SUITABILITY OF TUNISIA (GAFSA) ROCKPHOSPHATE FOR DIRECT APPLICATION IN ACID RICE SOILS OF KERALA

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I here by declare that the thesis entitled **"Suitability of Tunisia (Gafsa) rockphosphate for direct application in 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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Certified that the thesis entitled **"Suitability of Tunisia (Gafsa) rockphosphate for direct application in acid rice soils of Kerala"** is a record of the research work done independently by **Mr.V.C.Santhoskumar**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr.V.C.Santhoshkumar**, a candidate for the degree of **Master of Science in Agriculture**, with major in **Soil Science and Agricultural Chemistry** agree that the thesis entitled "**Suitability of Tunisia (Gafsa) rockphosphate for direct application in acid rice soils of Kerala**" may be submitted by Mr.V.C.Santhoshkumar, in partial fulfilment of the requirement for the degree.

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V.C.Santhoshkumar

To my parents

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
Ca	-	Calcium
Mg	-	Magnesium
Al-P	-	Aluminium phosphate
Fe-P	-	Iron phosphate
TRP	-	Tunisia rockphosphate
SSP	-	Single superphosphate
DAP	-	Diammonium phosphate
MRP	-	Mussorie rockphosphate
C	-	control
MT	-	maximum tillering
PI	-	panicle initiation

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N	-	Nitrogen
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$$P_1 - \frac{\text{TRP-}P_1 + \text{SSP-}P_1 + \text{DAP-}P_1 + \text{MRP-}P_1}{4}$$

$$P_2 - \frac{\text{TRP-}P_2 + \text{SSP-}P_2 + \text{DAP-}P_2 + \text{MRP-}P_2}{4}$$

$$P_3 - \frac{\text{TRP-}P_3 + \text{SSP-}P_3 + \text{DAP-}P_3 + \text{MRP-}P_3}{4}$$

INTRODUCTION

Agriculture is the back bone of Indian economy as 75 per cent of its 940 million population depend on agriculture in rural areas. Self sufficiency in food grains has been one of the most widely accepted achievements since independence. Way back in 1950's India was virtually dependent on import of food grains whereas today we have surplus food grain due to the effect of science and Technology. But the alarming growth of population and lack of scope for horizontal expansion make it compulsory to go for more vibrant methods of food production, so that we can achieve the target food grain production of 240 million tones by 2000 A.D. (Anon. 1996).

The vertical growth in agriculture through increased production per unit area per unit time involves intensive use of farm inputs such as fertilizers in balanced quantity as one of the major components. But unfortunately between 1990-93 there was about 20 per cent decline in the consumption of phosphatic fertilizer and 10 per cent increase in nitrogen fertilizer which aggravated the already existed imbalance in N, P and K ratio to 9.8 : 3.0 : 1 whereas the ideal ratio should be at 4:2:1. If this trend continues it will affect sustainable agriculture production in our country. The main reason for this imbalance is the two to three fold increase in price of phosphatic and potassic fertilizer.

Phosphorus is a major pillar for crop production in general and for acid soils in particular. It is considered as key to metabolism because of its involvement in various energy reactions. It is also needed for proper root development and early maturity of grain. The water soluble phosphorus when applied in acid soil is prone to fixation as Fe and Al-P and it has been reported that around 80 per cent of added soluble phosphate get fixed within 15 days of application. The direct application of cheap unprocessed reactive ground phosphate of Indian origin and imported are recommended to reduce the cost of fertilizer and to improve efficiency in acid soils. In India the estimated phosphate rock deposit is around 145 million tones, most of these phosphate rocks are of low grade and not suitable for their use in the production of chemically processed water soluble source of phosphatic fertilizer.

We started the systematic use of rockphosphate as direct source of P in crop production with the introduction of mussoorie rockphosphate. The suitability of mussoorie rockphosphate in acid soils have been proved unquestionably.

The major rice growing tracts of Kerala is acidic in nature where direct application of rockphosphate has a great potential. Kuttanad alluvium and laterites are the two main rice growing tracts of Kerala. The crop is grown in flooded condition in these soils. The behaviour of various phosphatic fertilizers in these soils should be known for a better fertilizer management. The mussoorie phosphate has proved its efficiency in Kuttanad and laterite soils and has been used by farmers of Kerala.

There are also a few most reactive phosphate rocks available in the world viz., North Carolina from U.S.A. and Gafsa from Tunisia. It is not economical to bring and utilise North Carolina rockphosphate from U.S.A. in India. However Tunisia Rockphosphate from Gafsa mines can find its use in India considering its efficacy and economics.

It is under this context, the problem entitled "Suitability of Tunisia (Gafsa) rockphosphate for direct application in the acid rice soils of Kerala" was taken up with the following main objectives.

1. To evaluate the effectiveness of Tunisia rockphosphate as a source of P compared to single superphosphate, diammonium phosphate and mussoorie rockphosphate in acid rice soils of Kerala.

2. To compare the residual effect of the above rockphosphates with continuous application of superphosphate.

3. To study the transformation of phosphorus from these phosphatic fertilizers in acid rice soils under submerged condition.

REVIEW OF LITERATURE

The phosphorus need of crops is commonly met, with the conventional water soluble sources of phosphorus namely single superphosphate, diammonium phosphate, triple superphosphate and complex fertilizers. But the phosphorus applied in this water soluble form often gets fixed. In this context it was found that application of some of naturally occurring high reactive phosphate rocks either of Indian origin or imported are more beneficial especially in acid soils.

Literature regarding status of P in Kerala soils, factors affecting available P, response of crop to P fertilizers, transformation of applied phosphorus, interaction of phosphorus with other nutrients, release of phosphorus as affected by P fertilizer, comparison of rockphosphates and residual effect of P sources are briefly explained in this chapter.

2.1 Status of P in rice soils of Kerala

2.1.a Laterite soil

Koshy and Thomas (1972) reported that laterite soils in general were low in available P content and had high P fixing capacity. Mathew (1985) reported a total nitrogen content of 887.2 ppm of which only 4.79 ppm was available. The predominant inorganic fraction was Fe-P followed by Al-P.

Vijayan (1993) reported a Fe-P content of 4.28 to 121.13 ppm vs Al-P content of 5.7 to 113.05 ppm. The 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 soil varied from 468.3 to 1806 ppm and available P was only 13.28 ppm.

2.1.b Kuttanad soil

Kuttanad soil in general were found to have a low phosphorus content (Venugopal, 1969, Varghese *et al.*, 1970 and Ghosh *et al.*, 1973). Mathews recorded a total P content of 793.40 ppm in Kari soils, of which only 3.84 ppm contributed to available fraction. Among the different inorganic fractions, there was predominance of Fe-P followed by Al-P in Kuttanad soil.

According to Vijayan (1993) the total P content of Kuttanad alluvium varied from 178.0 to 1490.80 ppm of which only 4.53 ppm was found to be available. The predominant inorganic fractions were Fe-P, Al-P, Ca-P and saloid phosphate.

2.2 Factors affecting availability of phosphorus

Dissolution of phosphate rock is the first step in transformation followed by utilisation by plants. It gives idea about solubility behaviour which may be related to agronomic effectiveness. Dissolution of rockphosphate governed by three factors namely reactivity of phosphate rock, soil factor and plant factors. These factors either alone or in combinations greatly influence the dissolution of rock-phosphate.

The dissolution and availability of phosphorus mainly depend on few characters of soil and source. One such major character is pH of soil.

Singh and Datta (1973) observed that citrate solubility of rockphosphate and pH of the soil were the most important factors governing availability and particle size of rockphosphate had little effect on solubility at low pH values.

Cooke (1978) identified soil pH, climate, and land use as some of the factors limiting the potential use of phosphate rock in England and Wales. The dissolution of North Carolina phosphate rock was significantly correlated with pH in acid Colombian soil (Chien *et al.*, 1980).

In a laboratory equilibration study Chaudhary and Mishra (1980) showed that transformation of rockphosphate in soil was mainly related to soil acidity and phosphate potential as these two accounted for 94 per cent variation in different soil.

The calcium phosphate in rocksphosphate gets easily acidulated by the soil acidity and phosphorus in it will become easily available to plants. Thus the ground rockphosphate has been found as a good source of phosphorus in acid soils due to its easy dissolution (Subramanian and Manjunath, 1983).

Anderson *et al.* (1985) noticed that the release of phosphorus from rockphosphate declined sharply, when the pH of soil was progressively increased by liming. They also found that the relative agronomic effectiveness of rocks were directly related to their substituted CO_3^{2-} content and the crystal size.

Kanabo and Gilkes (1988) found that dissolution of North Carolina rockphosphate was more in soil with pH 3.76 than in a soil with pH 5.09 and the dissolution decreased with incubation period.

Kumaraswamy (1995) reported that crop plants differ widely in their ability to absorb the phosphorus from the rockphosphate. Soil reaction, organic matter content and nature and extent of root system are found to influence the dissolution and absorption of phosphorus from rockphosphate.

2.3 Release of phosphorus in soil by different type of P fertilizers

Native and added water soluble monocalcium phosphate gets fixed in acid soil as iron and aluminium phosphate due to formation of insoluble precipitate with the dominant active ions of Fe and Al and thus availability of phosphorus for plant growth becomes limited. But when water insoluble tricalcium phosphate like rockphosphate is applied, less stable calcium phosphate gets easily acidulated by the soil acidity and organic acids of the organic matter and get converted to monocalcium phosphate. This is a very slow reaction. Along with this low cost of rockphosphate has tempted several scientists to investigate on the performance of rockphosphate as a source of phosphatic fertilizer for acid soils.

Mehrotra (1968) reported that finely ground rockphosphate could supplement the superphosphate in meeting the phosphorus requirement of wheat for the upland soils of U.P.

Puri (1969) observed that it is natural to obtain significant response to S/P since Indian soils are deficient in calcium and sulphur and especially so under high R.F. content.

Motsara and Datta (1971) found that application of P_2O_5 at the rate of 80 kg ha^{-1} through superphosphate and rockphosphate gave similar yields of paddy wheat and maize. Rockphosphate was better than SSP with respect to crop yield and residual phosphate status of soil.

Mandal and Khan (1972) studied the release pattern of phosphorus from insoluble phosphorus materials in acidic low land rice soils of West Bengal. They observed that rockphosphate maintained a higher level of available phosphorus than superphosphate due to larger P fixing capacity of those soils.

Minhas and Kich (1974) opined that in acid soils rockphosphate can easily replace SSP and is an economical source of phosphate for plant growth. Singh and Dutta (1974) reported that Udaipur and Mussoorie rockphosphate to be as good as superphosphate in acid soils.

However, according to Sarangnath *et al.* (1975) water soluble phosphate in P deficient laterites red and black soils gave good performance in terms of grain yield and P uptake by rice. But rockphosphate was less effective and was more or less comparable to control.

Singh and Datta (1973) in an incubation study with Laccadive phosphate earth and mussoorie rockphosphate reported that citrate solubility of phosphate rock and pH of soil are the most important factors governing the availability of P from rockphosphate.

According to Singh *et al.* (1976) SSP far excelled as a phosphate sources to all indigenous rockphosphate. They found that laccadive mussoorie and Udaipur rockphosphate as having 67, 66 and 64 per cent of effectiveness of SSP.

Prasad and Dixit (1976) reported that acidic laterite soils of Mangalore showed significant response of rice to application of rockphosphate, but not with superphospate of equal rates. Kadrekar and Talashilkar (1977) also reported the better performance of rockphosphate compared to S/P in paddy soils of Maharashtra.

Shinde *et al.* (1978) opined that rockphosphate from Gafsa could be made as efficient as superphosphate for growing rice in phosphorus deficient acid soils by their direct application 2-3 weeks prior to flooding and transplanting. In an incubation study Chien (1978) found increased amount of Bray-I extractable P from the soil treated with phosphate and the amount of Bray-I extractable P in the soil correlated well with citrate soluble P of phosphate rock.

Mishra and Gupta (1978) in a green house study obtained lower P uptake from mussoorie rockphosphate in comparison to superphosphate. The relative agronomic effectiveness of mussoorie rockphosphate was only 66.7 per cent of single superphosphate.

Tiwari *et al.* (1979) reported maximum efficiency of rockphosphate as seen from crop response and phosphorus uptake was about 50 per cent compared to SSP. Kulkarni (1980) reported that mussoorie rockphosphate was effective as single superphosphate for rice.

Nair and Padmaja (1982) from their experiments suggested that rock-phosphate could effectively replace water soluble phosphate in rice culture provided it was applied to the moist soil two weeks before flooding.

Jaggi and Luthra (1983) observed same agronomic values for mussoorie rockphosphate in comparison with water soluble sources in acid soils.

Subramanian and Manjunath (1983) comparing the mussoorie rockphosphate with SSP in ragi and paddy reported that the response of MRP was equal and is not more than SSP.

Chakraborty *et al.* (1986) observed similar wheat yield by SSP and mussoorie rockphosphate application under lateritic acid soils. In a multilocational trial involving indigenous sources of phosphorus under varying climatic condition, Gopalakrishna *et al.* (1986) found the possibility of substituting more soluble chemically processed P sources with mussooriephos for direct application in acid soil.

Regi and Jose (1986) reported that uptake of P by rice and available P content of soil were significantly higher in treatment receiving superphosphate than rockphosphate.

In a field trial conducted in different locations of farmers holdings, Pandurangaiah *et al.* (1986) noticed that performance of MRP to be on par with single superphosphate in improving the yield of rice in acid to neutral soils.

Karanth (1987) found that the response of mussoorie rockphosphate over superphosphate was on par in terms of grain yield of paddy whereas Krishnappa *et al.* (1987) reported that availability of P_2O_5 in the soil increased due to increased level of P_2O_5 irrespective of the source and maximum availability was noticed in

MRP treatments and least in SSP suggesting least fixation of P applied in the form of rockphosphate.

Dash *et al.* (1988) reported that the effect of phosphate rock from Gafsa is comparable and some times superior to Triple Superphosphate. The influence of reactivity of phosphate rock on available P in soil, dry matter production and nutrient uptake by daincha crop was examined and found that there was a significant correlation between citrate soluble P of the rock with Olson P, yield, N uptake and P uptake by daincha crop.

Dwivedi *et al.* (1989) studied relative efficiency of MRP and SSP in acid soil under maize-wheat and soyabean-wheat cropping sequence and found that performance at MRP was always superior to SSP regarding increased crop yield and phosphate availability.

Sharma (1995) reported an increase in soil P with application of different phosphatic sources. The SSP had resulted a higher P content than other applied sources.

Rajkhowa and Baroova (1996) reported that with increase in level of applied phosphorus there was increase in yield, available P content of soil and P uptake.

2.4 Comparison of rockphosphate

Rockphosphate from different sources will vary depending on the crystallographic properties of apatite mineral (Lehr and McClellan, 1972, Banerjee, 1979 and Luthra *et al.*, 1983).

Singh *et al.* (1976) studied the order of efficiency of rockphosphate from different sources and found as Laccadive > Mussoorie > Udapur. Singh and Datta opined Udaipur and Mussoorie rockphosphate to be as good as superphosphate in acid soils.

Shinde *et al.* (1978) in their phosphorus transformation studies indicated that the transformation from North Carolina, Gafsa and Jordhan rockphosphate was more than that from Honda rockphosphate.

Mathur *et al.* (1979) compared the igneous and sedimentary phosphate rocks of Bihar in acid red loam soil and reported that sedimentary phosphate rocks raised the soil pH and available phosphorus, but igneous ones left more residual phosphorus. Availability from mussoorie rockphosphate was more than from Udaipur or Laccadive deposits in Karnataka soils of varying acidity.

In a laboratory equilibration study Choudhary and Mishra (1980) showed that in transformation of rockphosphate in soil, acidity and phosphate potential accounted for 94 per cent variation in different soils. They also observed that dissolution and breakdown of rockphosphate from Udaipur and Jordan was inferior compared to Jhabua, Mussoorie and Kassipattanam rockphosphate.

Dash *et al.* (1980) from CRRI, Cuttack compared different rock-phosphates namely Kassipatanam, Mussoorie, Udaipur, Mahanagar, Jhamarkota and Purulia and found that they were not as efficient as North Carolina rockphosphate which was as good as superphosphate in acid soils. Hellums *et al.* (1989) reported that efficiency of P release in an incubation study followed the order of SP > MRP > Udaipur rockphosphate.

Biswas and Narayanaswamy (1995) reported that there was an increase in Olsen's P status of soil over P control irrespective of source of rockphosphate and level of P application.

Shyamala *et al.* (1995) reported that during an incubation study the release of P from Tunisia rockphosphate was more than that of Rajphos and Mussooriephos. The reason for high activity of mussooriephos is due to CO_3-apatite, high surface area and sedimentary nature.

Violet D'Souza (1995) observed that Gafsa rockphosphate performed better than Mussooriephos in a given level of P fertilizer at pH of 5.1 and 6.1.

2.5 Response of crop to phosphatic fertilizer

Water soluble phosphatic fertilizers when added to acid soils undergo fixation and thus availability of phosphorus for plant growth becomes limited. But when rockphosphate is applied into these soils the less stable calcium phosphate get acidulated by soil acidity and organic acids and becomes slowly available to plants. This has encouraged the use of rockphosphate as a source of P in increasing production. The various works have been conducted in this field and promising results have been given by different workers.

Kanwar and Grewal (1958) reported that among the different forms of phosphatic fertilizers to maize, sorghum and wheat, rockphosphate was found to be the most suitable.

Mehrotra (1968) reported that finely ground rockphosphate could supplement the superphosphate in meeting the P requirement of wheat for upland soils of U.P.

Motsara and Datta (1971) reported that rockphosphate as significantly better than superphosphate with respect to crop yield and residual P status.

Atanansu (1971) has reported that fertilizer containing water soluble phosphate showed a good response to yield of plants. More over Rhenania phosphate soluble in ammonium citrate had a better fertilizer effect than superphosphate in acid soils as well as in calcareous and alkaline soil. He also reported that in Kenya and Liberia on laterite soil the citrate soluble phosphate had a better effect than water soluble form.

Minhas and Kich (1974) reported that in acidic soils rockphosphate can easily replace superphosphate and is an economical source of phosphorus for plant growth. Similarly Singh and Datta (1974) reported that mussoorie rockphosphate compared well with superphosphate in acid soils of Coorg using paddy as test crop.

Sarangamath *et al.* (1977) reported that water soluble phosphate in P deficient laterites, red and black soils gave good performance in terms of grain yield and P uptake in rice. But rockphosphate was less effective and more or less comparable to control.

Prasad and Dixit (1976) reported that acid laterite soils gave significant response of rice to rockphosphate but not with superphosphate at equal rate.

Vardhan *et al.* (1977) reported that rockphosphate and superphosphate in acid soils of Bangalore did not differ significantly with respect to grain yield of ragi. Marwaha and Kanwar (1981) reported significant increase in yield and phosphorus uptake by wheat with rockphosphate application.

Nataraja *et al.* (1983) reported mussoorie rockphosphate as a good source of phosphorus compared to single superphosphate (SSP) in acid soil for ragi.

Subrahmaniyan and Manjunath (1983) while comparing the performance of superphosphate and mussooriephos on ragi and paddy in near neutral and acidic range soils reported that response to mussooriephos is equal if not more than superphosphate. Kadrekar *et al.* (1983) reported that rockphosphate as having equal effectiveness of superphosphate as a source of P in laterite soil.

Regi and Jose (1986) reported that phosphorus uptake by rice and available P content of the soil were significantly higher in treatment receiving superphosphate than rockphosphate. Rockphosphate was found to be less effective than fully processed fertilizer phosphate in soils with pH range of 5 to 7.

Pandurangaiah *et al.* (1986) reported that Mussoorie rockphosphate was on par with single superphosphate in improving yield of rice in acid to neutral soil. Karanth (1987) found that effect of MRP and SSP was on par in grain yield of rice. The effect of North Carolena rockphosphate and Gafsa rockphosphate are comparable and some time superior to TSP (Dash *et al.*, 1988). Dwivedi *et al.* (1989) studied the relative efficiency of mussoorie rockphosphate and single superphosphate in acid soil under maize-wheat, soyabean-wheat cropping sequence and found that performance of MRP was having superiority to SSP in increasing the crop yield and phosphate availability. Sadanandan and Hamza (1995) reported that mussoorie rockphosphate had a higher yield over single superphosphate. Patil *et al.* (1995) in a pot culture study using SSP, NP, MRP and URP found that SSP and NP were significantly superior to MRP and URP in increasing the drymatter yield and uptake of maize. But in second crop the MRP and URP gave increased dry matter yield.

2.6 Transformation of phosphorus in soil

There are many procedures for fractionation but the most commonly used one is that of Cheng and Jackson which was latter modified by Peterson and Corey (Hesse, 1971). The inorganic P identified in the process are saloid-P, Al-P, Fe-P, reductant soluble phosphorus, occluded phosphorus and calcium phosphate. The proportion of these fractions varied with soil pH, soil characteristics, moisture regime; period of incubation and level of application.

Ponnamperuma (1955) observed that waterlogging had a pronounced influence on the transformation of phosphorus. He confirmed the observation of many other workers that solubility of phosphate in both soil solution and acid extracts increased on submergence. According to Hsu and Jackson (1960) the phosphorus transformation in soil is mainly controlled by pH. It is seen that iron phosphate and aluminium phosphate dominate in acid soils. While calcium phosphate dominated the alkaline soil (Hsu and Jackson, 1960, Wright and Deech, 1960, Chang and Chu, 1961, Jose, 1973, Sharma *et al.*, 1980). Hsu and Jackson (1960) in a study of Wisconsin soil suggested that in a highly weathered soil with high iron oxide and high iron activity the content of iron phosphate was higher compared to other fractions.

Chang and Chu (1961) attributed the increased availability to the greater accumulation of Fe-P in submerged soil and greater mobility of iron in reduced condition. Mahapathra and Patrick (1969) found that waterlogging generally increased aluminium and iron phosphate, reduced reductant soluble phosphate and did not much affected calcium phosphates. They also found that, in black alluvial and red soil, calcium phosphate predominated over other fractions but was in traces in laterite soil where Fe and Al-P dominated.

Debnath and Hajra (1972) recovered most of the added phosphorus in the order of Al-P > Fe-P > Ca-P. On aging the quantity of Fe-P increased and that of Al-P decreased irrespective of soil characteristics and moisture regime. But the rate of change of added phosphate was found affected by moisture regime.

Jose (1973) in his studies on phosphorus transformations found a decrease in available phosphorus, saloid bound phosphorus and aluminium phosphate with increase in period of incubation. He also observed that irrespective of pH of soil aluminium phosphate was found in high amount initially, a part of which was transformed to iron phosphate in soils of relatively low pH and to calcium phosphate in soils of high calcium phosphate with lapse of time.

According to Mandal and Khan (1975) continuous waterlogged condition is beneficial for the availability of soil native phosphorus in acid soils.

Gupta and Nayan (1975) obtained an increase in iron phosphate content due to waterlogging. He also observed that iron phosphate as the dominant fraction in UP soils with pH up to 6.7.

Singh and Singh (1975) reported the conversion of added phosphorus to iron aluminium and calcium phosphate during waterlogging. Many reports showed that amount of iron and aluminium phosphate enhanced markedly while that of Ca-P decreased with period of incubation.

Singh and Ram (1977) showed that the conversion of added phosphorus to aluminium phosphate was more pronounced in laterite soil and conversion to calcium phosphate was low in acidic soil.

Sharma *et al.* (1980) studied the transformation of added phosphorus and found an increase in aluminium phosphate content upto 7 days which decreased slowly with the time till 90 days. The conversion of iron phosphate fraction increased slowly with time upto 90 days and a very little change was observed in calcium phosphate.

Nair and Padmaja (1982) in the rice soils of Kerala found that the added phosphorus was mainly converted to aluminium phosphate and iron phosphate.

Kumaraswamy (1995) reported that during incubation the dissolution and transformation of rockphosphate to Al-P and Fe-P showed a steady increase while the Ca-P did not show such increase.

Sharma and Sangrai (1993) reported an increase in content of available phosphorus as the incubation proceeded. The higher value was recorded for SSP compared to rockphosphate. The Al-P and Fe-P fraction of soil showed an increase in content till 12th week of incubation.

Sushama *et al.* (1995) observed a continuous increase in Al-P and Fe-P and available phosphorus with period of incubation.

2.7 Residual effect of rockphosphate

Only about 10 to 30 per cent of phosphorus applied to the soil is removed by the first crop and the rest will be remaining in the soil. Rockphosphate were found to be 93 to 94 per cent as effective as superphosphate as far as their residual value is considered (Singh *et al.*, 1976).

Sharma *et al.* (1976) compared different phosphorus sources for their direct and residual effect on potato and found that their direct effects as not good but residual effect similar to superphosphate. Khanna and Choudary (1979) observed that there exists no difference in yield of succeeding crops by different P sources.

Krishnappa *et al.* (1979) reported that an increase in yield of ragi grain and straw observed was due to residual effect of rockphosphate, superphosphate and dicalcium phosphate.

Raychowdury (1980) reported that only 10-30 per cent of phosphorus applied to soil was removed by the first crop and the rest will be remaining in the soil.

Marwah and Kanwar (1981) had observed the residual effect of rockphosphate to an extent of 48.7 per cent to 74.1 per cent compared to superphosphate for corn.

Gupta *et al.* (1983) found that the response of residual rockphosphate was curvilinear and they stated that for better efficiency of phosphate in a wheat paddy cropping system the application of phosphorus should be to wheat crop and its residual effect could be obtained in paddy crop.

Sahu and Pal (1983) stated that the residue of rockphosphate left after rice harvest had increased the grain and straw yield of succeeding wheat significantly.

Ramaswamy and Arunachalam (1983) reported that rockphosphate left more available phosphorus in soil compared to superphosphate after harvest of first crop. Natarajan *et al.* (1983) observed that residual effect of MRP as very effective in acid soils.

Poojari *et al.* (1987) reported significant increase in yield of succeeding crop of groundnut due to application of MRP to Kharif paddy in acid soils of Karnataka.

It is generally observed that the residual effect of phosphorus during first two cropping seasons was mainly depending on the citrate solubility of added material and this will disappear by a third cropping season.

Prakashan *et al.* (1987) in a laboratory incubation study with phosphorus as superphosphate MRP and Udaipur rockphosphate in an Ultisol on the available P content in soil during early stage of incubation indicated better performance of SSP in its combination with rock phosphates as compared with other treatments. In later stage of incubation higher P content was with higher dose of MRP.

Singaram (1995) in his studies on maize did not find any difference with any dose. By calculating the residual effect of rockphosphate with a crop in which SSP was applied he found that the residual effectiveness for SSP/PR and PR in relation to SSP were respectively 84 and 61 per cent.

2.8 Interaction of phosphorus with other nutrients

It has been found that application of rockphosphate in soil had a positive effect on the calcium content of soil. Singh *et al.* (1988) reported an increase in exchangeable cations like Na, K, Ca and Mg with increasing P application.

Hellums *et al.* (1989) recorded a higher calcium content increase by application of rockphosphate and noted that magnitude of increase was directly related to higher reactivity of applied rockphosphate.

Jaggi and Luthra (1995) reported that N uptake of crop was increased by P application. Manjunatha and Shankar (1995) reported à higher uptake of N with higher level application of phosphorus with organic matter.

Materials and Methods

MATERIALS AND METHODS

The study Entitled "Suitability of Tunisia Rock Phosphate for Direct application in acid rice soils of Kerala" was conducted in Horticultural College, Vellanikkara during 1993-95.

The study consisted of two experiments (1) An incubation study with two soils, four sources of phosphorus and three levels of phosphorus in order to study the transformation of phosphorus from the different sources under waterlogged condition.

Second experiment was a potculture experiment with the same soils, P sources and P levels using rice as a test crop grown continuously for two seasons in order to study the direct and residual effect of added phosphorus under rice cutlure in waterlogged condition.

3.1 Collection of soil samples

Two major acid soils of Kerala namely laterite and Kuttanad alluvium soils were collected from Pananchery in Trichur and Kidangara in Alapuzha district respectively. The soils collected were dried in sunshade, powdered, sieved and used for incubation and potculture experiment. The two soils were analysed for the basic properties and the analytical data are given in Table 1.

3.2 Incubation study

The incubation study was carried out with two types of soil (laterite, Kuttanad alluvium). Four sources of phosphorus namely Tunisia rockphosphate (TRP), Single superphosphate (SSP), Mussoorie rockphosphate (MRP) and Diammonium phosphate (DAP) and 3 levels of phosphorus (22.5, 45 and 67.5 kg P_2O_5 ha^{-1}) in a completely randomised design with two replications. The Mussoorie rockphosphate and Tunisia rockphosphate, imported from Tunisia were supplied by M/s.Pyrites Phosphates and Chemicals Ltd. A thirteenth treatment without phosphorus as control and another treatment with SSP applied on first and 120th day were also carried out in both soils. The analyses of these fertilizers are given in Appendix 1.

