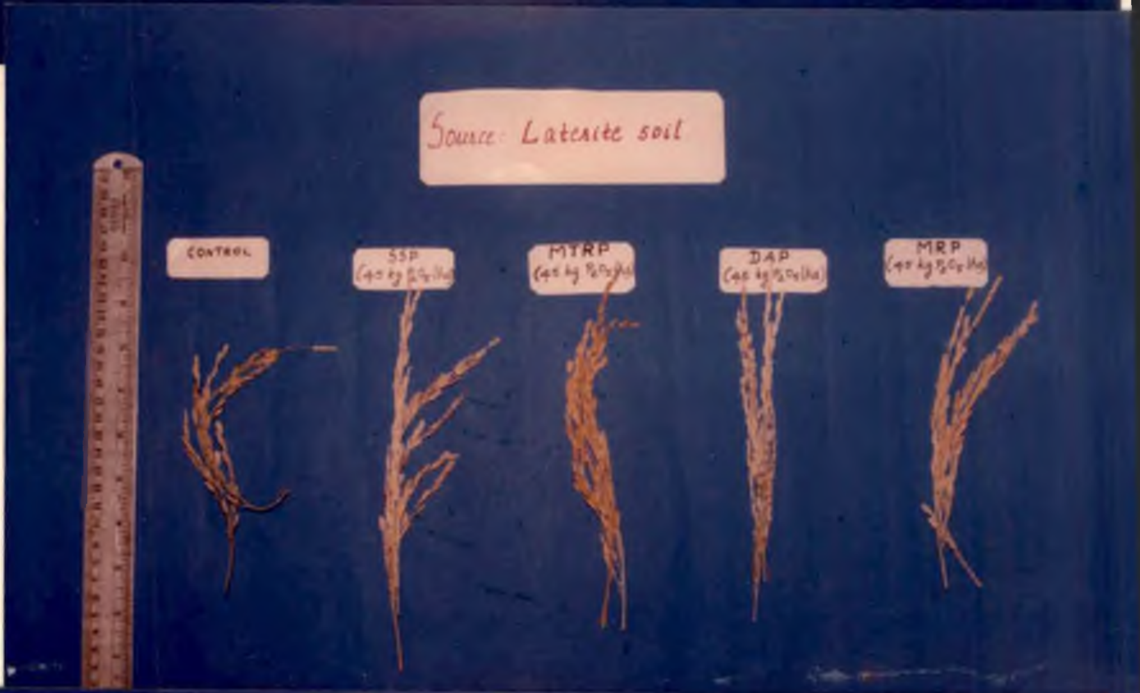

Source Laterite soil
CONTROL
DAP
MTRP
SSP
MRP

10



Source Kuttanad alluvium
CONTROL
MRP
MTRP
SSP
DAP


11



Source Laterite soil
CONTROL
SSP
MTRP
DAP
MRP


12

Source Laterite soil
CONTROL
DAP
MTRP
SSP
MRP

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# Appendices

# APPENDIX I

## Taxonomical classification and description of the soil types under study

a) Kuttanad alluvium

Surface soil samples were collected from Nedumudy which belonged to Champakulam series of order inceptisol suborder aquept and great soil group Tropa quept

Description of surface horizon

Very dark grey (7 5 YR 3/1) moist clay loam massive firm sticky and plastic abundant fine fibrous roots slow permeability clear smooth boundary

b) Laterite

Surface soil samples were collected from Mudikodu which belonged to Kuttala series of order ultisol suborder udult and great soil group Kandiudult

Description of surface horizon

Yellowish brown sandy clay loam weak granular fine non sticky very friable and soft very frequent small irregular hard iron stone nodules and con cretions smooth gradual boundary