Treatment combinations used were the following

Treatment No.	Treatment notation	Forms and levels of P_2O_5 (kg ha^{-1})	Soil type
1	2	3	4
1	TRP-P_1	TRP 22.5	Laterite
2	TRP-P_2	TRP 45	,,
3	TRP-P_3	TRP 67.5	,,
4	SSP-P_1	SSP 22.5	,,
5	SSP-P_2	SSP 45	,,
6	SSP-P_3	SAP 22.5	,,
7	DAP-P_1	SAP 22.5	,,
8	DAP-P_2	DAP 45	,,
9	DAP-P_3	DAP 67.5	,,
10	MRP-P_1	MRP 22.5	,,
11	MRP-P_2	MRP 45	,,
12	MRP-P_3	MRP 67.5	,,
13	Control	No P	,,
14	SSP(P_2+P_2)	Single superphosphate was given on the first and 120th day of incubation	,,

1	2	3	4
15	TRP-P_1	TRP 22.5	Kuttanad alluvium
16	TRP-P_2	TRP 45	,,
17	TRP-P_3	TRP 67.5	,,
18	SSP-P_1	SSP 22.5	,,
19	SSP-P_2	SSP 45	,,
20	SSP-P_3	SSP 67.5	,,
21	DAP-P_1	DAP 22.5	,,
22	DAP-P_2	DAP 45	,,
23	DAP-P_3	DAP 67.5	,,
24	MRP-P_1	MRP 22.5	,,
25	MRP-P_2	MRP 45	,,
26	MRP-P_3	MRP 67.5	,,
27	Control	No P	
28	SSP(P_2+P_2)	Single superphosphate was given in the first and 120th day of incubation	,,

The 14th and 28th treatments were included in the study to determine residual effect of rockphosphates applied only once in comparison with the residual effect of SSP applied twice, the second application being 120 days after the first application.

3.3 Experimental Procedure

Five hundred gram of air dried soils was transferred to plastic containers. The phosphatic fertilizers were applied as per the treatment combination described above and mixed well. The soils were kept in a water logged condition throughout the experiment, keeping a layer of water of 2 cm above the soil and incubated at room temperature for 240 days. Soil samples were drawn at 15, 30, 45, 60, 90, 120, 150, 180, 210 and 240th day for the determination of available P, fractions of inorganic P, available nitrogen, calcium, magnesium, potassium and pH. Also leachate was collected at 15 days interval to study the leaching loss of N, P and K.

3.4 Analytical procedure

The Mechanical analysis of original soil samples was done using International Pipette method (Piper, 1942) pH was determined using an elico pH meter in a 1:2.5 soil water suspension. Also specific conductance of 1:2.5 soil water extract was measured using a conductivity bridge. Total nitrogen of soil was estimated by Microkjeldahl method given by Hesse (1971). Total phosphorus of the soil was extracted by diacid extract and was determined by Vanadomolybdophosphoric yellow colour method in nitric acid system (Jackson, 1958). The samples drawn in incubation study were analysed for different parameters as follows.

pH

The pH of 1:2.5 soil water suspension was measured using a pH meter.

Available Nitrogen

The available nitrogen of soil at various interval was studied using the alkaline permanganate method developed by Subbiah and Asija (1956).

Available phosphorus

The available phosphorus content of the soil was estimated using Bray I extractant (Jackson, 1958) and Mathews triacid mixture (Mathew, 1979).

Bray No. 1 method

Five g of air dry soil was equilibrated for 5 minutes in 50 ml of 0.03N NH_4F + 0.025N HCl solution. Filtered through Whatman No.40 filterpaper and the P content in the extract was estimated.

Mathew's triacid method

Five g of air dry soil was equilibrated for 30 minutes in 50 ml Mathew's triacid mixture (0.06N H_2SO_4 + 0.06N HCl and 0.05N oxalic acid) and filtered through Whatman No.40 filter paper. The concentration of P in the extract was estimated (Mathew, 1979).

The phosphorus content of solution was determined colorimetrically using L ascorbic acid as the reductant as described by Hesse (1971).

Available potassium

Available potassium was estimated by extraction with 1N ammonium acetate solution as given by Hesse (1971).

Available calcium and Magnesium

Available calcium and magnesium in soil were extracted using 1N ammonium acetate solution and were determined by titration with Ethylene

Diammonium Tetra Acetic acid and in the presence of metal ion indicator (Hesse, 1971).

Calcium

Five ml of soil extract was taken. Added 3 ml of 5 per cent hydroxyl amine hydrochloride and 5 ml of potassium cyanide, 10 drops of triethanol amine and 4 ml of KOH solution diluted to 30 ml with water and titrated against the EDTA using calcon as indicator. The colour change from wine red to purple blue indicated the end point.

Magnesium

To 5 ml of soil solution added 5 ml of potassium hexacyanoferate, 10 drops of triethanol amine, 10 ml of Ammonium chloride - ammonium hydroxide buffer and 2 drops of erichrome black indicator and titrated against EDTA. At the end point the wine red colour of the solution changed to pure blue.

Fractions of soil phosphorus

For the fractionation of soil inorganic phosphorus procedure given by Chang and Jackson (1957) as modified by Peterson and Corey (1966) was followed (Hesse, 1971). The fractions such as Al-P, Fe-P and Ca-P were determined.

Aluminium bound P

To determine the Al-phosphate the saloid bound P has to be removed first. For that soil was extracted by shaking 0.5 g of soil with 25 ml of NH_4Cl for 30 minutes and the soil was saved. The same soil was again extracted with 25 ml of 0.5N NH_4F (pH 8.2) for one hour and then centrifuged. Phosphorus in the extract was estimated colorimetrically using boric acid to prevent the interference of fluride ions and using L ascorbic acid as reductant.

Iron bound P (Fe-P)

The soil saved from Al-P estimation was washed twice with 12.5 ml of saturated NaCl solution and centrifuged and decanted. The soil was then shaken with 25 ml of 0.1 NaOH for 4 hours and then centrifuged. After flocculation of organic matter in the extract with a few drops of concentrated H_2SO_4 and centrifuged and then P was estimated in clear extract colorimetrically.

Calcium bound Phosphorus

After extraction of iron bound phosphorus, the soil in the centrifuge tube was washed twice with 12.5 ml each of saturated NaCl solution. The washed residue was then shaken for one hour with 0.5N H_2SO_4, centrifuged and phosphorus was estimated colorimetrically from the extract.

Leachate Analysis

Leachate from incubation was collected at 15 days interval using a polythene tube with a sieving mechanism fitted at lower end of incubation pot and loss of available nitrogen, phosphorus and potassium was estimated.

Available Nitrogen

Available nitrogen of the leachate was estimated by Macrokjeldahl distillation using Devardas alloy. The ammonia liberated was collected in boric acid and estimated by back titration with 0.2N H_2SO_4 (Hesse, 1971).

Available Phosphorus

Available P in the leachate was estimated with colorimeter after blue colour development in ascorbic acid system as described by Hesse (1971).

Available Potassium

Available potassium in the leachate was estimated by directly reading in flamephotometer.

3.5 Pot culture experiment

Pot culture experiment was conducted with two soils, 4 sources of phosphorus and 3 levels of P using a photoinsensitive rice variety (Thriveni) in order to study the direct and residual effect of Tunisia rock in comparison with the other sources of phosphorus used in the study. The soils, sources and levels of P were exactly same as those used in incubation study. The experiment was laid out in a completely randomised design with 3 replications. A treatment without phosphorus (control) and another with SSP applied during first and second crop seasons were also used.

The residual effect of rockphosphates was assessed by continuing the experiment for the second season without application of phosphatic fertilizers. However, the 14th and 28th treatments received SSP both in first and second season at the rate of 45 kg P_2O_5 ha^{-1} to compare the residual effect of rockphosphate applied once with that of SSP applied for every crop.

3.6 Experimental procedure

The soils were dried, powdered and filled in earthern pots at the rate of 7.5 kg pot^{-1}. Sufficient water was added to the pots to wet the soil and to create a puddled condition. Application of N, K and organic matter was done as per the package of practices (90 kg N, 45 kg K_2O and 5 tones organic manure/ha) as recommended by KAU (Anon., 1993). Phosphorus was applied in different forms and levels as per the treatment combinations.

Rice seedlings were raised by wet method using the seeds obtained from Regional Agricultural Research Station, Pattambi. Seedlings of 25 days old were transplanted to the pots at the rate of 3 hills/pot with two seedlings in each hill. Plant protection and other interculture operations were carried out as per package of practices recommendations of KAU (Anon., 1993). Standing water was retained in the pot till 15 days before harvest. The biometrical observations such as height of plants, number of leaves, number of tillers and dry weight of plants were estimated at critical stages of plant growth viz., maximum tillering, panicle initiation and harvest stages. Soil and plant samples were drawn from the pots at these critical stages and leachate was collected from each pot at 15 days interval to determine the leaching loss of N, P and K.

3.7 Collection of soil and plant samples for analysis

Soil samples were collected from each pot at maximum tillering, panicle initiation and harvest stages of each crop to study the release of phosphorus and availability status of other nutrients. The collected soil samples were mixed thoroughly, air dried powdered and used for analysis of nutrients.

Plant samples were collected from each pot by destructive method at critical stages (MT, PI and harvest) of plant growth. These samples were dried, ground and used to study the uptake of nutrients.

3.8 Analytical procedure

3.8.1 Soil samples

Available nitrogen was analysed by Alkaline permanganate method reported by Subbiah and Asija (1956), available phosphorus was estimated by Bray No.1 extractant, available Ca, Mg and potash was extracted by neutral normal ammonium acetate and estimated. Also change in pH was determined using an Elico pH meter.

3.8.2 Plant samples

Plant samples collected were used for determination of uptake of N, P, K, Ca and Mg. For the determination of N, P, K, Ca and Mg in plant sample, 1 g of sample was digested with 10 ml of diacid extractant containing perchloric and nitric acid in 1:3 ratio. The P content in the extract was determined colorimetrically by Vanadomolybdophosphoric yellow colour method in nitric acid system (Jackson, 1958). The K in the extract was read with flame photometer and calcium and magnesium was determined titrimetrically using calcon as indicator. Nitrogen content of samples was determined by Microkjeldahl digestion-distillation method as described by Jackson (1958). Leachate analysis was carried out just as in the case of incubation study.

3.9 Statistical analysis of data

Statistical analysis of the data was carried out by adopting the standard methods described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

In order to study the suitability of Tunisia (Gafsa) rockphosphate for direct application in the acid rice soils of Kerala, a laboratory incubation study and two successive pot culture experiments were carried out using laterite and Kuttanad alluvium soils. The results are presented and discussed in this chapter.

4.1 General characters of soil

The physio-chemical characters of the soils used in the study are given in Table 1.

Laterite soil was of sandy clay loam type with a pH of 5.7 while Kuttanad soil also had same textural class with a pH of 4.6. Both the soils used were of low P content groups. The total phosphorus content in laterite soil was 824 ppm and available P content was 5.5 ppm. But in Kuttanad soil it was 222 ppm and 0.66 ppm respectively. When extracted with Mathew's Triacid extractant the corresponding values were 20.5 ppm and 23.5 ppm respectively for laterite and Kuttanad soils. The organic carbon content was 1.06% for laterite and 1.54% for Kuttanad soil. The available nitrogen, potassium, calcium, magnesium status were higher for Kuttanad soil. The results on the chemical analysis of the soil samples drawn during the course of incubation are discussed in the following paragraphs.

4.1.1 Available nitrogen content

The data on change in N content with period of incubation are schematically presented in Fig. 1 and 2. The data are presented in Table 2 and 3.

Table 1. Physico-chemical characters of soils

Characteristics	Laterite	Kuttanad
Coarse sand %	8.18	5.20
Fine sand %	56.20	67.40
Silt %	31.20	16.30
Clay %	4.42	11.10
Textural class	Sandy clay loam	Sandy clay loam
pH	5.70	4.60
CEC (m eq. 100 g^{-1})	10.8	13.1
Base saturation (%)	62.4	72.2
EC (dS m^{-1})	0.12	0.37
Org. Carbon %	1.06	1.54
Total N %	0.22	0.32
Total P (ppm)	824.00	222.00
Available nitrogen (ppm)	248.30	432.00
Available phosphorus (ppm)	* 5.50, 23.5	0.66, 20.5**
Available potassium (ppm)	44.50	108.50
Available calcium (ppm)	11.20	23.60
Available magnesium (ppm)	2.80	5.80
Sesqui oxide (%)	31.40	12.60

* With Bray-I Extractant

**With Mathew's Extractant

The data showed a general decreasing trend with period of incubation in both laterite and Kuttanad soils. In laterite soil the N content for all the sources of phosphate decreased from 15th to 60th day. From 60th day to 150th day the available N content fell rapidly and there after showed a stabilised value. The content of N in different treatments were comparable through out the incubation.

For Kuttanad soil the available N content showed a steady decrease till 90th day of incubation. From 90th to 120th day the content showed a sudden decrease and then showed a gradual decrease till the end of incubation. The data did not show any gradation with dose. In all treatments N content at the starting time was around 480-520 ppm which reduced to around 300 ppm on 240th day. In Kuttanad soil among all sources, DAP gave a higher content of nitrogen. For which the highest value came on 15th day and the lowest value was with mussooriephos T_{10} and T_{12} on 240th day of incubation.

It was found that in both soils the different P sources and different doses gave comparable value for nitrogen content. But the two soil types showed an absolute difference in their N content which may be attributed to the inherent variation in physio-chemical properties of soil.

4.1.2 Available phosphorus

The available phosphorus content of soil during the entire period of incubation was determined using two extractants namely Bray-I extractant and Mathew's triacid extractant. The data are presented in Tables 4 to 9, also the change is expressed graphically in Fig.3 to 6.

Table 2. Available Nitrogen during incubation as influenced by treatments at different period (Laterite) ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	277.20	266.00	266.00	264.00	254.80	204.40	187.60	182.00	176.40	176.40
2	TRP-P_2	282.80	260.40	257.60	257.60	224.00	204.40	184.80	179.20	176.40	173.60
3	TRP-P_3	277.20	257.60	257.60	254.80	224.00	200.40	190.40	187.60	182.00	176.40
4	SSP-P_1	305.20	257.60	260.40	249.20	240.80	193.20	190.40	179.20	176.40	170.80
5	SSP-P_2	271.60	260.40	243.60	229.60	226.80	195.90	193.20	182.00	173.60	170.80
6	SSP-P_3	268.80	249.20	252.00	252.00	215.40	196.00	198.80	187.60	176.40	170.80
7	DAP-P_1	265.70	260.10	243.60	243.60	224.00	201.60	207.20	187.60	179.20	168.00
8	DAP-P_2	274.40	246.40	240.80	229.60	218.40	190.40	184.90	179.20	173.60	179.20
9	DAP-P_3	277.20	254.80	252.00	238.00	221.20	190.40	198.80	193.40	184.80	168.00
10	MRP-P_1	280.00	268.80	248.20	229.60	221.20	187.60	176.40	173.60	170.80	170.80
11	MRP-P_2	277.20	252.00	246.40	240.80	210.00	187.90	190.40	182.00	176.40	170.80
12	MRP-P_3	263.20	243.60	240.80	226.60	210.00	187.60	184.80	176.40	176.10	168.00
13	Control	268.80	266.00	243.60	226.00	232.40	190.40	184.80	179.20	173.60	168.00
14	SSP(P_2+P_2)	277.20	243.40	235.20	232.40	224.00	182.00	181.90	176.40	173.60	180.80

Fig 1. Change of available nitrogen during incubation - Laterite soil

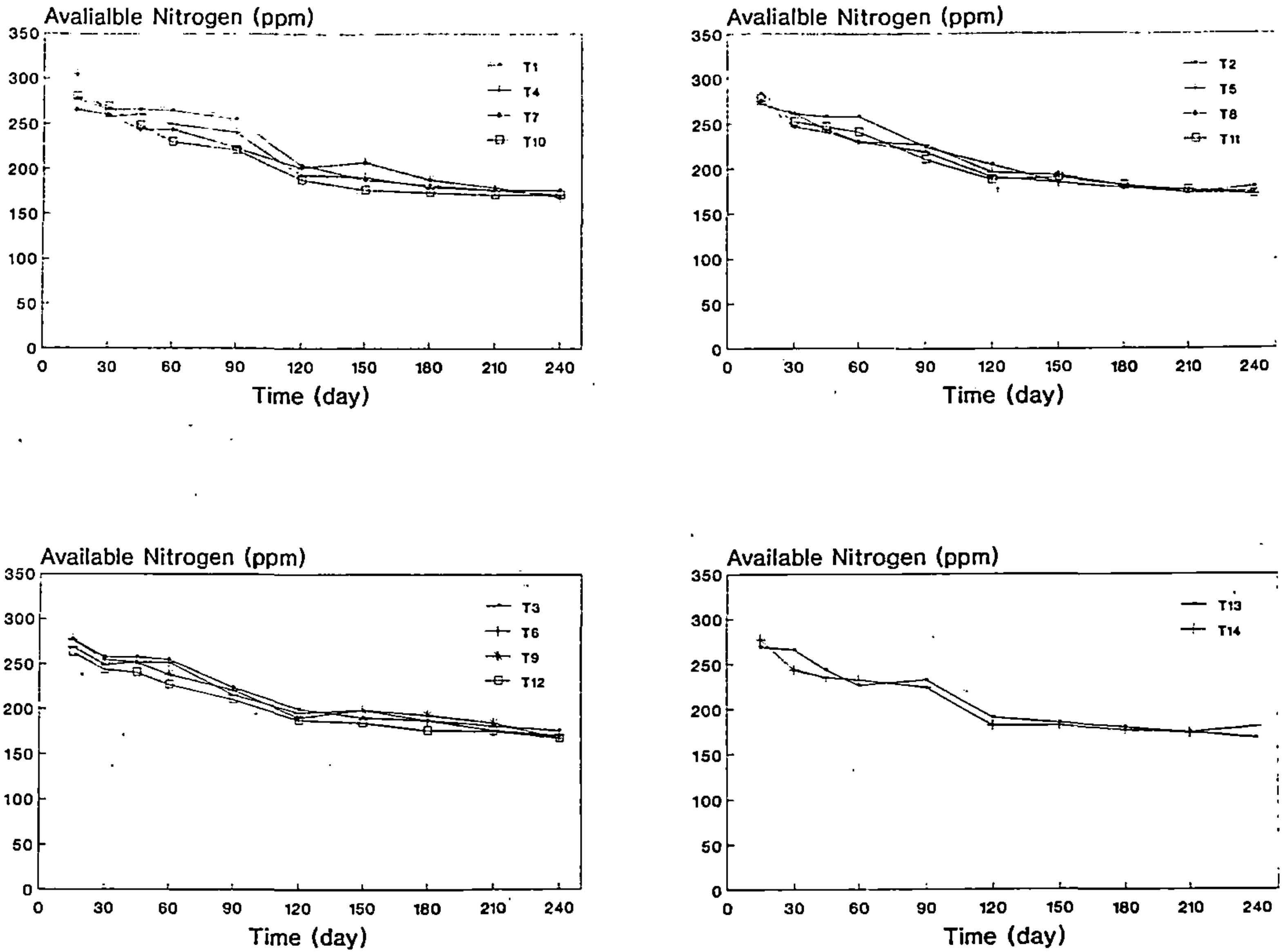
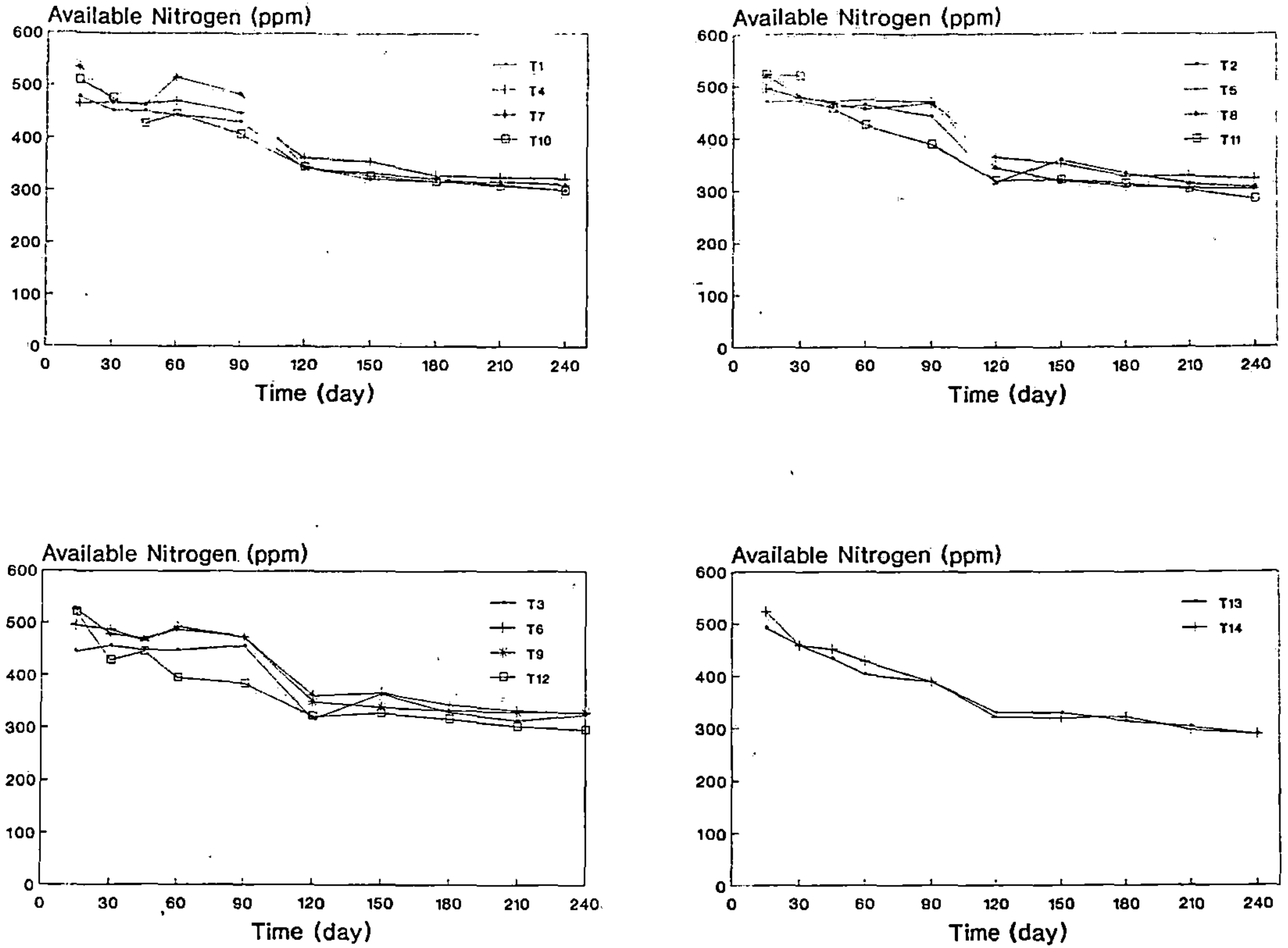


Table 3. Available Nitrogen during incubation as influenced by treatments at different period **(Kuttanad)** ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	478.80	452.00	450.80	442.40	430.90	341.80	333.20	322.00	310.80	299.60
2	TRP-P_2	470.40	470.40	459.20	464.80	442.40	316.40	359.20	333.20	313.60	305.20
3	TRP-P_3	445.40	456.40	448.00	448.00	456.40	316.40	364.00	330.40	313.60	324.80
4	SSP-P_1	464.80	467.60	464.80	470.40	448.00	361.20	355.60	327.60	324.80	322.00
5	SSP-P_2	495.60	476.00	470.40	473.20	470.40	364.00	352.80	327.60	327.60	322.00
6	SSP-P_3	495.60	487.20	464.80	492.80	473.40	361.20	366.80	344.40	333.20	327.60
7	DAP-P_1	535.95	467.60	462.00	515.20	483.20	344.40	322.00	316.40	316.40	310.80
8	DAP-P_2	520.80	478.80	467.60	456.40	467.60	344.40	319.20	308.00	305.20	302.40
9	DAP-P_3	526.40	478.80	470.40	487.20	473.20	349.75	338.80	333.20	330.40	330.40
10	MRP-P_1	509.60	476.00	426.40	445.20	406.00	344.40	327.60	316.40	308.00	299.60
11	MRP-P_2	523.60	518.00	456.40	425.60	389.20	319.20	322.00	313.60	302.40	282.80
12	MRP-P_3	520.80	428.80	445.20	394.80	383.60	322.00	327.60	316.40	302.40	296.80
13	Control	492.80	459.20	434.00	403.20	389.20	330.40	330.40	313.60	302.40	288.40
14	SSP(P_2+P_2)	523.60	459.20	450.80	428.40	388.60	322.00	319.20	322.00	296.80	288.40

Fig 2. Change of available nitrogen during incubation - Kuttanad alluvial soil



4.1.2.1 Laterite soil

The data reveal that on 15th day the maximum P release was by diammonium phosphate followed by single superphosphate, Tunisia rockphosphate and mussoorie rock phosphate using Bray-I extractant. Mean value of available phosphorus for different sources are TRP 10.53, SSP 11.01, DAP 11.39 and MRP 7.76 (Table 8). The control had a value of 5.49 ppm. But when analysed with Mathew's extractant the maximum content of phosphorus was associated with TRP followed by DAP, MRP and SSP. DAP was comparable to TRP. The contents were 27.26, 26.39, 26.27 and 26.16 respectively and control gave value of 23.48 ppm on 15th day.

On 30th day the P release by SSP, DAP, TRP and MRP were comparable. For SSP mean content was 9.72 ppm and the DAP, TRP and MRP gave available Phosphate content of 8.86, 8.78 and 8.08 ppm respectively. The analysis with Mathew's extractant gave comparable value for all the sources. The mean values were 27.72, 27.60, 27.26 and 26.72 respectively for SSP, TRP, DAP and MRP (Table 8).

On 45th day of incubation the mean available phosphorus estimated by Bray-I extractant was comparable for all the sources. The SSP and DAP had mean P content of 9.35 ppm and 9.41 ppm while TRP and MRP recorded 8.76 and 8.27 ppm respectively. The individual treatment with maximum P release in this period was SSP - P_3 (Table 4). The analyses with Mathew's extractant gave values of 28.55, 28.50, 28.49 and 27.99 for DAP, MRP, TRP and SSP. Thus TRP had a higher content than SSP.

Table 4. Available phosphorus (Bray-I) as influenced by the treatments at different period of incubation (Laterite) ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_I	9.14	7.83	8.60	8.49	8.82	9.66	6.66	6.48	6.11	6.81
2	TRP-P_2	10.83	9.32	8.14	9.31	9.15	9.66	8.08	7.94	6.48	7.30
3	TRP-P_3	11.46	9.13	9.32	13.49	11.65	11.96	9.16	8.41	8.12	8.31
4	SSP-P_I	10.61	8.12	7.81	8.66	7.64	8.14	6.48	6.66	6.29	6.48
5	SSP-P_2	11.31	9.28	9.52	12.56	8.97	8.99	7.66	7.16	6.83	8.41
6	SSP-P_3	10.80	11.99	10.67	13.49	12.80	12.31	9.16	8.00	7.81	7.49
7	DAP-P_I	10.49	9.11	8.90	11.10	9.66	8.41	7.66	6.99	6.25	6.26
8	DAP-P_2	12.16	9.52	9.18	10.64	11.44	9.32	7.40	7.33	7.66	6.83
9	DAP-P_3	11.25	10.87	9.91	13.62	12.78	12.00	9.49	8.79	7.66	7.00
10	MRP-P_I	7.33	7.49	7.14	8.49	6.99	7.16	6.49	6.48	6.00	6.16
11	MRP-P_2	7.14	7.72	7.97	8.97	7.99	7.83	6.49	6.81	6.66	7.66
12	MRP-P_3	8.66	8.99	9.66	9.29	8.97	9.49	7.16	7.12	6.66	6.99
13	Control	5.49	6.32	6.33	7.00	6.63	6.11	5.63	5.51	5.16	4.76
14	SSP(P_2+P_2)	10.06	9.52	8.00	10.32	10.97	8.99	14.66	11.77	10.99	10.80

Table 5. Available phosphorus (Mathew's triacid extraction) as influenced by the treatments at different period of incubation (Laterite) ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	26.33	24.66	25.66	27.17	30.17	32.49	29.66	26.63	25.49	24.49
2	TRP-P_2	28.66	30.49	31.00	31.16	32.98	33.48	31.83	30.17	26.33	25.49
3	TRP-P_3	30.83	32.00	33.66	34.17	34.99	35.17	33.49	31.49	28.99	26.63
4	SSP-P_1	26.83	28.17	27.66	29.30	31.17	29.66	29.50	27.17	25.63	25.17
5	SSP-P_2	28.48	28.17	28.49	29.48	31.66	32.17	30.98	26.48	26.63	25.49
6	SSP-P_3	32.67	35.65	33.15	34.17	36.16	33.48	32.33	32.33	28.83	28.15
7	DAP-P_1	24.45	25.17	28.17	28.49	30.99	27.83	26.16	25.99	25.99	25.17
8	DAP-P_2	26.33	26.49	26.66	27.99	30.67	31.68	32.16	31.83	28.33	26.99
9	DAP-P_3	30.17	30.49	31.49	32.17	33.17	35.66	34.33	31.16	28.33	28.16
10	MRP-P_1	23.49	25.49	26.17	27.49	28.67	28.17	28.17	27.16	25.80	25.16
11	MRP-P_2	25.00	27.49	28.49	30.16	31.49	32.17	31.16	30.67	28.82	27.17
12	MRP-P_3	31.17	31.49	32.17	32.66	33.17	34.49	32.66	31.83	30.17	27.99
13	Control	23.48	24.00	25.49	25.67	27.97	27.83	25.33	26.17	25.50	24.67
14	SSP(P_2+P_2)	25.17	26.66	26.66	27.83	28.49	28.83	30.10	30.80	28.49	26.60

Fig 3. Change of available phosphorus (Bray-I extractant) during incubation - Laterite soil

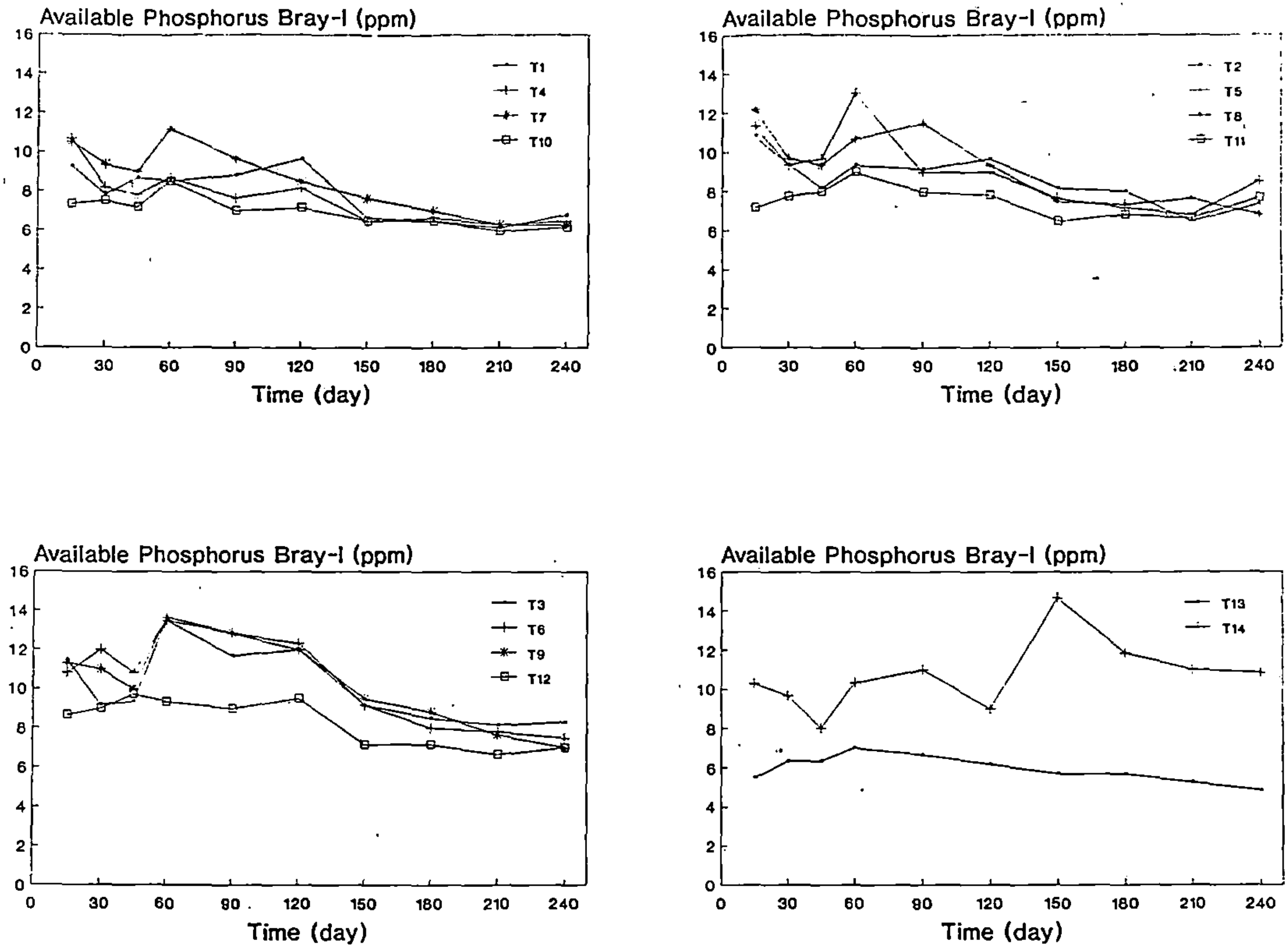
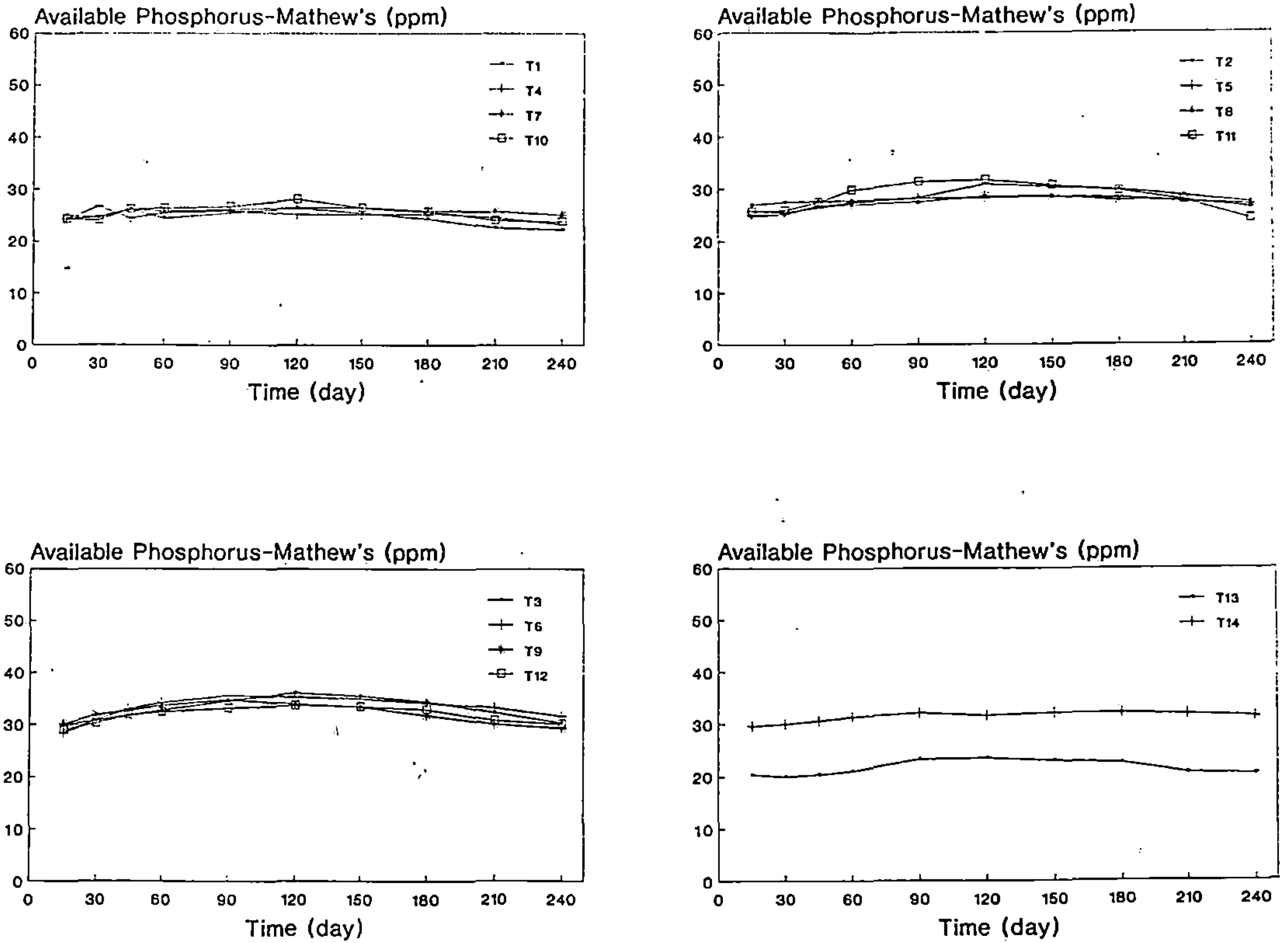


Fig 4 Change of available phosphorus(Mathew's extractant) during incubation-Laterite soil



On 60th day of incubation in laterite soil (Bray-I) the P release by DAP, TRP and SSP were higher than MRP. The DAP had a value of 11.78 ppm while SSP gave value of 11.43 ppm. The TRP and MRP gave values of 10.28 ppm and 8.96 ppm respectively. The Mathew's extractant shows that P release by MRP (29.55 ppm) was comparable with SSP, DAP (29.50, 28.84) and was higher than TRP with a content of 28.44 (Table 8).

On 90th day of incubation it was observed that P release was maximum for DAP followed by TRP, SSP and MRP and the values were 11.33, 9.89, 9.66 and 8.01 ppm respectively. Using Mathew's extractant the mean available phosphorus content were 30.39 (MRP), 29.98 (SSP) and 29.50 (DAP) and 30.32 ppm for TRP with MRP releasing a higher available P content than DAP.

On 120th day highest P release (Bray-I) was shown by TRP followed by DAP and SSP which were comparable. The MRP had the least value. The available P content corresponding to different sources were TRP 10.43 ppm, DAP 9.85 ppm, SSP 9.71 ppm and MRP 8.15 ppm. The extraction with Mathew's extractant gave the highest values with rockphosphates (MRP 31.15, TRP 31.11) while with SSP and DAP the contents were less and were 29.55 and 29.66, respectively (Table 8).

On 150th day the available P content (Bray-I) was comparable for DAP,TRP and SSP but DAP had a higher content than MRP. The mean available contents were in the order of 7.91, 7.70, 8.15 and 6.72 ppm respectively. When extracted with Mathew's extractant the different sources showed comparable value with TRP slightly superior to DAP. At this stage both the rockphosphates were found to have a higher value or comparable with water soluble sources.

On 180th day of incubation the phosphorus content (Bray-I) was comparable for all sources. The contents were 7.71 ppm, 7.61 ppm, 7.29 ppm and 6.84 ppm respectively for DAP, TRP, SSP and MRP. With Mathew's extractant the contents for different sources were as TRP 29.6, MRP 29.48, SSP 29.28 and DAP 28.58 ppm (Table 8). The rock phosphate showed a higher value in comparison with DAP similar to 120th and 150th day of incubation.

On 210th and 240th day of incubation all the four sources were having almost same content of available phosphorus when estimated with Bray-I extractant and Mathew's extractant.

The data clearly showed that for all phosphatic fertilizers used, the maximum P release (Bray-I) was on 60th day of incubation except for TRP. For TRP, the maximum content was on 15th day. It was found that during 15th day the SSP, TRP and DAP gave a higher value compared to MRP. After 15th day TRP showed a decrease till 45th day of incubation and again attained a higher value on 120th day. From 120th day onwards TRP showed decreasing trend while all other treatments decreased from 60th day itself. Thus it was clear that the treatments of DAP and SSP (water soluble sources) along with TRP gave a higher value in the first five sampling period but from 180th day onwards the MRP gave comparable value of available phosphorus with water soluble sources, underlining the fact that the rockphosphate had a higher residual P content compared to water soluble sources. The data with Mathew's extractant showed a maximum P release during 60th to 120th day of incubation and there after decreased without any regular pattern.

Table 6 . Available phosphorus (Bray-I) as influenced by the treatments at different period of incubation (Kuttanad alluvium) ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	2.83	2.63	2.63	2.83	3.50	4.00	4.00	4.76	2.64	2.49
2	TRP-P_2	3.05	3.16	2.82	4.28	4.00	4.47	4.33	3.83	3.33	2.98
3	TRP-P_3	3.94	3.46	3.31	4.76	6.66	5.49	4.47	3.83	3.68	3.31
4	SSP-P_1	2.00	2.45	2.58	3.49	4.53	4.16	3.65	2.64	2.28	2.58
5	SSP-P_2	3.26	3.33	3.26	4.32	4.32	4.79	4.49	3.16	3.20	3.46
6	SSP-P_3	3.52	3.46	3.52	4.66	6.89	5.48	4.96	3.31	4.00	3.46
7	DAP-P_1	2.00	2.31	2.45	2.58	3.64	4.00	3.65	2.33	2.31	2.64
8	DAP-P_2	2.15	3.33	3.31	4.00	4.00	3.65	3.78	3.31	3.65	2.79
9	DAP-P_3	2.15	3.64	4.47	5.55	3.87	4.92	3.98	3.66	3.80	3.60
10	MRP-P_1	2.00	2.98	2.71	2.58	3.52	4.41	3.65	2.64	2.64	2.64
11	MRP-P_2	2.48	2.45	3.05	3.32	3.73	3.80	3.98	3.24	2.66	2.92
12	MRP-P_3	2.48	3.16	3.65	3.33	3.93	4.98	4.32	4.13	2.98	3.12
13	Control	0.66	1.63	2.15	1.82	3.29	2.71	2.79	2.93	2.28	2.16
14	SSP(P_2+P_2)	1.62	3.12	4.13	3.64	4.21	4.47	4.49	4.65	4.08	4.32

Table 7. Available phosphorus (Mathew's triacid extractant) as influenced by the treatments at different period of incubation (Kuttanad alluvium) ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	24.83	24.50	26.16	24.49	25.48	26.33	25.50	24.49	22.67	22.33
2	TRP-P_2	26.98	27.48	27.66	27.83	28.33	30.83	30.33	29.83	28.67	27.16
3	TRP-P_3	29.98	30.83	34.66	32.99	37.16	36.16	35.50	34.48	32.33	30.33
4	SSP-P_1	24.16	26.67	24.49	25.49	25.82	25.15	25.16	25.33	24.67	23.30
5	SSP-P_2	25.83	25.49	26.49	27.49	28.47	28.17	28.50	28.33	27.48	26.80
6	SSP-P_3	28.48	30.99	32.99	34.17	35.66	35.33	34.99	34.17	33.33	31.67
7	DAP-P_1	24.17	24.65	26.17	25.80	26.17	26.50	26.49	26.00	25.83	25.17
8	DAP-P_2	24.83	25.16	26.83	27.05	27.49	28.49	28.49	27.83	27.67	26.30
9	DAP-P_3	30.17	31.98	32.66	33.67	34.83	33.99	33.49	31.91	30.17	29.30
10	MRP-P_1	24.17	23.99	26.16	26.33	26.67	28.13	26.80	25.80	24.17	23.83
11	MRP-P_2	25.65	25.83	27.49	29.83	31.33	31.66	30.67	29.65	27.82	25.99
12	MRP-P_3	28.98	30.33	31.83	32.48	33.17	33.66	33.50	32.98	30.83	30.15
13	Control	20.33	19.99	20.33	20.99	23.33	23.49	23.00	22.66	20.66	20.49
14	SSP(P_2+P_2)	29.66	29.99	30.67	31.33	32.17	31.67	32.16	32.17	32.33	31.49

Table 8. Mean value of available phosphorus during incubation with different extractants (Laterite)

Treatment		Period of incubation (ppm)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
	I. Bray I Extractant										
	a. Source										
1	TRP	10.53	8.78	8.76	10.28	9.89	10.43	7.91	7.61	6.88	7.51
2	SSP	11.01	9.72	9.35	11.43	9.66	9.71	7.70	7.29	6.98	7.48
3	DAP	11.39	8.86	9.41	11.78	11.33	9.85	8.15	7.71	7.19	6.74
4	MRP	7.76	8.09	8.27	8.96	8.02	8.15	6.72	6.84	6.46	6.96
5	Control	5.49	6.32	6.33	7.00	6.63	6.11	5.63	5.51	5.16	4.76
6	SSP (P_2+P_2)	10.06	9.52	8.00	10.32	10.97	8.99	14.66	11.77	10.99	10.80
	CD(0.05)	1.32	1.23	1.32	1.23	1.32	1.23	1.13	1.23	1.19	1.28
	b. Level										
1	P_1	8.69	8.03	7.80	8.95	8.39	8.02	7.50	7.12	6.61	6.70
2	P_2	10.23	8.97	8.74	10.32	9.38	8.96	7.39	7.33	6.91	7.57
3	P_3	10.56	10.21	9.95	12.37	11.52	11.43	8.70	8.09	7.56	7.47
	CD(0.05)	1.27	1.20	1.27	1.20	1.27	1.20	1.11	1.20	1.16	1.23
	II. Mathew's Extractant										
	a. Source										
1	TRP	27.26	27.60	29.49	28.44	30.32	31.11	30.44	29.60	27.89	26.61
2	SSP	26.16	27.72	27.99	29.05	29.98	29.55	29.55	29.28	28.49	27.26
3	DAP	26.39	27.26	28.55	28.84	29.50	29.66	29.49	28.58	27.89	26.92
4	MRP	26.27	26.72	28.49	29.55	30.39	31.15	30.32	29.48	27.61	26.66
5	Control	23.48	24.00	25.49	25.67	27.97	27.83	25.33	26.17	25.50	24.67
6	SSP (P_2+P_2)	25.17	26.66	26.66	27.83	28.49	28.83	30.10	30.80	28.49	26.60
	CD(0.05)	0.97	1.20	1.19	0.78	0.78	0.92	0.91	0.72	0.88	0.78
	b. Level										
1	P_1	24.55	24.97	25.66	25.74	26.61	26.88	26.52	26.08	25.05	24.44
2	P_2	25.82	25.99	27.12	28.05	28.90	29.79	29.50	28.91	27.91	26.56
3	P_3	29.40	31.03	33.03	33.33	35.21	34.78	34.37	33.39	31.67	30.36
	CD(0.05)	0.84	1.02	0.98	0.68	0.68	0.79	0.79	0.62	0.77	0.68

Table 9. Mean value of available phosphorus during incubation with different extractants (Kuttanad)

Treatment		Period of incubation (ppm)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
		I. Bray I Extractant									
	a. Source										
1	TRP	3.27	3.08	2.93	3.89	4.58	4.64	4.27	4.14	3.20	2.93
2	SSP	2.87	3.06	3.12	4.15	5.18	4.81	4.34	3.04	3.09	3.16
3	DAP	2.12	3.05	3.34	3.88	3.87	4.18	3.82	3.06	3.19	3.00
4	MRP	2.33	2.86	3.14	3.07	3.76	4.40	3.98	3.30	2.77	2.91
5	Control	0.66	1.63	2.15	1.82	3.29	2.71	2.79	2.93	2.28	2.16
6	SSP(P_2+P_2)	1.62	3.12	4.13	3.64	4.21	4.47	4.49	4.65	4.08	4.32
	CD(0.05)	1.32	1.23	1.32	1.23	1.32	1.23	1.13	1.23	1.19	1.27
	b. Level										
1	P_1	1.71	2.48	2.73	2.77	3.78	3.92	3.67	3.20	2.65	2.75
2	P_2	2.72	3.06	3.13	3.98	4.04	4.17	4.14	3.39	3.20	3.04
3	P_3	2.95	3.44	3.74	4.52	5.18	5.23	4.43	3.74	3.60	3.39
	CD(0.05)	1.27	1.20	1.27	1.20	1.27	1.30	1.11	1.20	1.16	1.23
		II. Mathew's Extractants									
	a. Source										
1	TRP	28.61	29.05	30.11	30.83	32.71	33.71	31.66	29.43	26.94	25.54
2	SSP	29.33	30.66	29.77	30.98	33.00	31.77	30.94	28.66	27.03	26.27
3	DAP	26.98	27.38	28.77	29.55	31.61	31.72	30.88	29.66	27.55	26.77
4	MRP	26.55	28.16	28.94	30.10	31.11	31.61	30.66	29.89	28.26	26.27
5	Control	20.33	19.99	20.33	20.99	23.33	23.49	23.00	22.66	20.66	20.49
6	SSP(P_2+P_2)	29.66	29.99	30.67	31.33	32.17	31.67	32.16	32.17	32.33	31.49
	CD(0.05)	0.97	1.20	1.13	0.78	0.78	0.92	0.92	0.72	0.88	0.78
	b. Level										
1	P_1	24.96	25.69	26.64	27.66	29.58	29.14	28.15	27.32	26.15	25.21
2	P_2	27.12	28.16	28.66	29.70	31.70	32.38	31.53	29.79	27.53	26.29
3	P_3	31.21	32.41	32.62	33.29	34.37	34.70	33.20	31.70	29.08	27.73
	CD(0.05)	0.84	1.04	0.98	0.68	0.68	0.79	0.79	0.62	0.77	0.68

The dose wise comparison showed that the lower dose of 22.5 kg P_2O_5 ha^{-1} gave maximum P release on 15th day which is corresponding to initial period of rice crop only. But the dose of 67.5 kg P_2O_5 ha gave highest P release corresponding to 60th day onwards, i.e., PI stage of plant. The data indicated that P application had a pronounced effect on available phosphorus content of the soil. The control showed a maximum value of 7 ppm only (Bray-I) and there after decreased.

The statistical analysis of the data at different periods of incubation showed that during incubation the available phosphorus content was significantly affected by type of soil and different doses of fertilizer. The different sources do not seem to make a significant impact on available P content. The different factors like soil, dose and type of source did not have interaction with each other.

4.1.2.2 Kuttanad soil

The data of available phosphorus content with Bray-I extractant at various stages of incubation are given in Table 7 and mean available P content is given in Table 9. On 15th day of incubation P release by different treatments was on par. The mean P contents by TRP, SSP, MRP and DAP were 3.27 ppm, 2.87 ppm, 2.33 ppm and 2.12 ppm respectively (Table 9). When extracted with Mathew's triacid extractant, the maximum mean P content was found associated with SSP followed by TRP, DAP and MRP.

On 30th day the (Bray-I) available phosphorus content was on par for all the sources. The mean P release content by different fertilizer showed content of 3.06 ppm with SSP, 3.05 ppm with DAP, 3.08 with TRP and 2.86 with MRP. The

Fig 5. Change of available phosphorus (Bray-I extractant) during incubation - Kuttanad alluvial soil

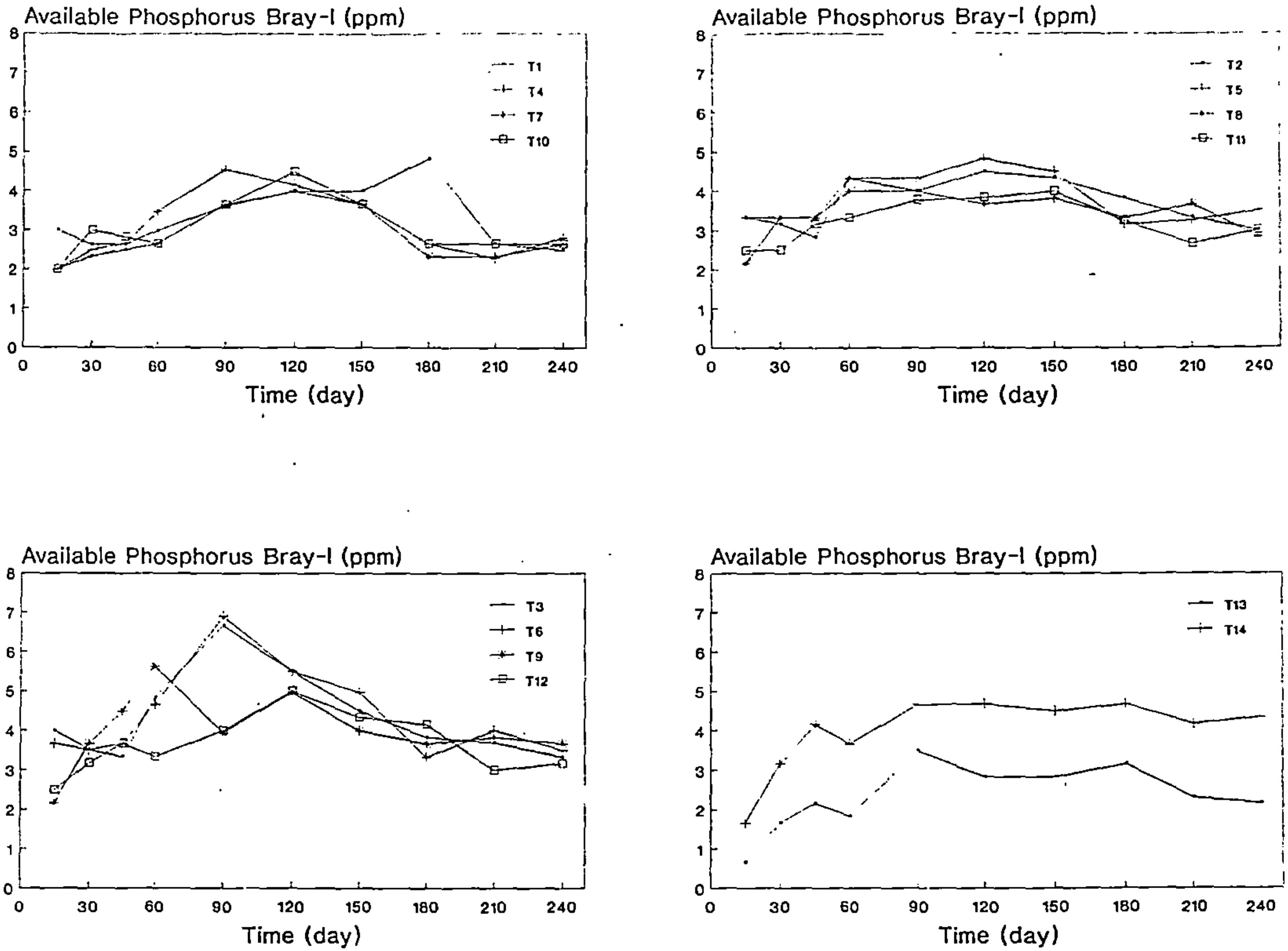
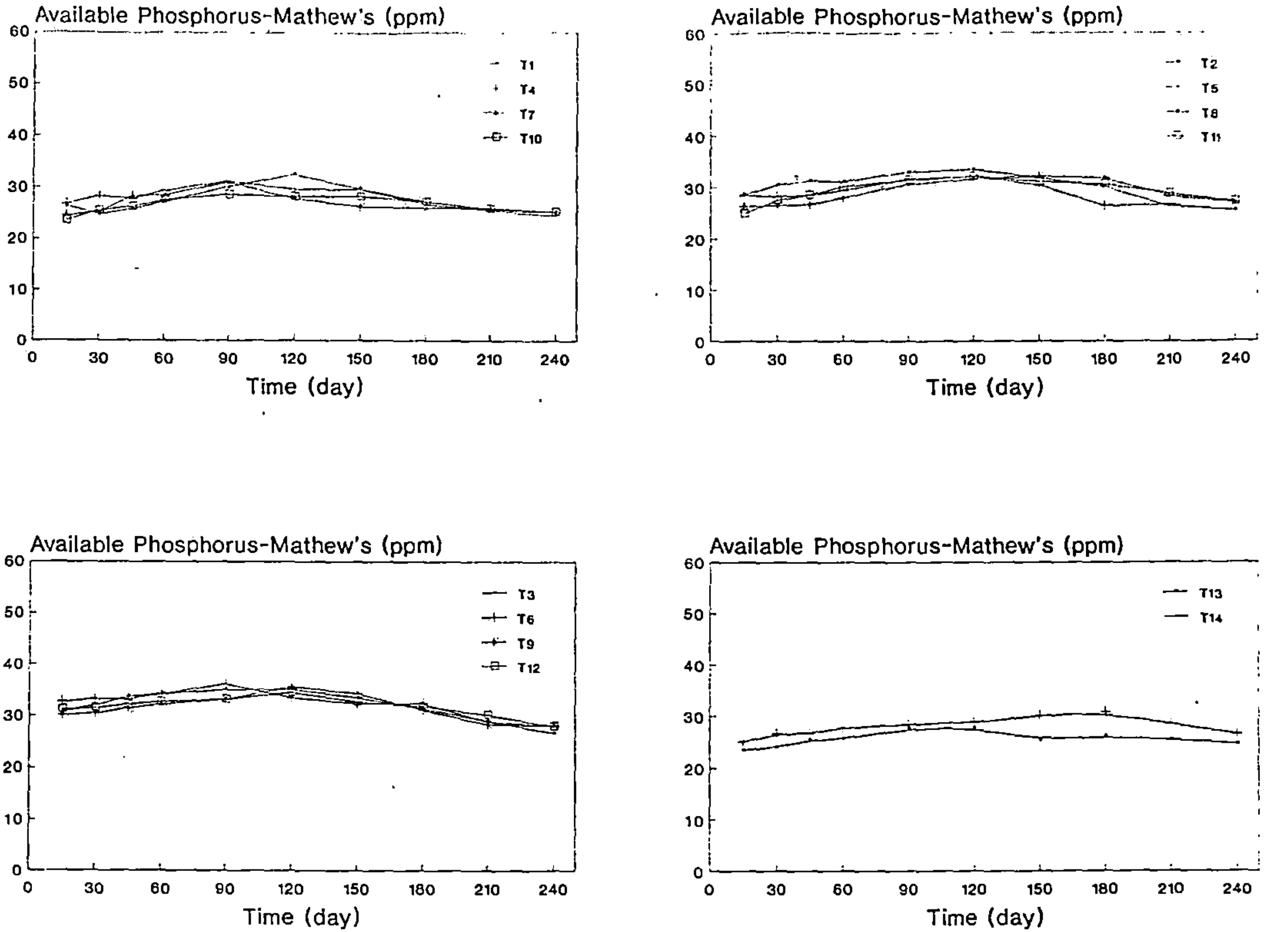


Fig 6. Change of available phosphorus(Mathew's extractant) during incubation-Kuttanad alluvial soil



Mathew's extractant P was high for SSP followed by TRP, MRP and DAP with a maximum content of 30.66 for SSP and a minimum of 27.38 for DAP (Table 9).