## APPENDIX II

The details of fertiliser analysis

| Content (%) | MTRP | MRP | SSP | DAP |
|---|---|---|---|---|
| Total $P_2O_5$ | 22 90 | 20 04 | 16 31 | 46 25 |
| Water soluble $P_2O_5$ | | | 14 31 | 45 23 |
| Citrate soluble $P_2O_5$ | 0 12 | 0 16 | 0 11 | 0 21 |
| Citrate insoluble $P_2O_5$ | 1 60 | 1 35 | 0 15 | |
| Nitrogen | | | | 17 60 |
| Potassium | 0 15 | 0 21 | 0 08 | 0 02 |
| Sodium | 0 19 | 0 20 | 0 44 | 0 11 |
| Iron | 0 28 | 0 19 | 0 04 | 0 14 |
| Aluminium | 1 64 | 1 65 | 1 89 | 2 50 |
| Calcium | 3 02 | 4 5 | 2 0 | 0 45 |
| Magnesium | | | | 0 66 |
| Silica | 7 5 | 2 30 | 0 12 | |
| Al P | 0 007 | 0 010 | 0 184 | 0 299 |
| Fe P | 0 019 | 0 014 | 0 002 | 0 184 |
| Ca P | 5 30 | 5 63 | 2 016 | 0 059 |

## APPENDIX III

Inter relationship between available P (extracted by Bray I and Mathew s extractant) and P uptake by rice
(Correlation coefficients

| | Bray No 1 | | Mathew s triacid | |
|---|---|---|---|---|
| | Kuttanad alluvium | Laterite | Kuttanad alluvium | Laterite |
| First crop | | | | |
| Maximum tillering | 0 900* | 0 150 | 0 749* | 0 250 |
| Panicle initiation | 0 013 | 0 500* | 0 513* | 0 242 |
| Harvest | 0 253 | 0 700* | 0 126 | 0 700* |
| Second crop | | | | |
| Maximum tillering | 0 242 | 0 890 | 0 208 | 0 389 |
| Panicle initiation | 0 203 | 0 500 | 0 500 | 0 256 |
| Harvest | 0 203 | 0 250 | 0 014 | 0 250 |

* Significant at 5 per cent level

# EVALUATION OF MATON ROCKPHOSPHATE IN THE ACID RICE SOILS OF KERALA


By

**SUJA THOMAS**


## ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
requirement for the degree of

**Master of Science in Agriculture**


Faculty of Agriculture
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**1997**

## ABSTRACT


A study was conducted at College of Horticulture during the period 1994 96 so as to assess the effectiveness of Maton rockphosphate (MTRP) as a source of P compared with single superphosphate (SSP) diammonium phosphate (DAP) and Mussoorie rockphosphate (MRP) In addition to the above sources a control treatment (with no P fertiliser) and another treatment with SSP at the rate of 45 kg $P_2O_5$ ha $^{1}$ given twice (conventional practice) were also included The P release from all the sources were monitored with an incubation experiment In order to evaluate the response of fertilisers two continuous pot culture experiments were undertaken using Jaya variety of rice Two acid rice soils of Kerala viz Kuttanad alluvium and laterite were used for the study

The variations in pH of the soil types indicated that there was increase with advancement of periods under waterlogging irrespective of the treatments including the control Available N was high in Kuttanad alluvium as compared to laterite and was found to decrease with periods of incubation The content of available P gradually increased with period of incubation reached a peak at 120 days for water soluble phosphates (SSP and DAP) and 180 days for rockphosphates irrespective of the soil types Comparing the two extractants Mathew's triacid extracted more available P than that of the Bray solution in both the soil types Available K decreased with periods of incubations In general Kuttanad alluvium recorded higher content of available nutrients as compared to laterite In both the soil types the most dominant P fraction was Fe P followed by Al P and Ca P

While evaluating the pot culture experiment it was observed that available nutrient content decreased with advancement of crop growth Even after

the harvest of second crop the residual effect of MTRP was recorded to be high There was maximum uptake of P at the second crop season as compared to the first crop irrespective of the soil types The leachate loss decreased with crop growth in both the soil types But the maximum leachate loss was recorded for N followed by K and P The grain yield as well as the relative yield was found to be maximum for the laterite soil on comparison to Kuttanad alluvium for the first and second crop of rice In Kuttanad alluvium DAP and MTRP yielded better in the first and second crop respectively While in laterites SSP was found to be better in grain yield as compared to other sources The source DAP was superior to others in straw yield for both the soil types with increase in levels of P application there was increase in grain and straw yield