On 45th day the (Bray-I) P release by different sources was on par. The SSP and MRP had almost the same P content. The P content in soil (Mathew's) was found to be maximum in TRP followed by SSP, MRP and DAP. The TRP and SSP were comparable to each other.

In 60th day of incubation, P release by different treatments was in the same rate. The mean P content (Bray-I) by different treatments showed comparative values for SSP, DAP and TRP. The contents were 4.15 ppm for SSP and 3.07 for MRP, which showed difference with each other. The extraction with Mathew's extractant gave a comparable value for TRP, SSP and MRP. DAP showed lower value compared to TRP and SSP.

On 90th day available P content (Bray-I) for SSP was on par with TRP and TRP was on par with other sources also. The single superphosphate recorded a value of 5.17 and MRP 3.76 ppm. The Mathew's phosphorus was maximum in SSP 33.00 ppm followed by TRP, DAP and MRP. The TRP was on par with SSP and was superior to other treatments (Table 9).

On 120th day of incubation the phosphorus release was on par for various sources. The minimum release was by the control. The mean available phosphorus content (Bray-I) for SSP was 4.81 ppm followed by TRP, MRP and DAP (4.64, 4.40 and 4.18 ppm). With Mathew's extractant phosphorus content was maximum for TRP followed by SSP, DAP and MRP. The contents for TRP was 33.71 ppm.

On 150th day of incubation the analysis of available phosphorus content showed that different sources gave similar P release. The mean content (Bray-I) for SSP was 4.34 ppm followed by TRP 4.27 ppm, MRP (3.98 ppm) and DAP (3.80 ppm). The Mathew's phosphorus content was on par for TRP (31.66 ppm) SSP, DAP. MRP had a value comparable with SSP and DAP but lower than TRP.

On 180th day of incubation the mean P content for different fertilizers were TRP 4.14, SSP 3.04, DAP 3.06 and MRP 3.30 (Table 9). The Mathew's extractant had given a mean value of P (29.89 ppm) for MRP followed by 29.66 ppm for DAP. On 210th day of incubation mean values of phosphorus content by Bray-I were as DAP 3.19 ppm, TRP 3.20 ppm, SSP 3.09 ppm and MRP 2.77 ppm. The mean content of P when analysed with Mathew's extractant was maximum for MRP (28.26 ppm) which was comparable to DAP but higher than other two sources.

On 240th day of incubation the mean values of phosphorus content for various fertilizers were SSP 3.16 ppm, DAP 3.00 ppm, TRP 2.93 ppm and MRP 2.91 ppm. The SSP was having comparable P release with other sources using Bray-I extractant. But with Mathew's extractant the mean available phosphorus content was lower for TRP in comparison with other sources.

It was found that after 150th day of incubation SSP applied twice at the rate of 45 kg ha^{-1} had higher value of available phosphorus compared to various other treatments.

The P release (Bray-I) showed an increasing trend in first 45 days in all P sources except TRP in which decrease was noted up to 30th day and from 45th day an increasing trend was observed. For all other sources the maximum phosphorus release was attained on either 90th or 120th day. There after it decreased. Similar trend was observed for extraction with Mathew's extractant in all the different sources. Comparing all the treatments, TRP gave highest P release with Mathew's reagent on 120th day and Mussoorie rock phosphate showed the lowest phosphorus content.

The dose wise analysis showed that with Bray extractant the dose of 22.25 kg ha^{-1} gave a highest value of 3.92 ppm on 120th day. With 2nd dose the maximum P release of 4.17 was obtained on 120th day of incubation and the dose of 67.5 kg P_2O_5 ha^{-1} gave a highest P release of 5.23 ppm on 120th day of incubation. With Mathew's extractant the lower dose gave the highest value of P release on 90th day and other two doses gave on 120th day.

The statistical analysis of data showed that the available phosphorus content was significantly affected by type of soil and different doses of fertilizer. The different P sources did not make a significant impact on available P content when extracted with Bray-I extractant. But with Mathew's extractant the sources showed clear difference. Laterite soil resulted in a higher P release (Bray-I) compared to Kuttanad soil and as the doses increased available P content increased.

The data clearly shows that the available P status of soil can be increased by application of rock phosphates similar to water soluble phosphatic fertilizers. Previous studies also reported similarly for acid soils (Sharma and Sangrai, 1993; Shivanna *et al.*, 1995). In the earlier period of incubation maximum available phosphorus was recorded by water soluble forms viz., SSP and DAP. Using Bray-I extractant maximum release of phosphorus was obtained on 60th day for these sources and it is in confirmity with that reported by Shivanna *et al* (1995). But with Mathew's extractant maximum release of available phosphorus was obtained on 120th day for these sources. The quantity of available phosphorus extracted by Mathew's extractant was much more than Bray-I extractant. The variation obtained may be due to changes in the extracting power of extractant and high value recorded for Mathew's extractant may be due to chelating power of Carboxylic group present in Mathew's extractant. After 60th day the content was decreased. Among the rock phosphates TRP released maximum content of phosphorus and that too in the earlier days of incubation. From 120th day onwards a decrease was observed for TRP as well as for MRP. Fixation of the released P into insoluble Fe and Al-phosphate could be the reason for decrease in available P content as the period of incubation progressed. This result was in confirmity with the findings of Shyamala *et al.* (1995). The same trend was observed for Mathew's extractant after 120th day.

The study clearly showed that the P release in the Kuttanad soil was comparatively less compared to laterite soil. This may be attributed to the higher pH of laterite soil (around 6) compared to Kuttanad soil, at which various phosphatic fertilizers performed better (D'Sousa *et al.*, 1995).

The per cent recovery of phosphorus from different treatments was much less in Kuttanad soil (12.8% for TRP on 120th day) compared to laterite (35% for TRP on 120th day). This may be due to high fixation of available phosphorus in Kuttanad soil which resulted in a higher amount of fixed Fe and Al-P as indicated by high fractions of phosphate estimated in incubation period. The mean recovery of applied phosphorus was found to be maximum for lowest dose for all the sources of P in both soils.

The study also showed that mean P release in many of the sampling period of incubation was maximum with DAP and SSP in laterite soil. But it was least with MRP. In Kuttanad soil, the mean available P (Mathew's) content of SSP and TRP was higher in a number of sampling intervals. Here also the least content was associated with MRP. This observation of increased performance of Tunisia rock phosphate in Kuttanad soil may be due to low pH and high organic matter status of Kuttanad soil. Similar results were reported by D'Souza *et al.* (1995). The observation that TRP had a higher performance than MRP can be justified by the fact that being a CO_3 apatite the reactivity of TRP was higher and in addition to the high surface area and sedimentary nature enhanced the dissolution rate. Similar result was obtained by Shyamala *et al.* (1995). These results showed that TRP can be used as a source of P in the acid soils to substitute water soluble phosphatic fertilizer.

4.1.3 Available potassium

Laterite soil

The data of available potassium in laterite soil is expressed in Table 10. The available potassium content showed a sudden decrease in initial period till 45th day of incubation. From 45-120th day, there was a slight increase in available potassium content and maximum observed on 120th day. Then from 120th day onward the content again decreased. The maximum content was associated with SSP - 3rd level on 120th day of incubation (48.5).

Table 10. Available Potassium as influenced by treatments at different period of incubation (Laterite) ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	35.00	31.00	29.50	38.50	39.00	48.00	36.50	31.00	32.00	33.50
2	TRP-P_2	36.50	34.50	32.00	36.50	40.50	40.50	35.50	33.00	30.00	36.00
3	TRP-P_3	41.00	34.00	33.00	34.00	31.00	41.00	38.00	38.00	33.00	30.00
4	SSP-P_1	41.00	33.50	30.00	36.00	41.50	38.00	34.00	29.50	34.00	30.00
5	SSP-P_2	37.00	34.00	33.50	29.00	42.50	45.00	38.00	35.00	33.50	35.00
6	SSP-P_3	37.00	36.00	29.50	34.50	42.50	45.50	39.50	37.50	35.00	33.00
7	DAP-P_1	39.00	33.50	30.50	32.00	39.50	48.50	35.00	44.00	32.50	31.00
8	DAP-P_2	40.50	34.50	38.00	29.50	42.00	43.50	35.00	41.00	30.00	31.00
9	DAP-P_3	43.00	40.00	29.50	35.00	42.00	44.00	36.50	41.50	35.00	33.50
10	MRP-P_1	43.00	37.00	36.50	28.50	33.00	39.00	35.00	36.50	32.00	29.50
11	MRP-P_2	44.00	37.00	36.50	28.50	46.50	36.00	37.50	30.50	35.50	30.00
12	MRP-P_1	40.00	37.50	36.50	27.50	40.00	35.50	37.50	36.50	30.50	29.00
13	Control	44.50	35.00	30.00	37.00	47.00	40.00	34.00	39.00	33.00	31.50
14	SSP(P_2+P_2)	37.00	35.00	35.00	37.00	34.50	40.50	35.50	37.50	30.00	31.50

Fig 7. Change of available potassium during incubation- Laterite soil

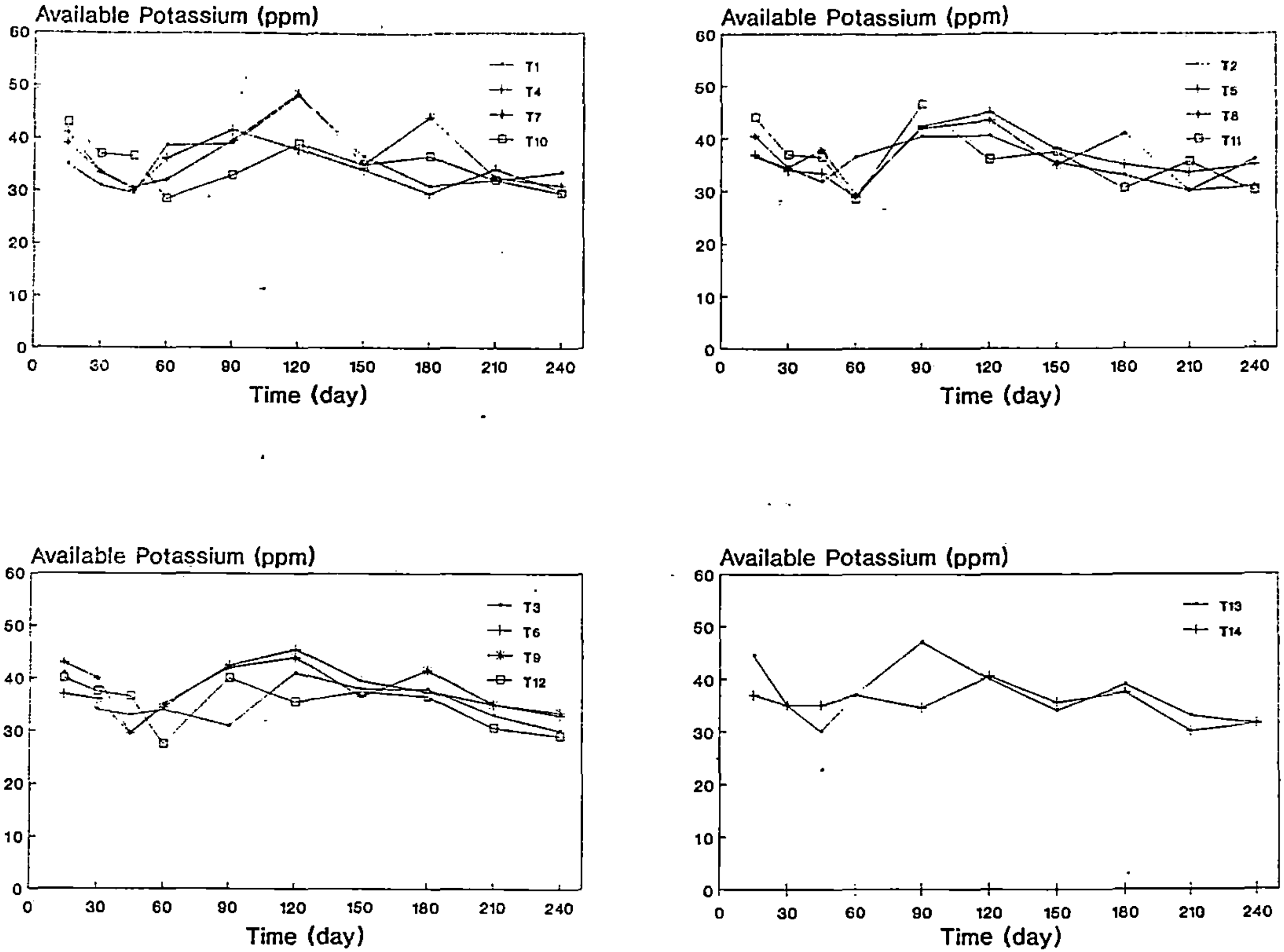
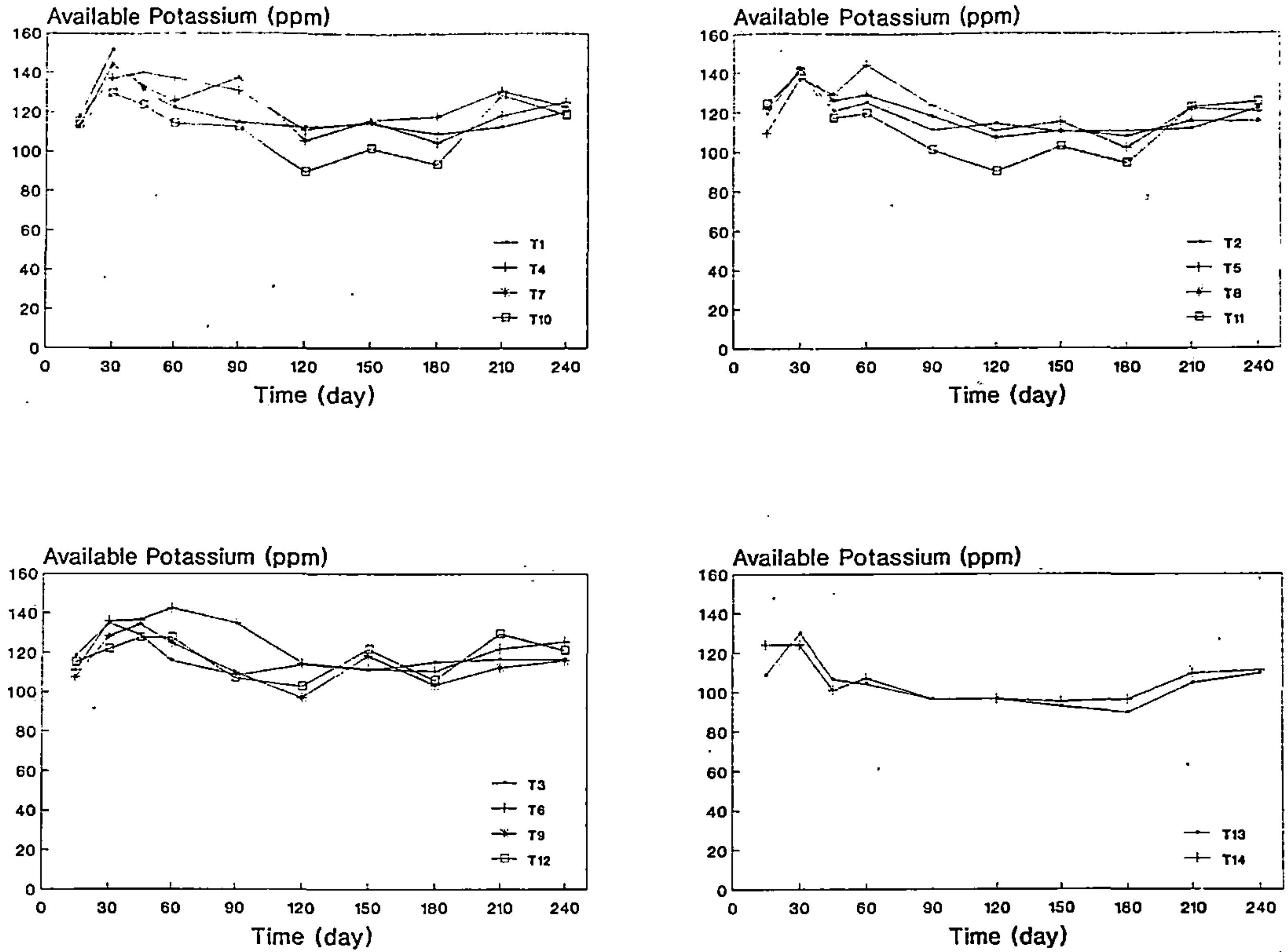


Table 11. Available Potassium as influenced by treatments at different period of incubation (Kuttanad) ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	117.50	151.50	131.00	122.00	115.00	112.50	114.00	109.00	112.50	120.00
2	TRP-P_2	119.00	142.00	120.50	125.00	111.00	114.00	110.00	110.50	111.50	121.50
3	TRP-P_3	118.50	135.00	129.00	116.00	108.50	114.00	111.00	115.00	116.50	116.50
4	SSP-P_1	117.00	137.00	140.00	137.00	130.50	111.00	115.00	104.50	118.00	125.00
5	SSP-P_2	109.50	137.00	129.00	144.00	123.50	110.50	115.00	102.00	122.00	120.00
6	SSP-P_3	111.00	136.00	136.50	142.50	135.00	114.50	111.50	110.50	122.00	125.50
7	DAP-P_1	113.00	144.00	133.00	125.50	137.00	105.50	116.00	117.50	130.50	122.50
8	DAP-P_2	121.50	142.00	126.00	129.00	118.00	107.00	110.50	108.00	115.50	115.00
9	DAP-P_3	107.50	128.50	134.50	125.00	110.00	97.00	118.50	103.50	112.50	116.00
10	MRP-P_1	113.50	129.50	123.50	114.00	112.50	90.00	101.50	93.50	128.50	118.50
11	MRP-P_2	124.00	140.50	117.00	119.50	101.00	90.00	102.50	94.00	122.50	125.00
12	MRP-P_3	115.00	122.00	127.50	127.50	107.00	102.50	121.50	106.00	129.50	121.00
13	Control	108.50	130.00	106.50	104.00	96.50	96.50	92.50	89.50	104.50	109.50
14	SSP(P_2+P_2)	124.00	124.00	101.00	107.00	96.50	96.50	95.00	96.50	109.50	111.00

Fig 8. Change of available potassium during incubation- Kuttanad alluvial soil



Kuttanad soil

The available potassium content showed an upward trend up to 45th day of incubation except for mussooriephos and DAP in which maximum value was 134 and 127 ppm (Table 11). Then content diminished till 120th day of incubation and then showed a stabilised effect. The different doses and different sources behaved in the same pattern. The highest available potassium content was associated with TRP-P_2 on 30th day of incubation (151.5 ppm) and the minimum content was given by control on 180th day of incubation (89.5 ppm).

The graphical expression of variation of different treatments with period of incubation is given in Fig.7 and 8. The figure revealed that there was no difference among different P sources during various period of incubation. Also different doses did not show any significant effect. But the two soil types used were significantly different.

4.1.4 Available calcium

The data are presented in Table 12 and 13. The effect of application of different rock phosphate on available calcium content in soil is shown graphically in Fig.9 and 10 and the content showed irregular behaviour during the period. The soils were found to show difference throughout the period.

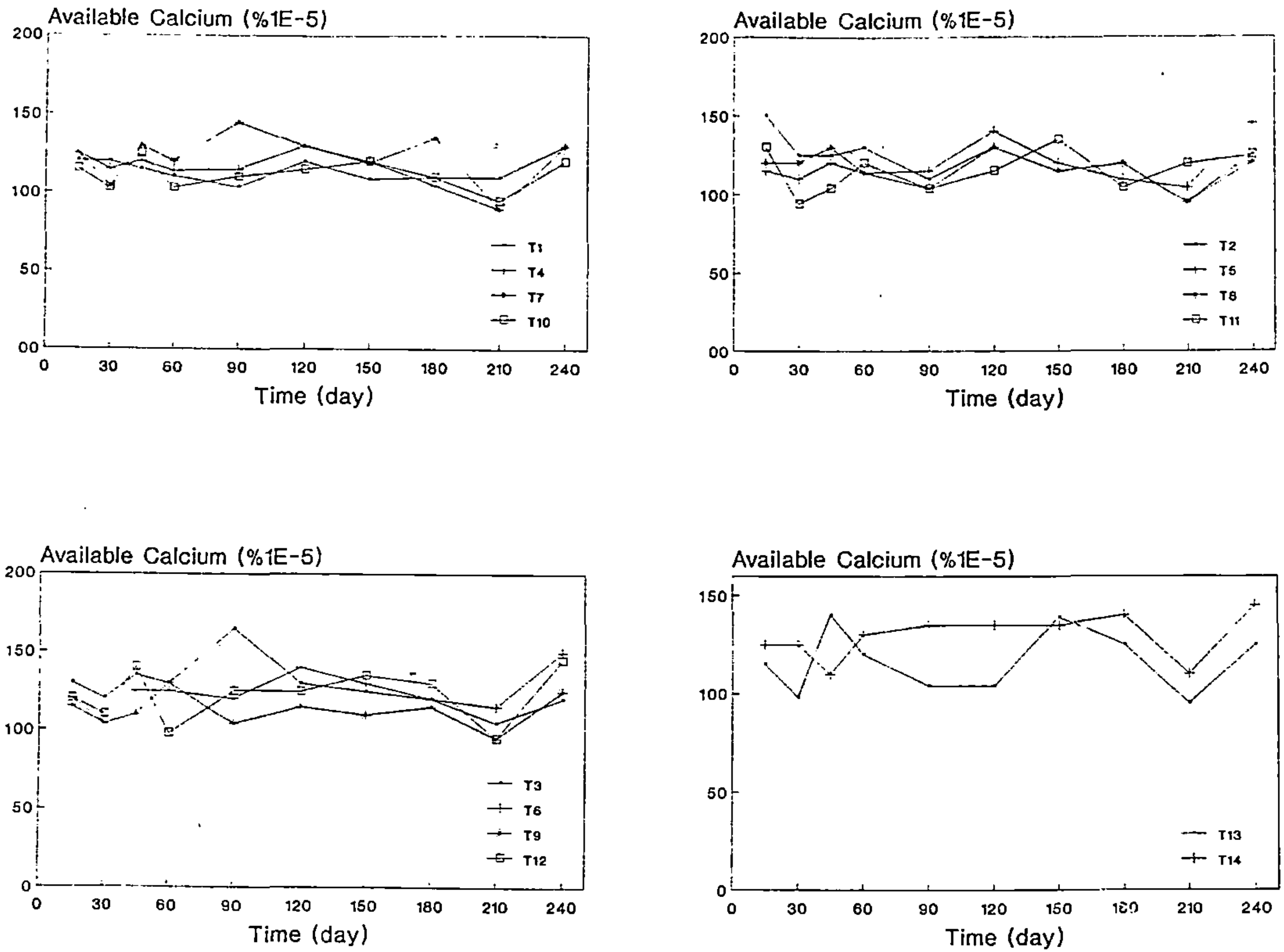
Laterite soil

The calcium content of the soil applied with various P sources showed an increase till 120th day and then decreased. The maximum content was associated

Table 12. Available calcium as influenced by treatments at different period of incubation (Laterite) (ppm)

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	12.0	12.0	11.5	11.0	10.5	12.0	11.0	11.0	11.0	13.0
2	TRP-P_2	15.0	12.5	12.5	13.0	11.0	13.0	11.5	12.0	9.5	12.5
3	TRP-P_3	13.0	12.0	13.5	13.0	16.5	13.0	12.5	12.0	10.5	12.0
4	SSP-P_1	12.5	11.5	12.0	12.0	11.5	13.0	12.0	10.5	9.0	13.0
5	SSP-P_2	11.5	11.0	12.0	11.5	11.5	14.0	12.0	11.0	10.5	14.5
6	SSP-P_3	12.0	10.4	12.5	12.5	12.0	14.0	13.0	12.0	11.5	15.0
7	DAP-P_1	12.5	10.4	13.0	12.0	14.5	13.0	12.0	13.5	9.0	13.0
8	DAP-P_2	12.0	12.0	13.0	11.5	10.5	13.0	11.5	12.0	9.5	12.0
9	DAP-P_3	11.5	10.4	11.0	13.0	10.5	11.5	11.0	11.5	9.5	12.5
10	MRP-P_1	11.5	10.4	12.5	10.5	11.0	11.5	17.0	11.4	9.5	12.0
11	MRP-P_2	13.0	9.4	10.4	12.0	10.5	11.5	13.5	10.5	12.0	12.5
12	MRP-P_1	12.0	11.0	14.0	10.0	12.5	12.5	13.5	13.0	9.5	14.5
13	Control	11.5	9.9	14.0	12.0	10.5	10.5	14.0	12.5	9.5	12.5
14	SSP(P_2+P_2)	12.5	12.5	11.0	13.0	13.5	13.5	13.5	14.0	11.0	14.5

Fig 9. Change of available calcium during incubation - Laterite soil



with TRP at highest level on 120th day of incubation. The minimum content was shown by SSP at its lowest level on 15th day. The control did not show any difference with other treatment. The SSP applied twice also does not gave any special effect.

Kuttanad soil

The data (Table 13) showed an increasing trend till 120th day of incubation and there after decreased. The highest content was given by the treatment SSP-P_3 on 120th day. The lowest content was shown by control on 15th day of incubation. The control showed a slightly lower value compared to other treatments throughout the incubation. There was no marked difference between treatments or dose but the soil showed difference with each other.

4.1.5 Available magnesium

The effect of application of different P sources and their different levels on available Magnesium contents of the soil are given in Table 14 and 15 and the variation is presented in Fig.11 and 12. In both the soil the Magnesium content showed an overall decrease with period of incubation. The data are presented Table 14 and 15.

In laterite soil the magnesium content decreased upto 45th day in SSP, DAP and MRP. But Tunisia rockphosphate showed decline upto 45th day. From there onwards the Mg content remained steady or slightly increased till 90th day in TRP, MRP and DAP. But in SSP the increasing trend remained till 120th day. From 120th day the content reduced slowly. The SSP applied twice gave similar effect as

Table 13. Available calcium as influenced by treatments at different period of incubation (Kuttanad) (ppm)

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	27.5	27.5	34.5	35.5	29.0	28.0	26.5	24.5	22.0	21.0
2	TRP-P_2	35.0	26.5	36.0	35.5	30.5	31.0	26.0	23.0	21.5	20.0
3	TRP-P_3	30.0	27.5	37.0	39.0	29.0	29.0	27.5	24.5	25.0	21.0
4	SSP-P_1	30.0	26.0	35.5	36.0	29.0	27.5	28.0	21.5	21.5	21.0
5	SSP-P_2	22.0	25.0	39.0	37.0	28.5	27.5	30.0	23.0	22.5	21.0
6	SSP-P_3	27.0	28.0	36.0	37.0	36.0	31.5	28.5	24.0	22.0	20.5
7	DAP-P_1	30.0	27.0	37.5	35.5	28.5	27.0	25.0	24.5	22.0	21.5
8	DAP-P_2	22.5	29.5	37.0	38.0	30.0	22.0	24.5	24.0	21.5	20.5
9	DAP-P_3	28.5	28.5	36.0	35.5	27.5	27.0	27.0	21.5	21.0	20.5
10	MRP-P_1	29.0	28.5	35.5	37.0	29.0	20.0	24.5	23.5	26.0	20.5
11	MRP-P_2	30.5	29.5	36.0	35.0	24.0	25.5	26.0	19.0	23.0	21.0
12	MRP-P_1	29.5	29.0	34.0	38.0	26.5	28.0	28.0	24.0	21.5	20.0
13	Control	24.5	25.0	34.0	34.0	23.5	25.0	26.5	19.5	21.0	20.5
14	SSP(P_2+P_2)	26.5	26.5	36.0	35.0	23.0	26.5	27.5	21.5	21.0	20.5

Fig 10. Change of available calcium during incubation - Kuttanad alluvial soil

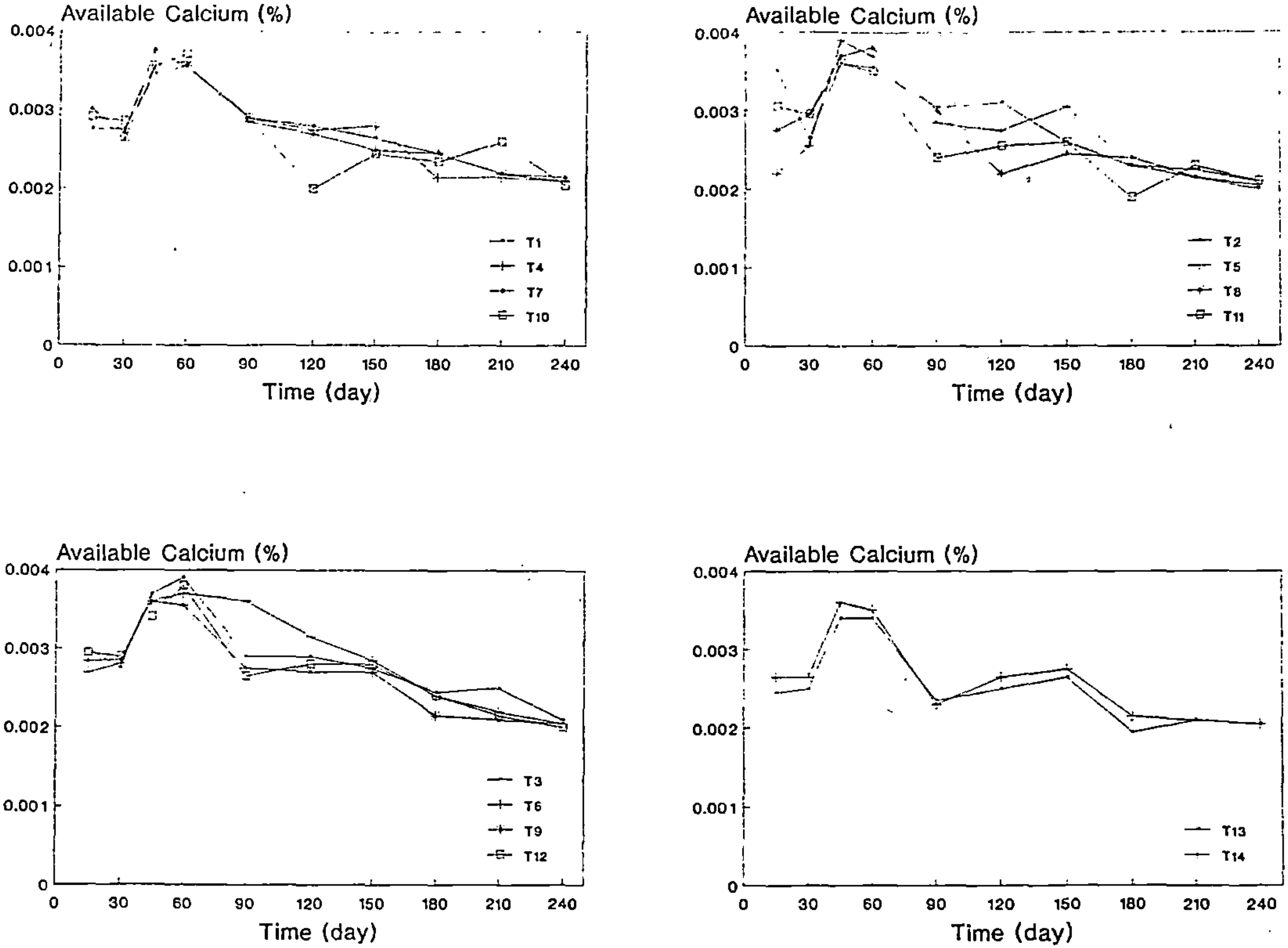


Table 14. Available Magnesium as influenced by treatments at different period of incubation (Laterite) ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	3.6	3.3	2.6	2.6	3.6	3.9	2.6	2.0	1.7	2.4
2	TRP-P_2	2.3	2.5	2.0	2.3	3.3	2.6	4.0	3.1	1.7	2.1
3	TRP-P_3	2.3	2.3	2.3	2.8	3.3	2.3	2.3	2.4	1.7	2.8
4	SSP-P_1	1.9	2.3	3.2	3.3	3.3	4.0	3.0	1.7	1.7	2.1
5	SSP-P_2	2.6	2.3	3.7	2.3	3.3	3.5	3.0	2.4	2.1	1.7
6	SSP-P_3	3.8	2.3	3.0	2.0	2.6	4.3	3.3	2.1	1.4	1.4
7	DAP-P_1	3.9	1.6	3.2	3.0	3.0	1.9	3.0	2.4	1.4	1.4
8	DAP-P_2	2.3	2.3	2.6	3.0	3.0	2.6	3.0	2.4	2.1	2.4
9	DAP-P_3	2.3	2.3	3.2	3.0	3.0	3.6	3.9	2.1	2.4	1.4
10	MRP-P_1	3.0	2.6	3.2	2.8	3.6	3.3	2.6	1.7	2.4	2.1
11	MRP-P_2	3.3	3.3	4.0	2.8	3.3	3.3	3.3	2.1	4.2	4.2
12	MRP-P_1	3.3	3.3	3.3	2.8	3.3	3.0	2.6	2.8	4.2	4.9
13	Control	3.0	3.0	1.6	2.6	3.3	3.3	2.6	3.0	4.2	4.2
14	SSP(P_2+P_2)	1.3	1.3	3.0	3.0	4.6	3.6	2.6	2.4	2.8	1.7

Fig 11. Change of available magnesium during incubation - Laterite soil

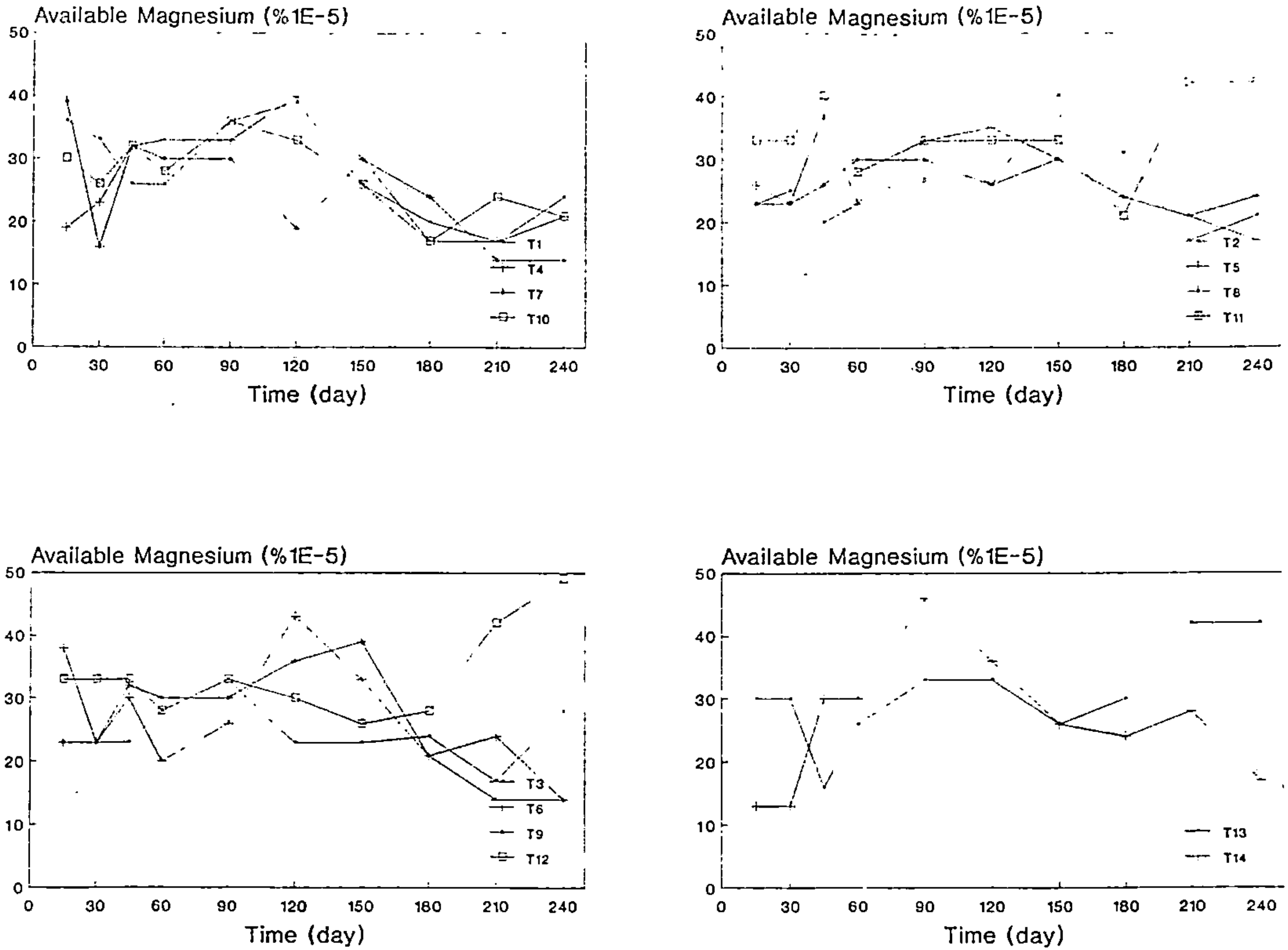
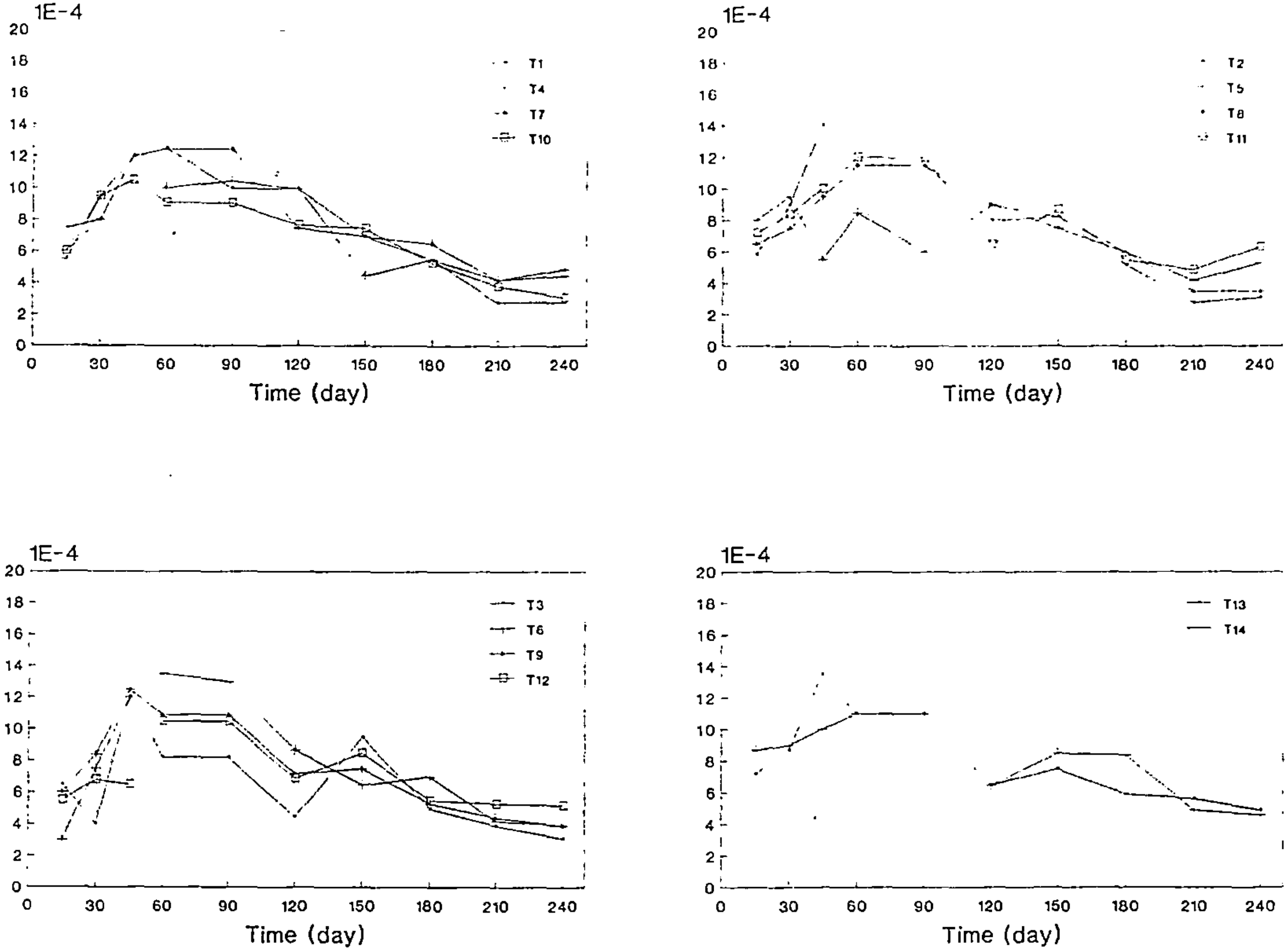


Table 15. Available Magnesium as influenced by treatments at different period of incubation (Kuttanad) ppm

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	7.5	8.0	12.0	12.5	10.0	10.0	7.0	5.5	2.8	2.8
2	TRP-P_2	5.8	9.0	14.0	11.5	11.5	8.0	8.2	5.2	2.8	3.1
3	TRP-P_3	6.5	40.0	12.0	8.2	8.2	4.5	9.5	5.0	3.9	3.1
4	SSP-P_1	6.0	8.0	12.0	10.0	10.5	10.0	4.5	5.5	4.2	4.5
5	SSP-P_2	8.0	9.5	5.5	8.5	57.0	9.0	8.2	6.0	4.2	5.3
6	SSP-P_3	3.0	7.5	12.0	13.5	13.0	8.7	6.5	7.0	4.2	3.9
7	DAP-P_1	5.5	9.5	12.0	12.5	12.5	7.5	7.0	6.5	4.2	4.9
8	DAP-P_2	6.5	7.5	9.5	11.5	11.5	9.0	7.5	6.0	3.5	3.5
9	DAP-P_3	6.0	8.4	12.5	10.9	10.9	7.2	7.5	5.3	4.4	3.9
10	MRP-P_1	6.0	9.5	10.5	9.1	9.1	7.7	7.5	5.3	3.8	3.1
11	MRP-P_2	7.2	8.4	10.0	12.0	12.0	6.5	8.7	5.5	4.9	6.3
12	MRP-P_3	5.5	6.8	6.5	10.5	10.5	6.9	8.5	5.5	5.3	5.2
13	Control	7.2	8.7	13.5	11.0	11.0	6.5	7.5	5.9	5.6	4.9
14	SSP(P_2+P_2)	8.7	9.0	10.0	11.0	11.0	6.5	8.5	8.4	4.9	4.6

Fig 12. Change of available magnesium during incubation - Kuttanad alluvial soil



that of single application. The lowest Mg content was associated with control and highest content was associated with SSP applied twice on 90th day of incubation.

In Kuttanad soil the values of available magnesium content were found to range from 5.5 ppm to 8.7 ppm on 15th day of incubation, which showed a slight increase till 45th day-60th day. From 60th day onward the different treatments slightly reduced in its content till the end of incubation. The highest content was associated with SSP-P_3 on 60th day, (13.5 ppm) and the lowest content was associated with (TRP-P_1) on 240th day.

The statistical analysis showed that there was no significant variation between different sources and doses at the different stages.

4.1.6 Fractions of phosphorus

The effect of different treatments on the transformation of different fractions of phosphorus was studied for three specific stages of incubation experiment which correspond to initial stage of first crop (15th day), harvest of first crop (120th day) and harvest of 2nd crop (240th day). Data pertaining to the contents of Al-P, Fe-P and Ca-P at 15th, 120th and 240th day of incubation are given in Tables 16 to 18. Graphical illustrations are presented in Figs. 13 to 18.

4.1.6.1 Aluminium phosphate (Al-P)

Laterite soil

The data in Table 16 revealed that Al-P content ranged from 38.25 ppm (control) to 74.9 ppm (SSP-P_3) during the course of incubation. On 15th day of

Table 16. Aluminium phosphate as influenced by treatments at 15th, 120th and 240th day of incubation (ppm)

Treatment No.	Notation	Laterite			Kuttanad		
		Period of incubation (days)			Period of incubation (days)		
		15	120	240	15	120	240
1	TRP-P_1	51.13	73.30	79.90	86.60	133.20	183.30
2	TRP-P_2	56.60	75.10	89.90	98.25	148.15	293.15
3	TRP-P_3	66.60	88.25	103.20	106.60	166.50	221.10
4	SSP-P_1	61.30	74.95	94.90	89.90	131.55	179.95
5	SSP-P_2	69.90	81.60	98.25	106.60	141.50	196.60
6	SSP-P_3	74.90	91.60	106.60	116.60	173.25	228.15
7	DAP-P_1	48.25	74.95	88.25	81.60	131.10	166.50
8	DAP-P_2	58.25	79.90	91.60	103.30	148.20	193.15
9	DAP-P_3	64.95	88.25	103.25	108.25	173.10	218.30
10	MRP-P_1	46.60	73.15	88.25	74.95	116.10	166.50
11	MRP-P_2	54.95	78.25	91.60	86.60	141.60	188.20
12	MRP-P_3	64.95	84.95	94.95	111.75	163.15	214.90
13	Control	38.25	61.55	69.95	54.95	101.05	142.70
14	SSP (P_2+P_2)	54.95	76.60	106.60	83.20	124.90	203.20
				Mean			
	<u>Sources</u>						
	TRP	58.11	78.88	91.00	97.15	149.28	199.18
	SSP	68.70	82.72	99.92	104.37	148.77	201.57
	DAP	57.15	81.03	94.37	97.72	150.80	192.65
	MRP	55.50	78.78	91.60	91.10	140.28	189.87
	CD(0.05)	2.9725	6.2757	7.3052	2.9725	6.2757	7.3052
	<u>Dose</u>						
	P_1	50.8	72.42	87.98	78.53	122.98	173.69
	P_2	59.93	78.71	92.84	98.69	144.86	192.77
	P_3	67.85	88.26	102.00	110.80	169.00	220.61
	CD(0.05)	2.5743	5.4349	6.3265	1.5743	5.4349	6.3265

Fig 13. Change of aluminium phosphate during incubation - Laterite soil

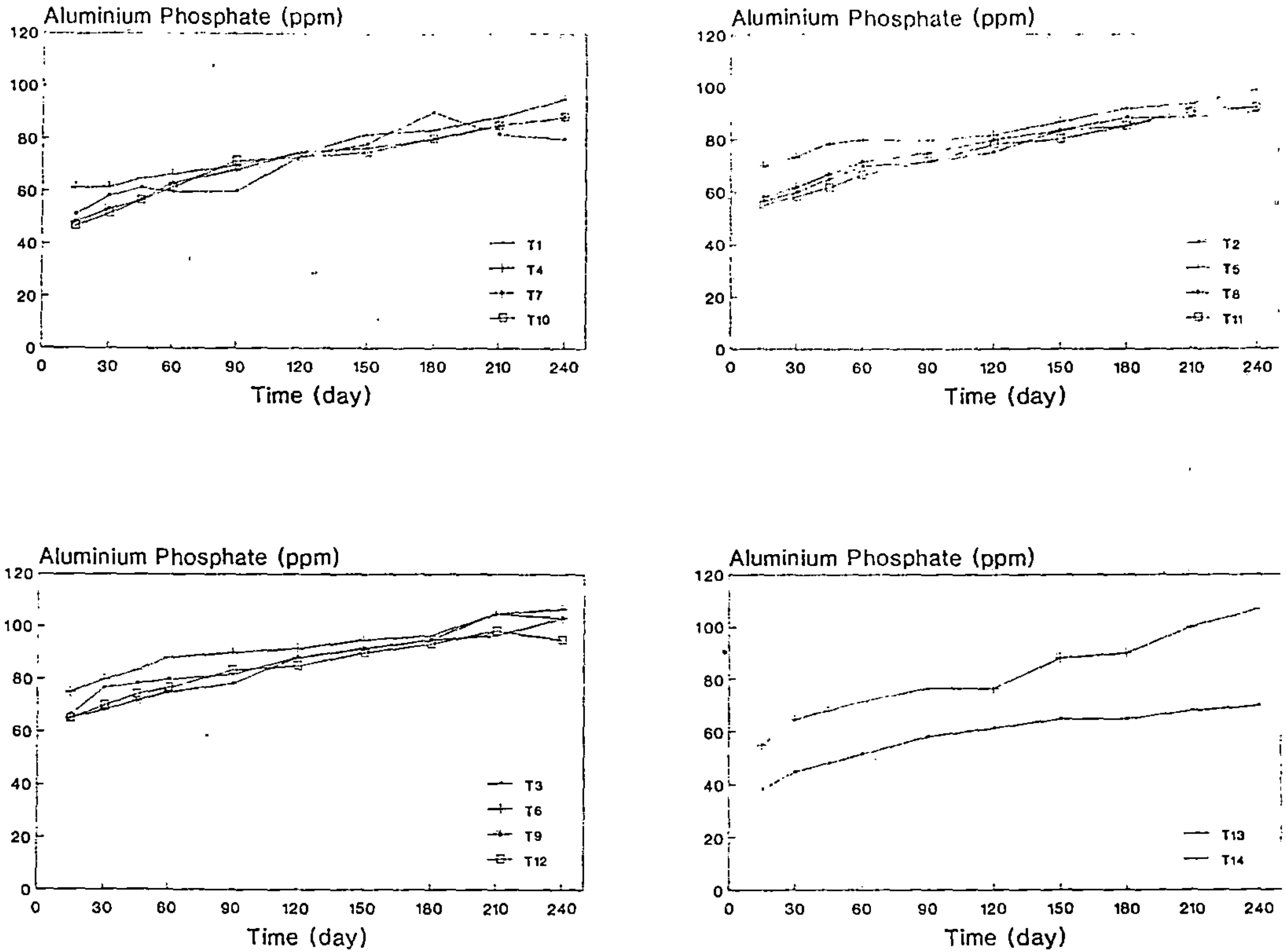
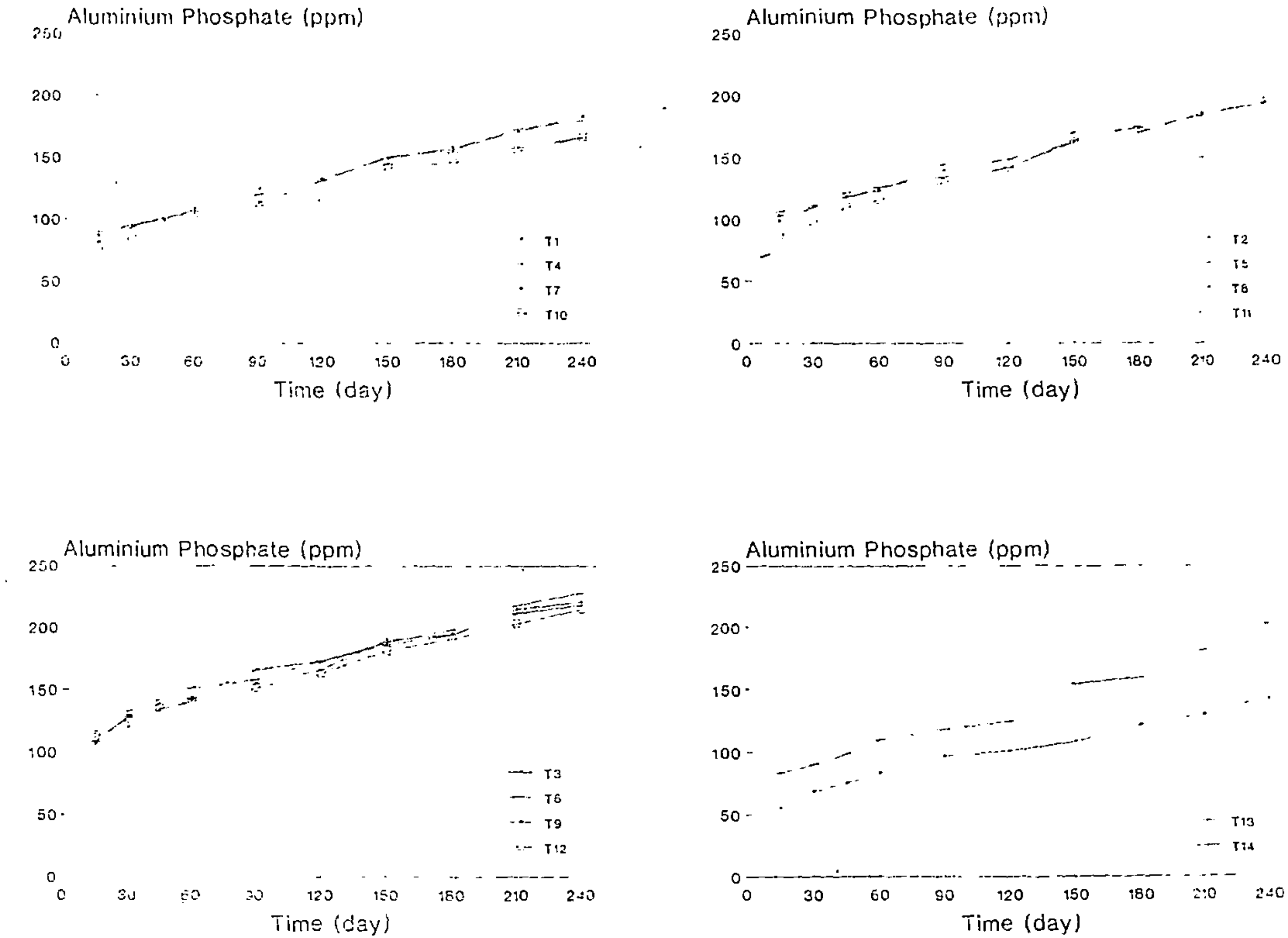


Fig 14. Change of aluminium phosphate during incubation - Kuttanad alluvium



incubation the mean Al-P content for TRP applied soil was 58.11 while for single superphosphate it was 68.7 ppm. The DAP and MRP gave values of 57.15 ppm and 55.5 ppm respectively on the same day. It was also observed that the different doses of P applied i.e., 22.5, 45.0 and 67.5 kg ha^{-1} gave an Al-P content of 50.08, 59.93 and 67.85 ppm respectively.

On 120th day of incubation the Al-P content ranged from 61.55 ppm (control) to 91.6 ppm (SSP-P_3). The mean Al-P contents were 78.88, 82.72, 81.83 and 78.78 ppm respectively for TRP, SSP, DAP and MRP. The different doses of P have resulted in an aluminium phosphate content of 72.42, 78.71 and 88.26 ppm respectively (Table 16).

On 240th day of incubation Al-P content varied from 69.95 ppm (control) to 106.6 ppm (SSP-P_3). The mean Al-P content for different rock phosphate were TRP - 91.00 ppm, SSP - 99.92 ppm, DAP - 94.37 ppm and MRP - 91.60 ppm. The different doses of P gave values of 87.98 ppm, 92.84 ppm and 102.00 ppm in the ascending order.

Thus it clearly indicated that on 15th and 120th day of incubation maximum Al-P content was shown by single superphosphate. On 240th day it was on par with Tunisia rockphosphate. Other sources had comparable effect, with DAP having slightly higher content of Al-P in comparison with TRP and MRP. The water soluble P-source (SSP) got early converted to Al-P followed by DAP. Among the different rockphosphates, the TRP gave a higher Al-P content than MRP. This may be due to higher release of P from TRP than MRP. The Al-P content of the soil showed a linear increase with duration from an original value of 38.25 to 69.98 ppm for control.

Kuttanad soil

On 15th day of incubation Al-P content ranged from 54.95 ppm (control) to 116.6 ppm (SSP-P_3). The mean content of Al-P on soil applied with different P sources were TRP - 97.15 ppm, SSP - 104.37 ppm, DAP - 97.72 ppm and MRP 91.10 ppm (Table 16). The different doses of P fertilisers gave values of 78.53, 98.69 and 110.8 ppm respectively for 1st, 2nd and 3rd level of phosphorus.

On 120th day of incubation the Al-P ranged from 101.05 ppm (control) to 173.25 ppm (SSP-P_3). The mean content of Al-P as a result of application of different sources were TRP - 149.28 ppm, SSP - 148.77 ppm, DAP - 150.80 ppm and MRP - 140.28 ppm. The different doses of fertilizer, viz., 22.5, 45.0 and 67.5 kg ha^{-1} resulted in an Al-P content of 122.98, 144.86 and 169.00 ppm respectively.

On 240th day of incubation the Al-P content ranged from 142.7 ppm (control) to 228.15 ppm (SSP-P_3). The different P sources resulted in a mean Al-P content of 199.8, 201.57 and 192.65 and 189.87 ppm for TRP, SSP, DAP and MRP respectively. The three levels of P gave values of 173.69, 192.77 and 220.61 ppm respectively.

Thus in Kuttanad soil also the maximum Al-P content was given by SSP on 15th day of incubation. On 120th and 240th day the SSP and TRP had higher Al-P content in comparison with DAP and MRP. It was found that SSP resulted in highest transformation of available P to Al-P closely followed by TRP. The native Al-P content of Kuttanad soil was 54.95 ppm which increased to 142.7 ppm on submergence. Among different treatments control registered least content of Al-P. It was found that during initial period of incubation water soluble P source easily transferred to Al-P. By 60th day TRP was comparable to SSP in their effect on the formation of Al-P. But mussooriephos gave a lower value. In both the soil types the SSP had the highest Al-P content and mussooriephos had the minimum. For DAP and TRP the content was almost same.

4.1.6.2 Iron Phosphate (Fe-P)

Laterite soil

The data of variation of Fe-P with period of incubation are given in Table 17. The data revealed that Fe-P content ranged from 35.46 ppm (control) to 65.53 ppm (DAP-P_3) on 15th day of incubation. The mean Fe-P content on 15th day of incubation was 46.98 ppm for TRP, 52.36 ppm for SSP, 59.39 ppm for DAP and 43.32 ppm for MRP. The different doses of various fertilizers gave an Fe-P content of 41.10, 52.78 and 57.71 ppm for 1st, 2nd and 3rd level of P_2O_5.

On 120th day of incubation the Fe-P content ranged from 58.47 ppm to 96.78 ppm (MRP-P_3). The mean Fe-P content on 120th day of incubation were TRP - 71.97 ppm, SSP - 78.52 ppm, DAP - 71.49 ppm and MRP - 77.74 ppm. The different doses gave an iron phosphate content of 63.74 ppm for first dose 74.48 ppm for 2nd dose and 87.33 ppm for third dose.

On 240th day of incubation the Fe-P content ranged from 65.59 ppm (control) to 122.33 ppm (SSP-P_3). The mean Fe-P content on 240th day in soil applied with various fertilizers were TRP - 97.39, SSP - 103.53, DAP - 90.45 and

Table 17. Iron phosphate as influenced by treatments at 15th, 120th and 240th day of incubation (ppm)

Treatment No.	Notation	Laterite			Kuttanad		
		Period of incubation (days)			Period of incubation (days)		
		15	120	240	15	120	240
1	TRP-P_1	38.79	65.18	180.62	336.33	396.90	432.85
2	TRP-P_2	45.54	66.85	98.98	351.39	418.56	445.27
3	TRP-P_3	58.93	85.22	115.75	358.00	440.17	472.90
4	SSP-P_1	38.79	65.18	87.31	349.68	385.24	431.20
5	SSP-P_2	57.28	81.81	104.04	359.65	426.81	451.24
6	SSP-P_3	64.02	80.15	122.33	344.22	436.85	482.94
7	DAP-P_1	52.23	61.82	82.27	332.99	390.19	431.26
8	DAP-P_2	62.21	75.20	87.26	359.27	411.71	446.27
9	DAP-P_3	65.53	78.51	104.04	368.33	426.86	476.28
10	MRP-P_1	37.15	63.54	85.68	334.64	391.84	427.90
11	MRP-P_2	48.86	75.20	87.06	344.21	418.56	446.24
12	MRP-P_3	45.58	96.78	118.83	358.00	433.51	471.23
13	Control	35.46	58.47	65.59	314.59	373.36	407.81
14	SSP(P_2+P_2)	48.86	78.51	110.64	351.39	42186	461.26
				Mean			
	Source						
	TRP	46.98	71.97	97.39	347.39	417.95	449.39
	SSP	52.36	78.52	103.53	350.03	415.59	453.74
	DAP	59.39	71.49	90.45	352.24	409.04	449.95
	MRP	43.32	77.74	96.09	344.44	414.05	447.15
	CD(0.05)	0.1367	0.0440	0.1209	0.1367	0.0440	0.1209
	Dose						
	P_1	41.10	63.74	83.40	337.14	390.58	429.56
	P_2	52.78	74.48	93.61	352.33	418.43	446.24
	P_3	57.72	87.33	114.50	355.81	433.87	474.52
	CD(0.05)	0.1014	0.0328	0.0898	0.1014	0.0328	0.0898

MRP - 96.09 ppm. The doses gave Fe-P content of 83.40, 93.61 and 114.50 ppm respectively with increase in dosage.

Thus it has been found that at different period of incubation the Fe-P content were higher in soil applied with water soluble P sources. On comparing all the sources DAP and SSP gave maximum Fe-P content than rockphosphates. Thus it was observed that DAP had a higher Fe-P content in earlier stage due to higher transformation but in later stages the SSP had the highest transformation.

Kuttanad soil

On 15th day of incubation Fe-P content showed a range of 314.59 ppm (control) to 368.33 ppm (DAP-P_3). The mean Fe-P content for different fertilizer sources were as follows. TRP - 347.39, SSP - 350.03, DAP - 352.24 and MRP - 344.44 ppm. The different doses gave a mean content of 337.14 ppm, 352.33 ppm and 355.81 ppm respectively for 22.5 kg, 45 kg and 67.5 kg P_2O_5 ha^{-1} (Table 17).

On 120th day the Fe-P content showed a range of 373.37 ppm (control) to 440.17 ppm (TRP-P_3). The mean content for different fertilizers were TRP - 417.95, SSP - 415.59, DAP - 409.04 and MRP - 414.05 ppm respectively. The different doses gave a linear increase with the dose.

On 240th day of incubation the Fe-P content ranged from 407.81 (control) to 482.94 ppm (SSP-P_3). The mean Fe-P content for different sources were TRP - 449.39, SSP - 453.75, DAP - 449.95 and MRP - 447.15 ppm respectively (Table 17). The different doses gave Fe-P content ranging from 429.56 ppm for 22.5 kg to 446.24 ppm for 45 kg and 474.52 ppm for 67.5 kg P_2O_5 ha^{-1}.

Fig 15. Change of iron phosphate during incubation - Laterite soil

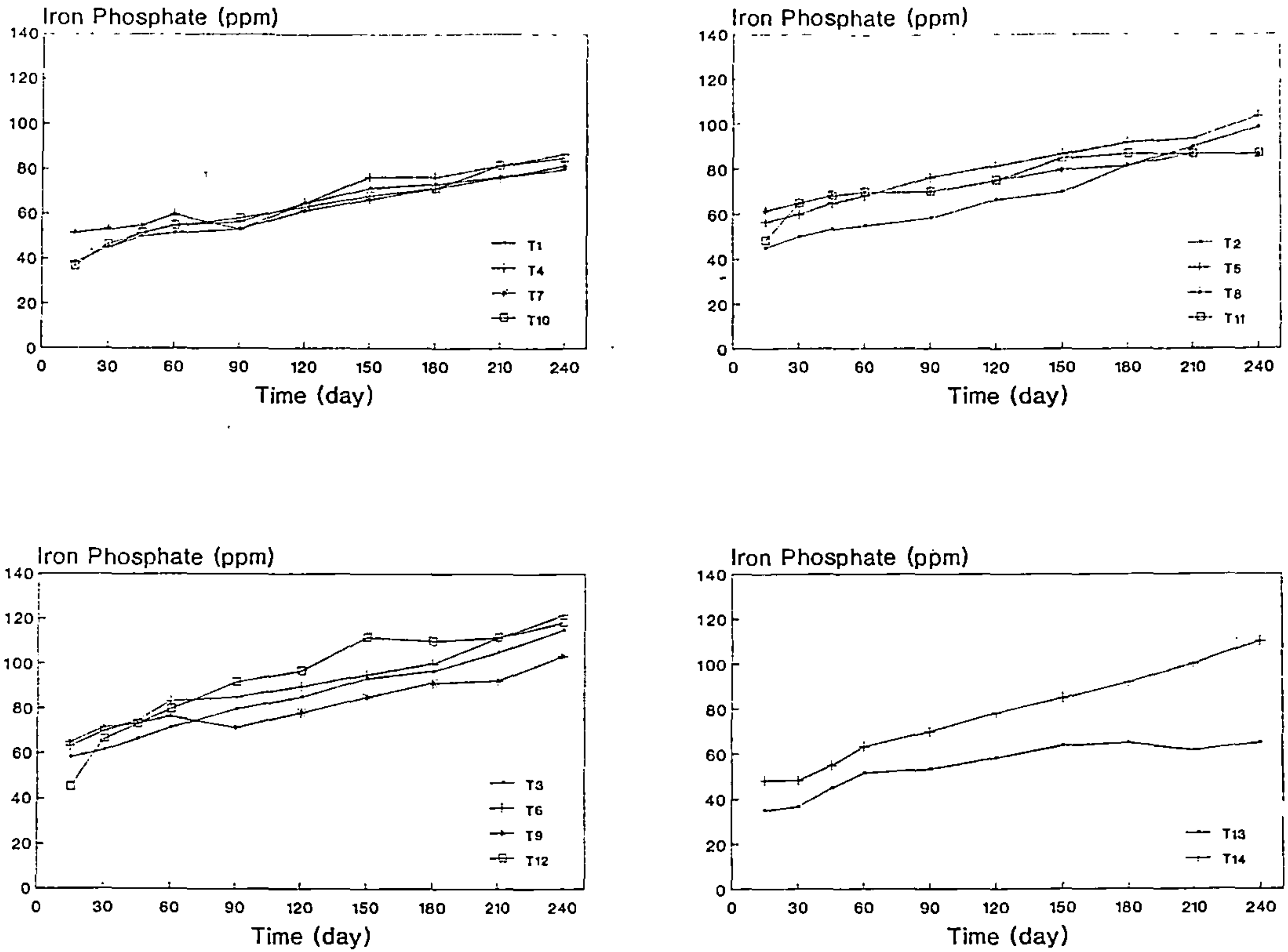
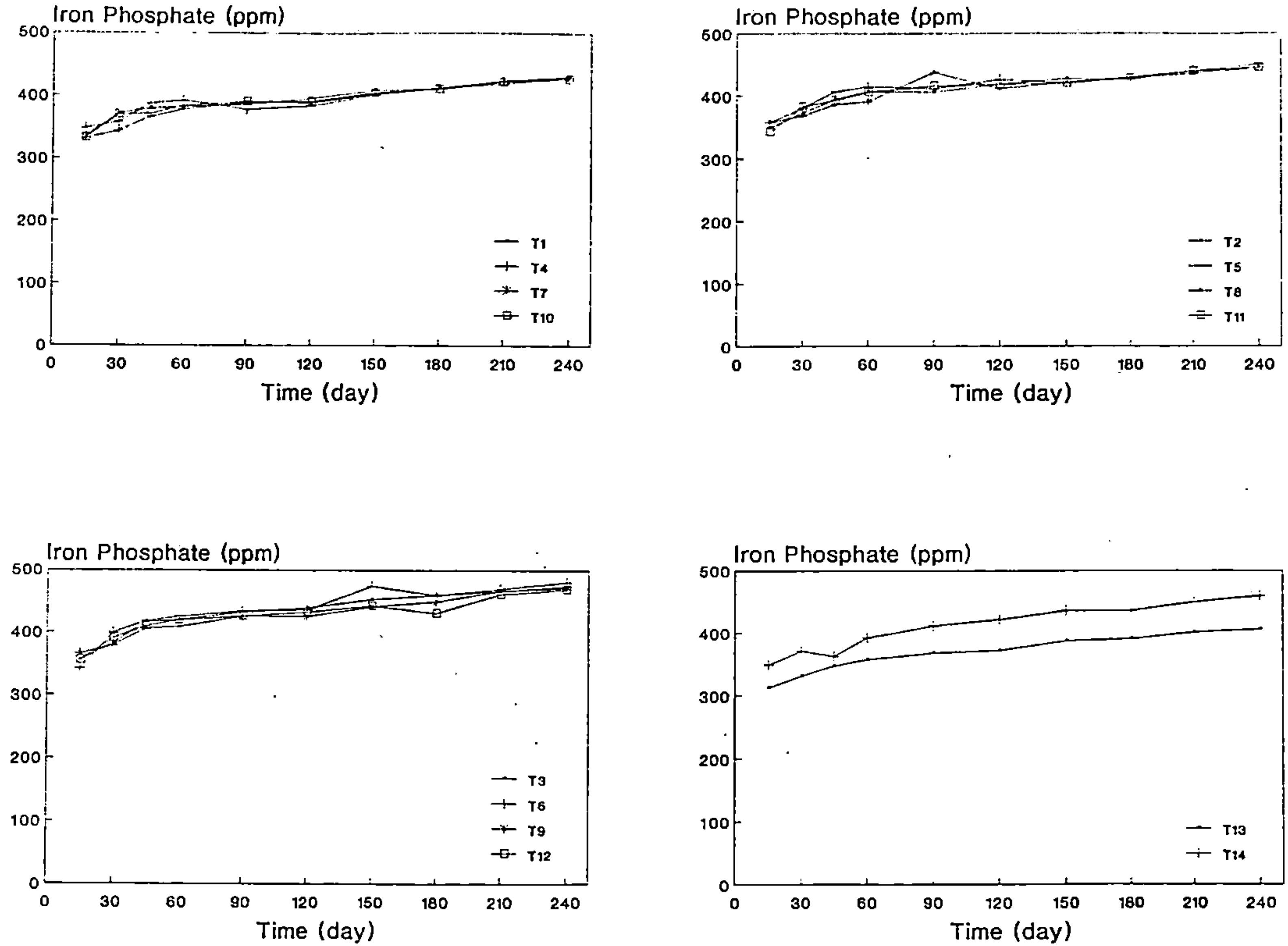


Fig 16. Change of iron phosphate during incubation - Kuttanad alluvial soil



The iron phosphate was the major inorganic P fraction in Kuttanad soil. Eventhough the single superphosphate had highest Fe-P content through out the incubation, the diammonium phosphate was the highest source in earlier periods. The minimum content of Fe-P was associated with MRP throughout the incubation.

In general Fe-P showed a steady increase with the period in both the soils. Single superphosphate had the highest Fe-P content and MRP had the lowest Fe-P content in laterite soil. In Kuttanad soil DAP had maximum Fe-P content on 15th day, TRP on 120th day and SSP on 240th day. The higher content of Fe-P associated with Kuttanad soil may be due to free iron oxide present in the soil.

The statistical analysis of data showed that Fe-P content of soil was significantly affected by P source and dose at various stages of incubation. The control was significantly different from other treatments at various stages of incubation. Of the different sources SSP had higher value than other sources in later periods of incubation and in earlier periods it was DAP which had the highest Fe-P content.

4.1.6.3 Calcium phosphate

Laterite soil

The effect of different treatments on Ca-P content is given in Table 18. The data revealed that on 15th day calcium phosphate content ranged from 21.65 ppm (SSP-P_1) to 43.30 ppm (DAP-P_3). The mean data of calcium phosphate content associated with different P sources on 15th day were TRP - 31.09, SSP - 27.68 ppm, DAP - 31.05 ppm and MRP 31.73 ppm. The dose of fertilizer

Table 18. Calcium phosphate as influenced by treatments at 15th, 120th and 240th day of incubation (ppm)

Treatment No.	Notation	Laterite			Kuttanad		
		Period of incubation (days)			Period of incubation (days)		
		15	120	240	15	120	240
1	TRP-P_1	24.97	48.25	36.60	106.55	144.85	121.65
2	TRP-P_2	29.99	56.60	38.30	113.20	154.90	123.30
3	TRP-P_3	38.30	68.25	43.30	124.95	166.55	124.95
4	SSP-P_1	21.65	48.25	36.60	101.55	144.85	121.60
5	SSP-P_2	26.45	53.30	38.30	121.55	158.25	121.65
6	SSP-P_3	34.95	69.95	44.95	143.20	171.50	124.95
7	DAP-P_1	24.90	46.60	36.60	94.95	144.85	121.65
8	DAP-P_2	24.95	56.60	41.65	101.55	154.90	123.30
9	DAP-P_3	43.30	66.60	41.65	119.90	164.85	124.80
10	MRP-P_1	27.10	48.25	36.60	88.25	138.25	120.00
11	MRP-P_2	33.30	54.95	36.60	104.05	149.85	123.30
12	MRP-P_3	34.80	68.25	41.65	121.50	139.90	126.65
13	Control	26.60	46.63	30.00	71.65	118.25	108.25
14	SSP(P_2+P_2)	29.90	61.75	39.95	104.90	149.80	123.30
				Mean			
	<u>Source</u>						
	TRP	31.09	57.70	39.40	114.90	155.43	123.30
	SSP	27.68	57.17	39.95	122.10	158.20	122.73
	DAP	31.05	56.60	39.97	105.47	164.87	123.25
	MRP	31.73	57.15	38.28	104.60	142.67	123.32
	CD(0.05)	-	-	-	-	-	-
	<u>Dose</u>						
	P_1	25.85	49.96	36.06	94.64	140.14	119.41
	P_2	28.67	55.36	38.71	110.09	154.49	122.89
	P_3	37.84	68.26	42.89	127.39	160.70	125.34
	CD(0.05)	3.2592	8.0961	2.3306	3.2592	8.0961	2.3306

irrespective of source also gave an increase from 25.85 ppm to 28.67 ppm and 37.84 ppm for 1st, 2nd and 3rd level.

On 120th day of incubation the content ranged from 46.63 ppm (control) to 69.95 ppm (SSP-P_3). The mean data of Calcium P for different sources were TRP 57.7 ppm, SSP 57.17, DAP 56.60 and MRP 57.15 ppm. The different doses gave an increase from 49.96 ppm to 55.36 ppm and 68.26 ppm as increased from 1st to 2nd and 3rd level.

On 240th day of incubation Ca-P content ranged from 30.0 ppm (control) to 44.95 ppm (SSP-P_3). The mean calcium phosphate content for different sources were TRP-39.4 ppm, SSP 39.95 ppm, DAP 39.97 ppm and DAP 38.28 ppm respectively.

The data revealed that there was an increase in calcium phosphate content till 120th day and there after it reduced. The content of calcium phosphate was comparable for TRP, MRP, DAP and SSP. On 15th, 120th and 240th day the SSP value was comparable with TRP. Statistical analysis of data showed that there was no significant difference between different sources at any of the stages. But the doses were found to be significantly different in their effect on Ca-phosphate content and showed a linear relationship with Ca-P content.

Kuttanad soil

On 15th day of incubation the calcium phosphate ranged between 71.65 ppm (control) to 143.2 ppm SSP (P_3) (Table 18). The mean value of calcium phosphate for different sources were TRP-114.9, SSP-122.1, DAP-105.47 and

Fig 17. Cahange of calcium phosphate during incubation - Laterite soil

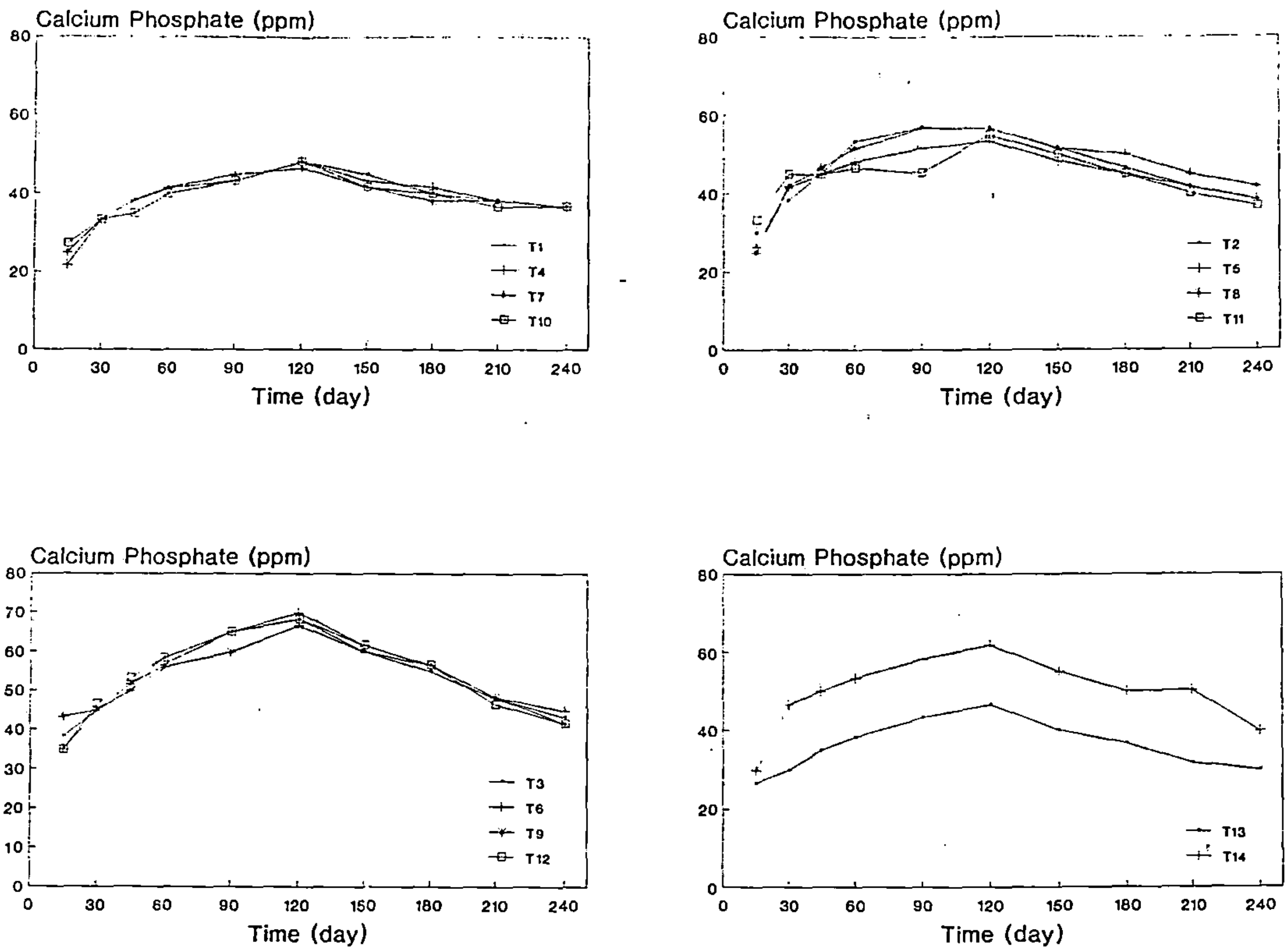
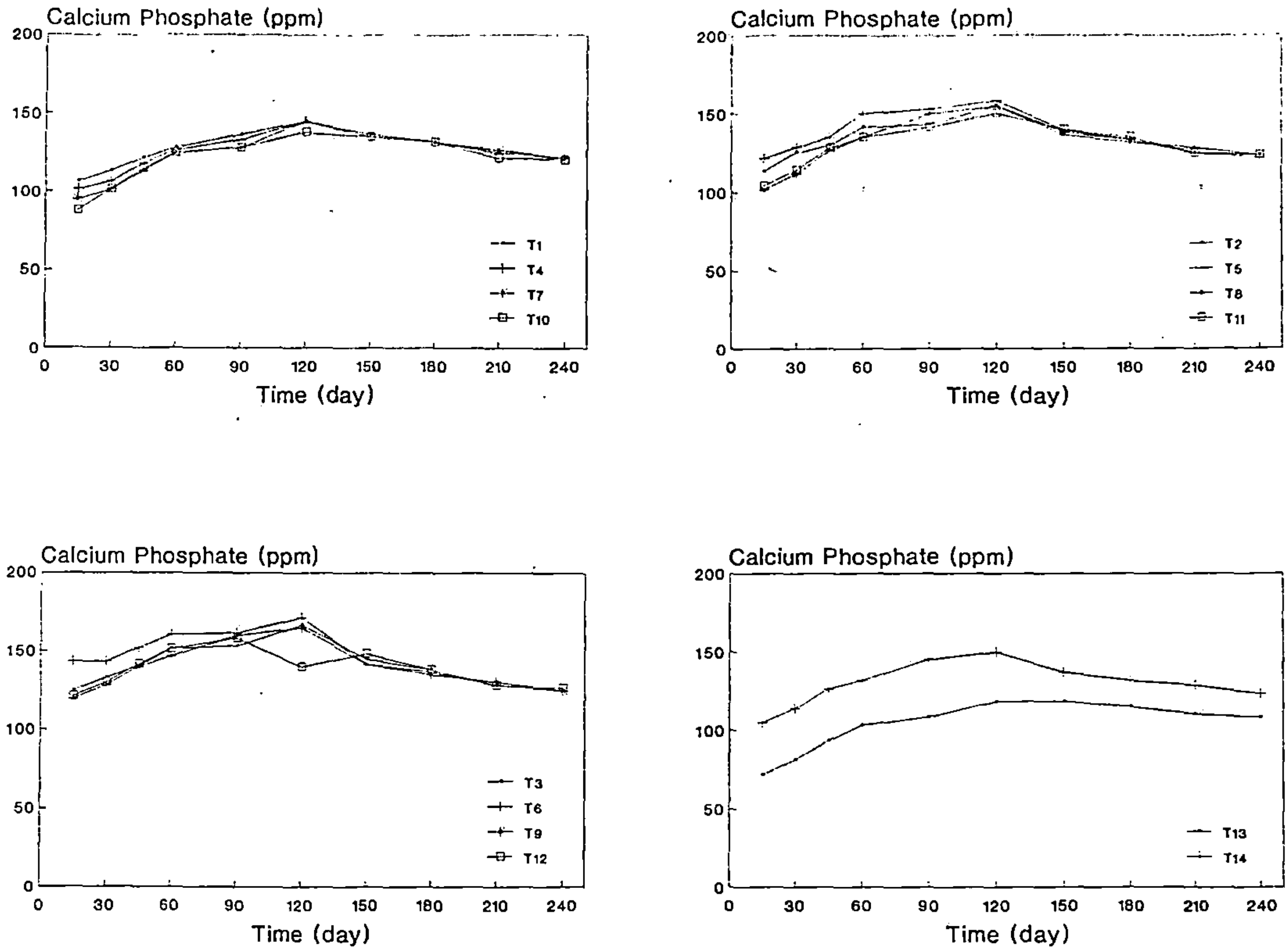


Fig 18. Change of calcium phosphate during incubation - Kuttanad alluvial soil



MRP-104.6. The different doses of fertilizer like 22.5 kg, 45 kg x 67.5 kg P_2O_5 ha^{-1} gave corresponding values of 94.64, 110.09 and 127.39 respectively.

On 120th day the calcium phosphate values ranged between 118.25 ppm (control) and 171.50 ppm (SSP-P_3). The mean content of calcium phosphate were 155.43 ppm, 158.20 ppm, 164.87 ppm and 142.67 ppm for TRP, SSP, DAP, MRP respectively. As the dose of application increased from 1st level to 2nd and 3rd the content showed a corresponding increase from 140.14 ppm to 154.48 ppm and 160.70 ppm.

On 240th day of incubation the calcium-phosphate value ranged between 108.25 ppm (control) to 126.65 ppm (MRP-P_3). The mean content of calcium phosphate was maximum for Mussooriephos closely followed by TRP, DAP and SSP respectively. The doses of fertilizer resulted in an increase from 119.41 ppm to 122.89 ppm and 125.34 ppm on increase from 1st to 2nd and 3rd level.

Thus it has been found that in Kuttanad soil the calcium-phosphate content was comparable for various sources of phosphorus through out the incubation. But as the incubation proceeded the rockphosphate had higher dissolution as indicated by higher values observed by all sources at the later periods.

Thus in general it has been observed that in both soils the Ca-P content showed the highest value on 120th day of incubation and there after decreased. This may be due to reversion of fixed calcium phosphate into some other forms. Also it has been noticed that the two rockphosphates had a similar effect as that of water soluble phosphates in initial phase and slightly higher effect on later part of incubation. The higher value of Ca-P in Kuttanad may be due to higher amount of calcium in Kuttanad soil. The statistical analysis showed that there was no significant difference between different sources, but different doses and soils showed significant difference.

The present study have shown that Al-phosphate content showed a linear increase in their content from beginning of incubation till the end of the study. This increase may be attributed to conversion of reductant soluble P, occluded P and Ca-P into Al-P (Sushama *et al.*, 1995). It was also clear from the data that single superphosphate resulted in a higher Al-P content compared to other sources. This may be due to the fact that the water soluble P sources like SSP and DAP released higher amount of available phosphorus compared to other sources which was easily got converted to Al-Phosphate. Similar results were reported by Srinivasamurthy *et al.* (1995) in Mudigre soils of Karnataka and Sharma and Sangrai (1993) in acid alfisol of Himachal Pradesh.

Present study also revealed an increase in Al-P content with increase in dose. The magnitude of increase was more in Kuttanad soil. Similar results were recorded earlier by Regi and Jose (1986) in Kuttanad soils of Kerala. Such differences among soils may be due to low pH of the soil and prominance of exchangeable aluminium in the soil. Among the rock phosphates the Al-phosphate content was maximum in TRP as compared to MRP in Kuttanad soil and thus may be attributed to be difference in their reactivity.

The study revealed that Fe-Phosphate content of soil was maximum with water soluble P sources like SSP and DAP on 15th, 120th and 240th day of incubation in both laterite soils. This is due to high P-releasing capacity of water soluble P sources, which resulted in easy formation of Fe-phosphate. Similar results were obtained by Sharma and Sangrai (1993).

It was also evident that Fe-P was the dominant fraction among the inorganic P fraction in Kuttanad soil. The results further showed that with incubation there was constant increase in Fe-P with all the P sources. The dominance of Fe-P as concluded by the result in Kuttanad soil may be partly due to relative dominance of exchangeable Fe in the soil and due to low pH of soil. This result is in confirmity with findings of Regi and Jose (1986).

A higher content of Fe-P and a low content of Al-P were observed for DAP in initial phase of incubation in both soils. This may be due to the fact that most readily formed insoluble P fraction is Al-P. The chance of conversion of easily available form of phosphate to fixed form (Al-P) was more vigorous in easily available formed phosphate like SSP. This is indicated by higher content of Al-P recorded in both soils on earlier days of incubation for SSP (on 15th day) and that may be the reason for low value of Fe-P recorded for SSP in comparison with DAP.

The total Fe-P content of different sources during entire period of incubation was in the order SSP > DAP > TRP > MRP in laterite soil and SSP > TRP > DAP > MRP. though the Fe-P content of SSP was less during earlier period of incubation, it recorded maximum mean value towards the end of incubation period. The different rock phosphates gave a low content of Fe phosphate in incubation. This may be explained by the fact that the rock phosphate contained insoluble phosphate which were released in a slower pace only.

The incubation experiment revealed that calcium phosphate of soil showed an increase till 120th day and there after reduced. This may be explained by the fact that calcium phosphate get slowly reverted back into more stable phosphate fraction like Fe-P and Al-Phosphate. This is very clear from the fact that after 120th day also there was an increase in the content of iron phosphate and aluminium phosphate. Similar result was given by earlier investigation of Sharma and Sangrai (1993).

The present experiment thus shows that by applying phosphate fertilizer, water soluble or insoluble source to different soils there was conversion and reversion into other forms of phosphate namely available P, Al-Phosphate, Fe-P and Ca-P etc. Among the sources the water soluble sources had higher tendency to undergo these transformations as clearly shown by the present study.

In the laterite soil the conversion of SSP in to fractions were in the order of Al-P > Fe-P> Ca-P. While in Kuttanad soil it was Fe-P > Al-P > Ca-P. The other sources of phosphorus also had same order in both soil. The stage wise order of different fractions were Al-P > Fe-P > Ca-P in laterite soil on 15th and 120th day but on 240th day the order was Fe-P > Al-P > Ca-P. But in Kuttanad soil the different fractions were in the order of Fe-P > Ca-P > Al-P on 15th and 120th day. But on 240th day the order was Fe-P > Al-P > Ca-P.

This variation in the order may be due to dissolution of added calcium phosphate by H^+ ions under very acid soil conditions which ultimately get precipitated as Al-P or Fe-P. The same process was there in the conversion of Al-P to iron phosphate also. This result is in confirmity with findings of D'Souza *et al.* (1995).

4.1.7 pH

The variation in soil reaction (pH) with the application of various P sources was monitered and the variation at different stages of incubation is given in Figs.19 and 20 and the data are present in Table 19 and 20.

In laterite soil the pH was found to be increasing with the duration of incubation. The pH showed an increase from 5.7 on 15th day of incubation to 6.40 on 240th day of incubation. It was found that the highest pH was associated with SSP @ 22.5 kg ha^{-1} on 180th day (ie. 6.7). The lowest pH was with DAP on 15th day (5.45).

In Kuttanad soil also the trend of change was similar. pH increased from 4.6 on 15th day to 5.3 on 240th day with a steady increase through out the incubation. The lowest pH was 4.6 given by SSP, TRP and MRP at initial phase on 15th day of incubation and highest content was given by SSP @ 67.5 kg ha^{-1} on 240th day (5.35).

The different P sources did not show any significant effect on the pH content. But it was found that as the dose of P increased the pH was reduced. The control had a higher value comparable to other treatments.

4.1.8 Leachate analysis during incubation

The leachate samples were collected from incubation soil on every 15th day interval and the leachate samples were analysed to asses the loss of primary nutrients N, P and K.

Table 19. pH as influenced by treatments at different period of incubation (Laterite)

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	5.70	5.90	6.00	6.00	6.10	6.20	6.20	6.45	6.40	6.35
2	TRP-P_2	5.70	5.70	5.80	6.00	6.25	6.20	6.20	6.50	6.45	6.45
3	TRP-P_3	5.70	6.00	6.00	6.00	6.10	6.20	6.15	6.15	6.15	6.15
4	SSP-P_1	5.80	5.90	5.85	5.95	6.05	6.15	6.20	6.70	6.40	6.35
5	SSP-P_2	5.70	5.90	5.90	6.05	6.30	6.25	6.20	6.25	6.20	6.20
6	SSP-P_3	5.65	5.70	5.80	6.00	6.05	6.10	6.20	6.45	6.20	6.20
7	DAP-P_1	5.45	5.90	5.90	6.00	6.05	6.05	5.85	5.90	6.05	6.30
8	DAP-P_2	5.80	6.10	6.10	6.10	6.25	6.15	6.05	6.20	6.10	6.25
9	DAP-P_3	5.86	5.83	6.00	6.15	6.10	6.10	5.90	5.90	5.90	6.15
10	MRP-P_1	5.75	6.10	6.05	6.05	6.20	6.35	6.20	6.25	6.10	6.25
11	MRP-P_2	5.65	5.85	5.85	5.95	6.05	6.05	6.05	5.95	5.90	6.25
12	MRP-P_1	5.70	5.72	6.35	5.95	6.00	6.05	6.00	5.95	5.90	6.15
13	Control	5.90	6.10	6.20	6.30	6.40	6.20	5.90	6.20	6.20	6.40
14	SSP(P_2+P_2)	5.70	6.00	6.10	6.10	6.00	6.20	5.60	5.90	5.90	6.20

Fig 19. Change of pH during incubation - Laterite soil

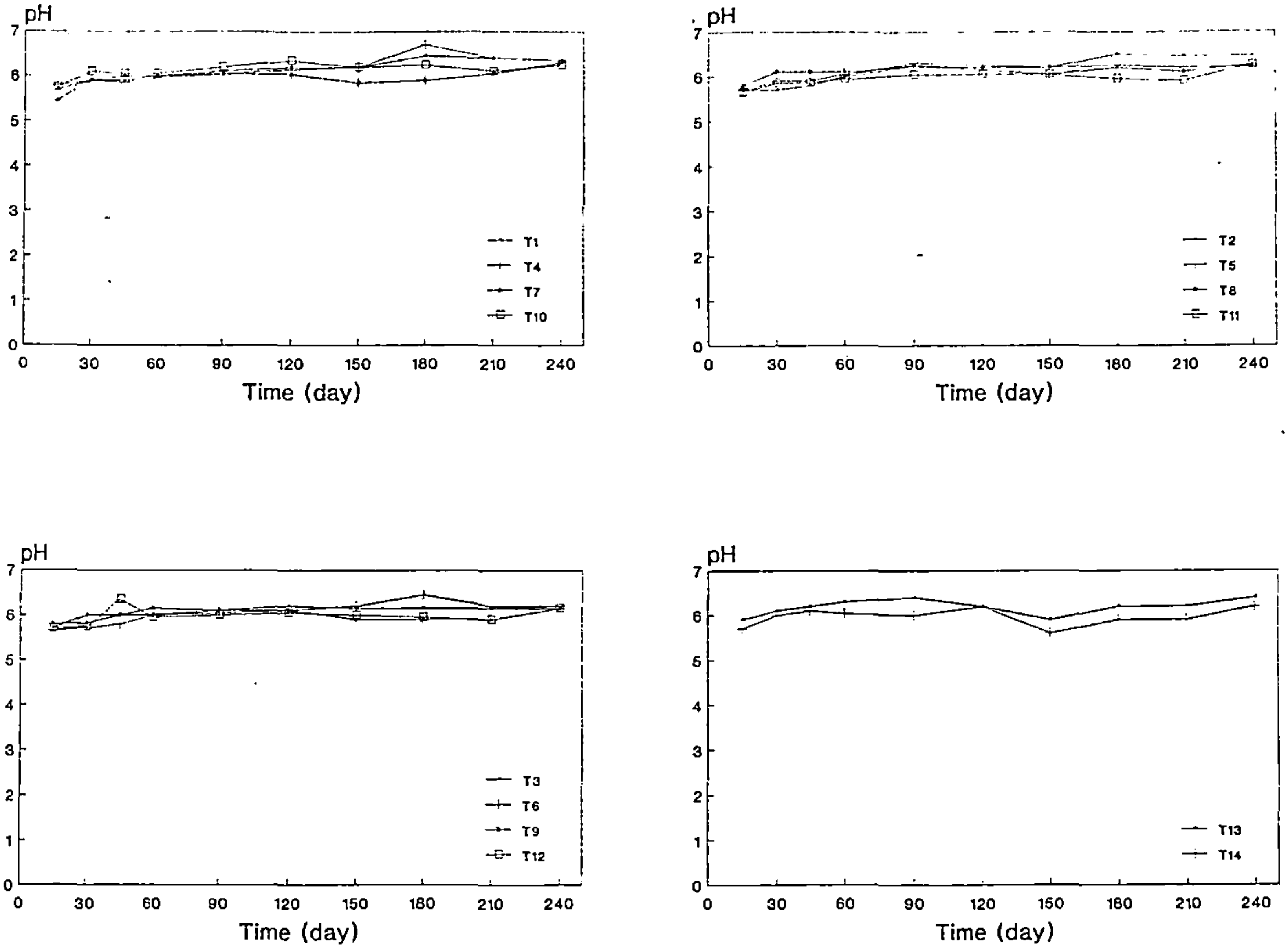
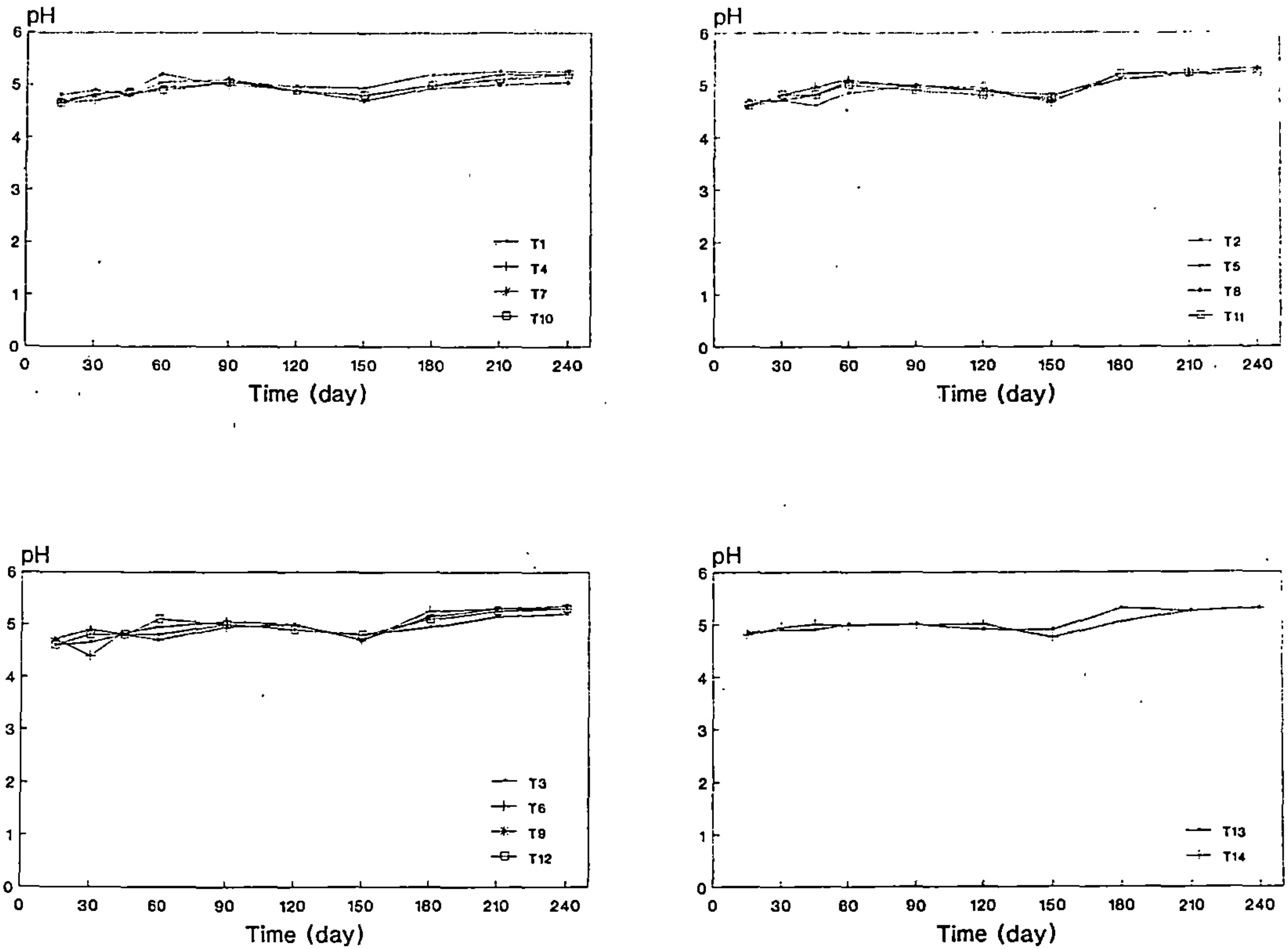


Table 20. pH as influenced by treatments at different period of incubation (Kuttanad)

Treatment		Period of incubation (days)									
No.	Notation	15	30	45	60	90	120	150	180	210	240
1	TRP-P_1	4.80	4.90	4.80	4.95	5.05	4.98	4.95	5.20	5.25	5.24
2	TRP-P_2	4.70	4.70	4.60	4.85	5.00	4.90	4.70	5.10	5.20	5.30
3	TRP-P_3	4.60	4.65	4.80	4.80	5.00	4.90	4.80	4.95	5.15	5.20
4	SSP-P_1	4.65	4.70	4.80	5.05	5.10	4.90	4.80	5.00	5.20	5.20
5	SSP-P_2	4.60	4.70	4.80	5.05	5.00	4.95	4.65	5.20	5.25	5.30
6	SSP-P_3	4.73	4.40	4.85	4.95	5.05	5.00	4.70	5.25	5.30	5.35
7	DAP-P_1	4.70	4.80	4.90	5.20	5.00	4.90	4.70	4.95	5.00	5.05
8	DAP-P_2	4.60	4.80	4.95	5.10	4.95	4.90	4.80	5.10	5.15	5.25
9	DAP-P_3	4.73	4.90	4.80	4.70	4.95	5.00	4.70	5.15	5.30	5.30
10	MRP-P_1	4.65	4.83	4.85	4.90	5.05	4.90	4.80	5.00	5.10	5.20
11	MRP-P_2	4.60	4.80	4.80	5.00	4.90	4.80	4.75	5.20	5.20	5.20
12	MRP-P_1	4.60	4.80	4.80	5.10	5.00	4.90	4.80	5.10	5.25	5.30
13	Control	4.85	4.90	4.90	5.00	5.00	4.90	4.90	5.30	5.25	5.30
14	SSP(P_2+P_2)	4.85	4.95	5.00	4.98	5.00	5.00	4.75	5.05	5.25	5.30

Fig 20. Change of pH during incubation - Kuttanad alluvial soil



4.1.8.1 Nitrogen

The available nitrogen content in leachate showed a drastic reduction with incubation in laterite soil. The nitrogen content become significantly low by 105th day and was untraceable. The change of leachate nitrogen with period is given in Figs.21 and 22. The data are presented in Table 21 and 22.

In Kuttanad soil, the nitrogen content in leachate was high compared to laterite soil. In the first 45 days the decrease in nitrogen content of leachate was slow and there after the decrease was rapid. The nitrogen content in leachate became significantly low and untraceable by 150th day.

4.1.8.2 Available phosphorus

In the laterite soil the available P content was very low or nonsignificant from initial stage itself. The available phosphorus content in leachate was 0.2 to 0.3 ppm in initial stage of incubation. In Kuttanad soil also the available P content was very minute and trend of variation was similar. The phosphorus become untraceable in leachate by 150th day in laterite soil and by 180th day in Kuttanad soil. The graphical representation of variation of available P with period is given in Figs.23 and 24. Data is presented in Table 23 and 24.

4.1.8.3 Available potassium

The schematic representation of variation of available potassium with period of incubation is given in Figs.25 and 26. Data of the incubation are presented

Table 21. Change of available Nitrogen during incubation in leachate (Laterite) (ppm)

Treatment		Period of incubation (days)						
No.	Notation	15	30	45	60	75	90	105
1	TRP-P_1	3.9	2.1	1.4	1.4	1.0	0.7	0.0
2	TRP-P_2	2.1	2.1	1.8	1.4	1.0	0.7	0.0
3	TRP-P_3	2.1	2.1	2.1	1.8	1.0	0.7	0.0
4	SSP-P_1	1.8	1.8	1.8	1.4	0.7	0.7	0.0
5	SSP-P_2	1.8	1.8	1.8	1.8	1.0	1.0	0.0
6	SSP-P_3	1.8	1.8	1.4	1.4	1.0	0.7	0.0
7	DAP-P_1	2.5	2.5	3.2	2.1	1.0	0.7	0.0
8	DAP-P_2	2.8	2.1	2.7	1.4	0.7	0.3	0.0
9	DAP-P_3	3.1	2.5	2.1	1.4	1.0	0.7	0.0
10	MRP-P_1	3.1	2.5	2.5	2.1	1.0	0.7	0.0
11	MRP-P_2	2.5	1.8	1.4	1.4	1.0	0.7	0.7
12	MRP-P_3	2.8	1.7	1.4	1.8	1.0	1.0	0.0
13	Control	3.5	1.7	2.5	1.4	1.0	0.7	0.0
14	SSP(P_2 +P_2)	3.9	2.5	2.6	1.4	1.0	1.0	0.0

Fig 21. Change of available nitrogen during incubation in leachate - Laterite soil

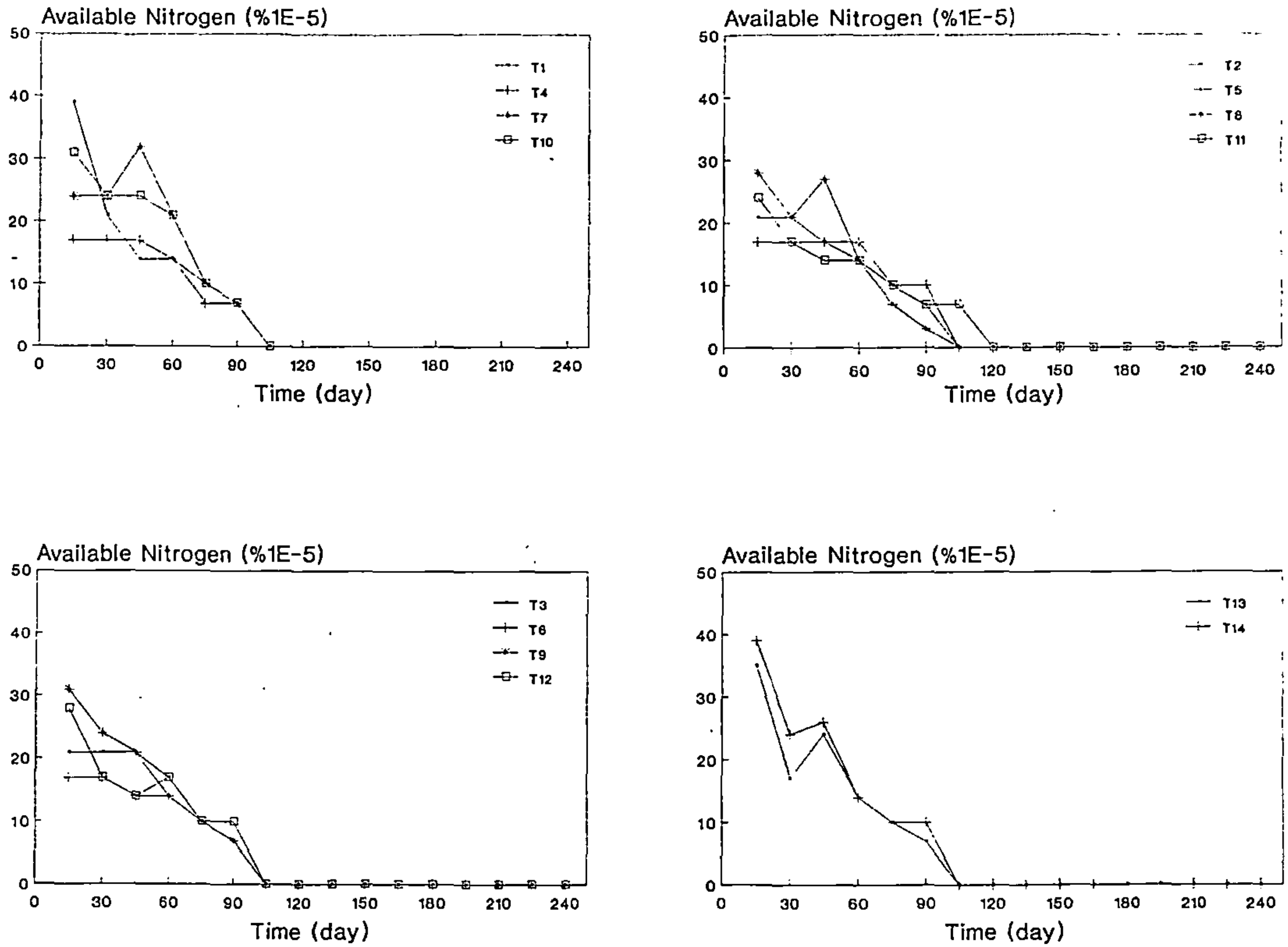


Table 22. Change of available Nitrogen during incubation in leachate (Kuttanad) (ppm)

Treatment		Period of incubation (days)								
No.	Notation	15	30	45	60	75	90	105	120	135
1	TRP-P_1	18.2	17.5	22.4	15.0	13.5	11.7	11.2	5.6	1.4
2	TRP-P_2	18.2	21.5	21.0	15.2	14.0	11.7	12.1	6.3	2.6
3	TRP-P_3	19.9	17.5	21.9	16.0	15.3	16.0	11.1	7.4	2.1
4	SSP-P_1	18.2	18.2	18.9	15.2	13.9	11.6	11.1	6.0	1.8
5	SSP-P_2	20.8	22.4	21.9	16.0	14.7	55.3	47.3	6.7	0.7
6	SSP-P_3	21.7	18.9	16.0	16.5	15.4	16.0	11.0	6.7	1.4
7	DAP-P_1	21.3	22.4	22.0	15.7	13.5	55.3	11.5	6.0	1.4
8	DAP-P_2	16.1	14.7	12.6	13.0	12.0	55.0	9.3	6.7	1.4
9	DAP-P_3	14.4	20.7	18.4	15.5	14.0	12.3	12.5	4.3	2.5
10	MRP-P_1	13.1	13.0	13.8	12.7	11.7	10.1	10.0	37.0	0.0
11	MRP-P_2	16.0	11.9	11.9	11.2	10.9	10.5	8.5	6.5	0.7
12	MRP-P_3	15.5	16.2	13.9	11.6	11.2	64.2	9.5	6.0	0.0
13	Control	11.2	16.2	7.7	12.2	11.7	10.5	8.7	5.2	1.1
14	SSP(P_2 +P_2)	14.6	18.9	17.0	17.3	11.9	10.1	46.5	5.3	0.0

Fig 22. Change of available nitrogen during incubation in leachate - Kuttanad alluvial soil

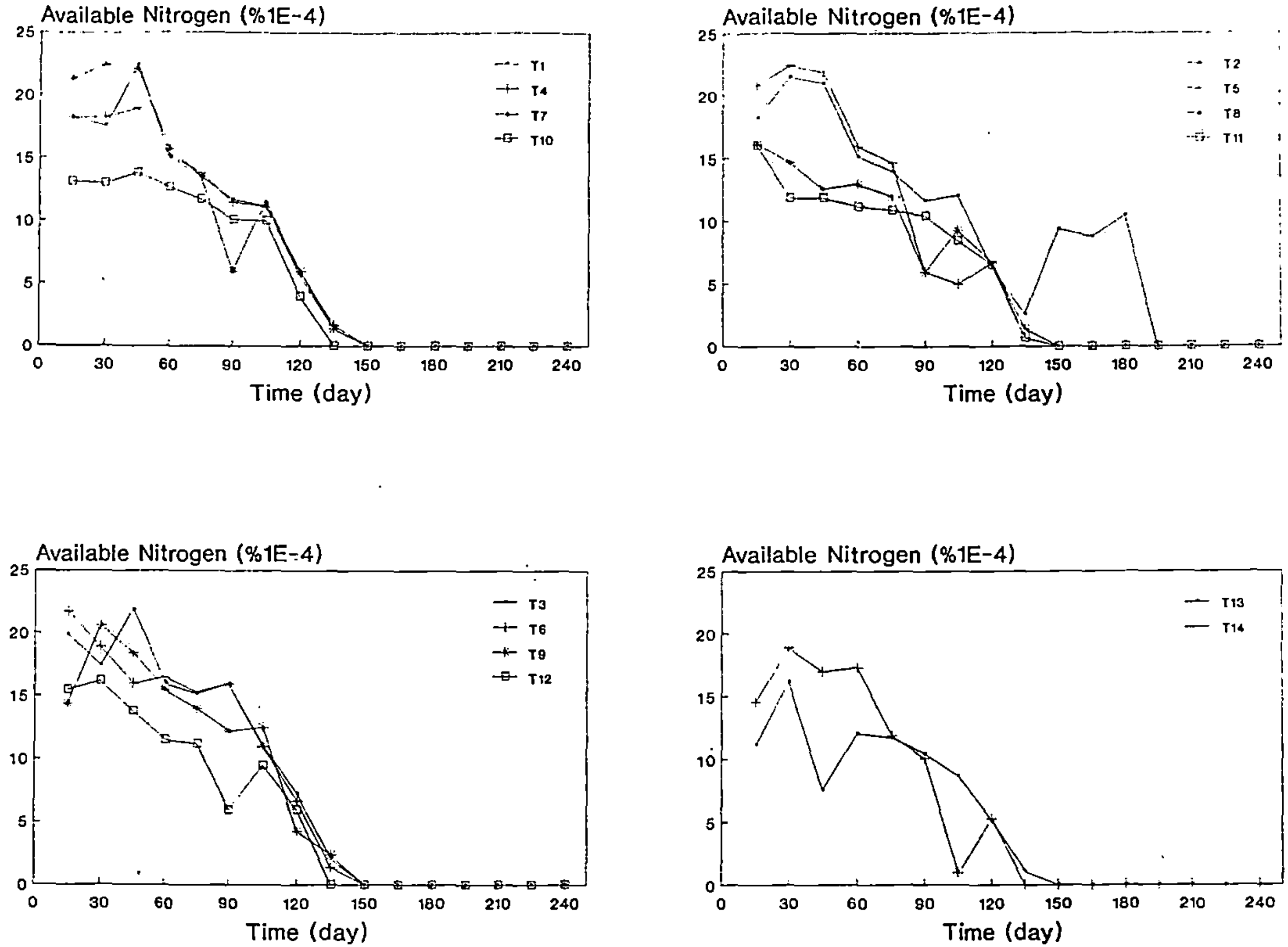


Table 23. Change of available Phosphorus during incubation in leachate (Laterite) ppm

Treatment		Period of incubation (days)											
No.	Notation	15	30	45	60	75	90	105	120	135	150	165	180
1	TRP-P_1	0.1250	0.3440	0.1880	0.1565	0.1880	0.1880	0.3130	0.1250	0.1250	0.0315	0.0625	0.0315
2	TRP-P_2	0.2190	0.2505	0.1250	0.1565	0.1880	0.2190	0.1565	0.2190	0.1565	0.1250	0.0315	0.0000
3	TRP-P_3	0.1250	0.3125	0.1565	0.1565	0.1880	0.2190	0.3765	0.1875	0.1565	0.0940	0.0940	0.0940
4	SSP-P_1	0.1250	0.2500	0.2190	0.1875	0.1565	0.1880	0.2190	0.0940	0.0940	0.0625	0.0000	0.0000
5	SSP-P_2	0.1880	0.2500	0.1875	0.1565	0.1250	0.1875	0.3130	0.1875	0.1250	0.0940	0.0000	0.0000
6	SSP-P_3	0.2190	0.1925	0.1565	0.1565	0.1875	0.2190	0.3465	0.1565	0.1565	0.1875	0.0000	0.0000
7	DAP-P_1	0.2190	0.2190	0.2190	0.1250	0.1565	0.1880	0.1880	0.0940	0.0625	0.0625	0.0000	0.0000
8	DAP-P_2	0.1565	0.1880	0.1875	0.1565	0.1565	0.1880	0.1880	0.1565	0.1255	0.0625	0.0000	0.0000
9	DAP-P_3	0.1565	0.2500	0.1250	0.1250	0.1565	0.1880	0.2505	0.1565	0.1250	0.0940	0.0000	0.0000
10	MRP-P_1	0.2190	0.1875	0.1565	0.1250	0.2815	0.2505	0.2505	0.1565	0.1250	0.0940	0.0000	0.0000
11	MRP-P_2	0.1565	0.1875	0.1565	0.1565	0.1880	0.2815	0.2815	0.1565	0.0940	0.0940	0.0000	0.0000
12	MRP-P_3	0.1840	0.2815	0.1875	0.1565	0.1880	0.2190	0.2190	0.1880	0.1250	0.1250	0.0000	0.0000
13	Control	0.2500	0.2000	0.1565	0.1565	0.1880	0.2190	0.1880	0.1255	0.0940	0.0315	0.0000	0.0000
14	SSP(P_2 +P_2)	0.1880	0.1660	0.2500	0.1565	0.2815	0.2815	0.2505	0.2505	0.1565	0.0940	0.0000	0.0000

Fig 23. Change of available phosphorus during incubation in leachate - Laterite soil

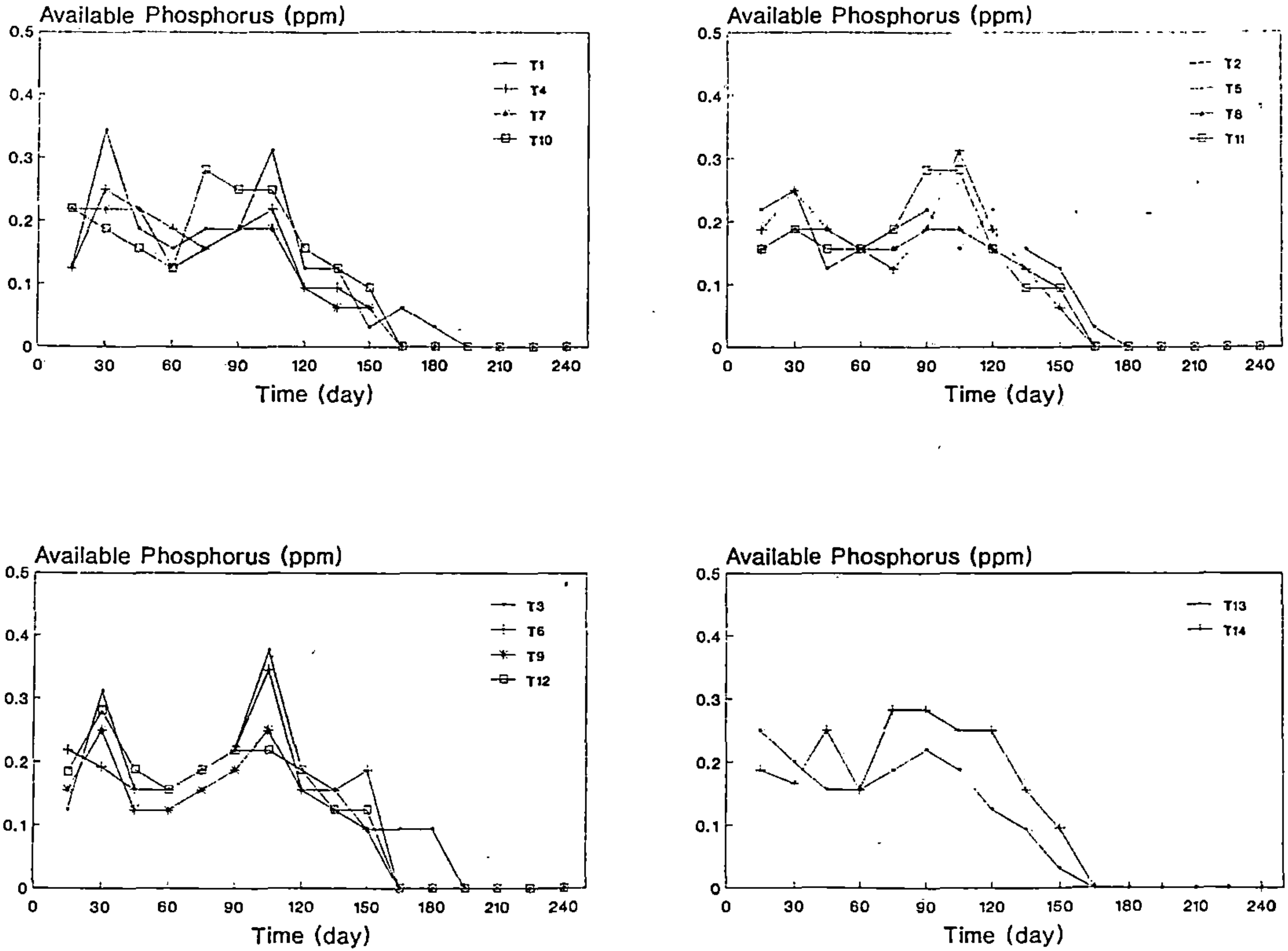


Table 24. Change of available Phosphorus during incubation in leachate (Kuttanad) ppm

Treatment		Period of incubation (days)											
No.	Notation	15	30	45	60	75	90	105	120	135	150	165	180
1	TRP-P_1	0.25000	0.21900	0.15650	0.21900	0.25000	0.25000	0.15650	0.18750	0.15650	0.12500	0.12500	0.06250
2	TRP-P_2	0.21900	0.21900	0.12500	0.21900	0.18800	0.18800	0.28150	0.15650	0.12500	0.03150	0.03150	0.03150
3	TRP-P_3	0.18800	0.25000	0.15650	0.28150	0.12500	0.21900	0.21900	0.15650	0.09400	0.06250	0.06250	0.06250
4	SSP-P_1	0.12500	0.18750	0.15650	0.21900	0.18800	0.22750	0.18750	0.15650	0.09400	0.09400	0.00000	0.00000
5	SSP-P_2	0.18800	0.31500	0.18750	0.18800	0.25050	0.18800	0.15650	0.18750	0.09400	0.09400	0.06250	0.00000
6	SSP-P_3	0.18750	0.40500	0.15650	0.25000	0.22500	0.25000	0.25050	0.18800	0.09400	0.09400	0.06250	0.06250
7	DAP-P_1	0.18750	0.25250	0.18750	0.18750	0.31250	0.33250	0.18800	0.15650	0.06250	0.12500	0.06250	0.06250
8	DAP-P_2	0.18800	0.25000	0.18750	0.18800	0.31250	0.31250	0.21900	0.18800	0.06250	0.06250	0.06250	0.00000
9	DAP-P_3	0.20000	0.28150	0.18750	0.21900	0.21900	0.18750	0.47150	0.18800	0.09400	0.06250	0.06250	0.06250
10	MRP-P_1	0.18800	0.25050	0.15650	0.15650	0.18750	0.18750	0.21900	0.06250	0.09400	0.06250	0.06250	0.00000
11	MRP-P_2	0.15650	0.28150	0.21900	0.25050	0.15650	0.12500	0.18800	0.09400	0.00000	0.00000	0.00000	0.00000
12	MRP-P_3	0.25000	0.28150	0.18750	0.21900	0.18750	0.18750	0.28150	0.12500	0.06250	0.00000	0.00000	0.00000
13	Control	0.09400	0.18750	0.18750	0.18750	0.12500	0.15650	0.21900	0.06250	0.03150	0.00000	0.00000	0.00000
14	SSP(P_2 +P_2)	0.18750	0.28150	0.15650	0.21900	0.18750	0.18750	0.28150	0.12500	0.09400	0.12500	0.18800	0.00000

Fig 24. Change of available phosphorus during incubation in leachate - Kuttanad alluvial soil

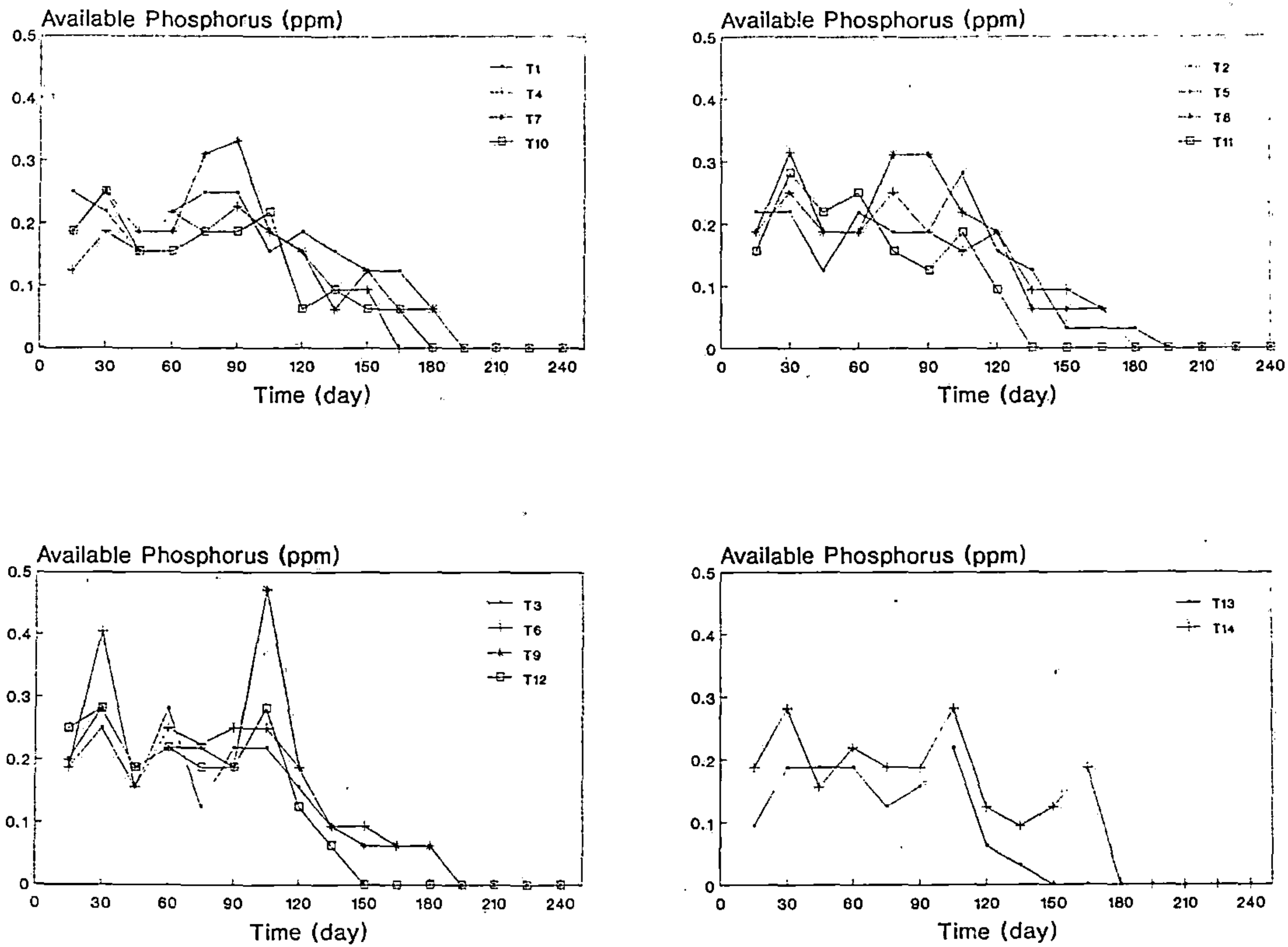


Table 25. Change of available Potassium during incubation in leachate (Laterite) ppm

Treatment		Period of incubation (days)															
No.	Notation	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240
1	TRP-P_1	3.50	3.50	3.10	2.90	2.70	2.60	2.60	2.40	2.30	2.50	1.90	1.80	1.80	1.80	1.50	1.40
2	TRP-P_2	2.70	2.60	2.60	2.60	2.70	2.50	2.50	2.50	2.00	1.70	1.70	1.60	1.35	1.30	1.25	0.60
3	TRP-P_3	2.40	2.70	2.70	2.70	2.50	2.40	2.50	2.30	2.10	1.70	1.50	1.30	1.20	1.10	1.10	1.10
4	SSP-P_1	2.60	2.60	2.50	2.50	2.60	2.50	2.40	2.10	1.90	1.80	1.60	1.40	1.40	1.40	1.15	1.10
5	SSP-P_2	2.60	2.70	2.70	2.60	3.10	2.30	2.40	2.10	1.90	1.80	1.50	1.30	1.30	1.40	1.15	1.10
6	SSP-P_3	3.20	2.90	2.80	2.70	2.50	2.50	2.50	2.40	1.80	1.80	1.60	1.20	1.15	1.10	0.95	0.90
7	DAP-P_1	2.90	2.90	2.60	2.60	2.60	2.60	2.50	2.30	2.20	1.90	1.60	1.50	1.30	1.20	1.10	1.00
8	DAP-P_2	4.00	3.00	2.80	2.90	2.90	3.00	2.70	2.20	2.20	2.00	1.70	1.60	1.30	1.20	1.10	1.10
9	DAP-P_3	4.20	2.90	2.80	2.90	3.20	3.30	2.30	2.20	2.20	2.00	1.60	1.50	1.30	1.10	1.00	0.90
10	MRP-P_1	2.30	2.80	2.80	2.80	3.00	3.00	2.60	2.40	2.00	2.20	1.80	1.50	1.25	1.00	1.00	1.00
11	MRP-P_2	2.30	2.70	2.90	2.90	2.90	2.40	2.40	2.20	2.10	1.90	1.80	1.80	1.70	1.60	1.50	1.30
12	MRP-P_3	2.10	2.10	2.90	2.80	3.00	2.80	2.50	2.40	2.00	1.80	1.70	1.50	1.45	1.40	1.15	1.10
13	Control	2.90	3.00	2.90	2.90	2.90	2.90	2.40	2.10	1.90	2.10	1.80	1.90	1.70	1.60	1.35	1.00
14	SSP(P_2+P_2)	3.40	2.60	2.70	2.70	2.90	2.70	2.60	2.40	2.00	2.50	1.90	1.50	1.30	1.20	1.15	1.10

Fig 25. Change of available potassium during incubation in leachate - Laterite soil

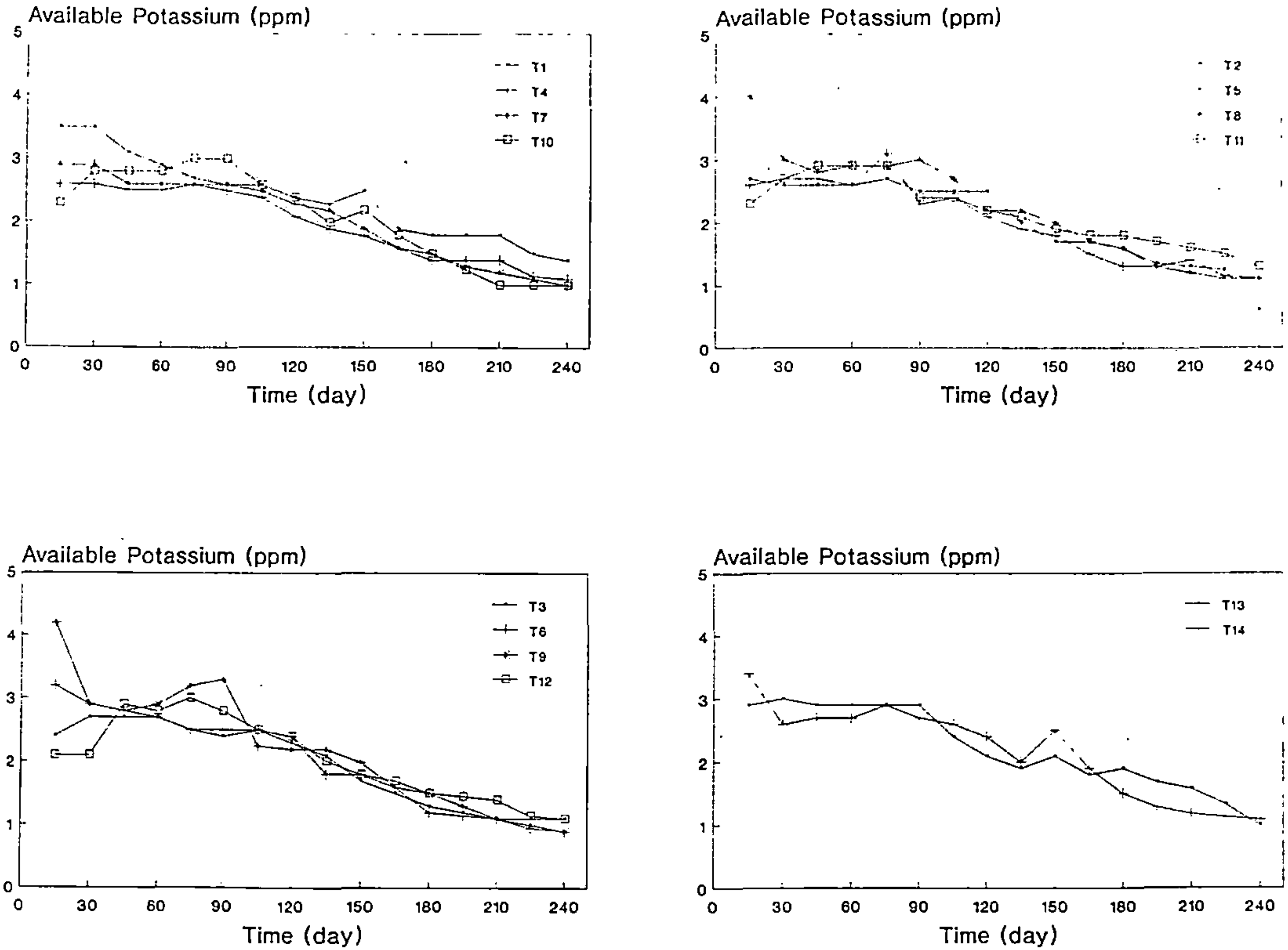
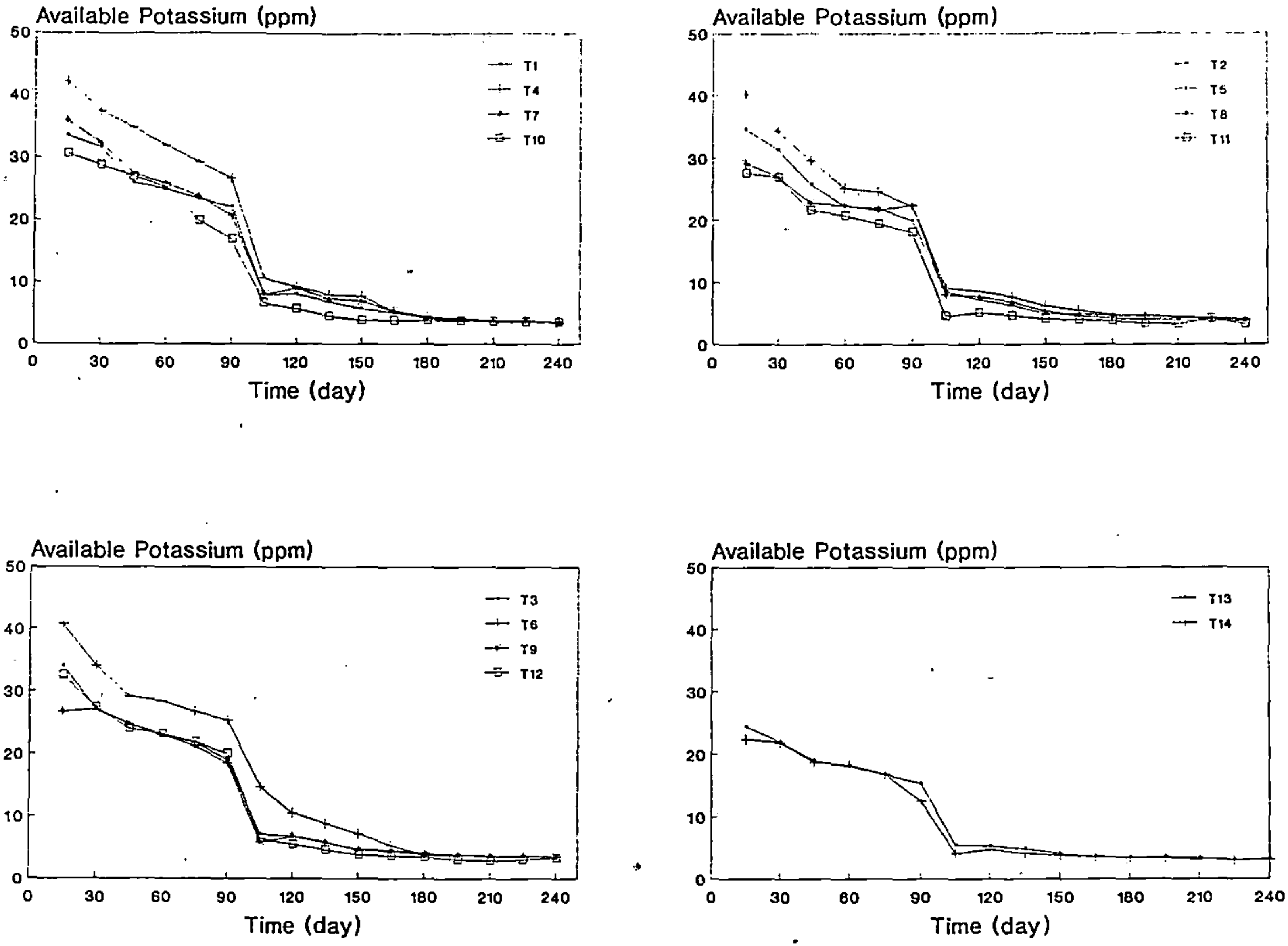


Table 26. Change of available Potassium during incubation in leachate (Kuttanad) ppm

Treatment		Period of incubation (days)															
No.	Notation	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240
1	TRP-P_1	33.50	31.60	26.00	25.00	23.40	22.20	8.00	8.10	6.90	5.70	5.10	4.30	3.90	3.70	3.70	3.65
2	TRP-P_2	34.60	31.40	25.80	22.30	22.00	20.00	8.60	7.20	6.40	4.90	4.90	4.70	4.70	4.30	4.20	4.00
3	TRP-P_3	34.00	27.20	24.80	22.80	21.80	19.10	7.10	6.90	5.90	4.80	4.60	4.15	3.90	3.70	3.70	3.50
4	SSP-P_1	42.20	37.40	34.80	32.00	29.40	26.80	10.60	9.30	8.00	7.70	5.40	4.40	4.20	3.90	3.70	3.55
5	SSP-P_2	40.20	34.40	29.60	25.20	24.60	22.40	9.20	8.60	7.70	6.20	5.50	4.80	4.60	4.50	4.30	4.05
6	SSP-P_3	40.80	34.00	29.20	28.40	26.75	25.40	14.70	10.60	8.90	7.20	5.40	3.80	3.75	3.70	3.65	3.60
7	DAP-P_1	36.00	32.20	27.40	26.00	23.85	20.80	8.00	9.00	7.40	7.00	5.40	4.10	4.00	3.90	3.80	3.40
8	DAP-P_2	29.20	27.00	22.80	22.40	21.60	22.60	8.10	7.70	6.90	5.40	4.60	4.30	4.05	4.00	3.75	3.85
9	DAP-P_3	26.70	27.10	24.80	23.00	21.20	18.60	5.90	6.80	5.90	4.60	4.40	3.90	3.75	3.70	3.60	3.55
10	MRP-P_1	30.60	28.80	27.00	25.40	20.00	17.00	6.60	5.70	4.50	3.80	3.80	3.80	3.75	3.70	3.60	3.55
11	MRP-P_2	27.60	27.00	21.60	20.75	19.40	18.20	4.60	5.10	4.70	4.10	4.00	3.80	3.40	3.30	4.15	3.35
12	MRP-P_3	32.60	27.40	24.00	23.20	21.80	20.10	6.50	5.50	4.70	3.80	3.70	3.50	3.10	2.90	3.10	3.30
13	Control	24.40	22.00	19.00	18.20	16.80	15.40	5.55	5.40	4.90	4.10	3.70	3.50	3.55	3.40	3.10	3.25
14	SSP(P_2+P_2)	22.40	21.90	18.80	18.20	16.80	12.60	4.20	4.80	4.20	3.80	3.60	3.40	3.30	3.15	3.10	3.10

Fig 26. Change of availbale potassium during incubation in leachate - Kuttanad alluvial soil



in Table 25 and 26. In laterite soil the available potassium in initial phase of incubation was around 3-4 ppm. The potassium content remained almost in a steady state till 90th day of incubation. Then from there onwards potassium content of leachate depleted slowly till the end of incubation.

In Kuttanad soil the available potassium content of leachate showed a steady decline till 90th day of incubation. From 90th day onwards it fell abruptly and from 150th day onwards it kept a steady and slow declining trend.

Though leaching loss of P was very negligible and affected available soil phosphorus in a very minute fraction, the leaching loss of nitrogen and potassium was considerable and affected the soil content of available nitrogen and available potassium.

4.2 Pot culture

The results of the pot culture experiment conducted are presented and discussed below.

4.2.1 Biometric observations

4.2.1.1 First crop

The data on the number of leaves with different period of crop are given in Table 27 and 28. In laterite soil the number of leaves was found to be decreasing from MT stage to PI and harvest stages. As the dose of applied P increased it was found that the number of leaves also increased. In Kuttanad soil also the variation followed same trend. In both soil DAP had shown highest number of leaves during

MT stage and in other stages there was no uniform trend. In PI and harvest stages of 1st crop SSP treatments showed highest number of leaves in laterite and TRP in Kuttanad soils. The statistical analysis of data showed no significant difference with source and dose.

The number of tillers showed an increase in number from MT to PI stage in both soil. After PI stage it remained steady in laterite soil. Statistical analysis showed that there was no significant difference in number of tillers due to different sources and doses of fertiliser.

The height of plants increased from MT to PI stage and then decreased. The variation in height was similar type in both soils. The statistical analysis showed that there was no significant difference in plants due to difference in doses or P sources.

Dry weight of plants showed an increase from MT stage to panicle initiation and harvest stages in both the soils. The statistical analysis showed significant difference in dry weight with the doses in all the stages and with different P sources in panicle initiation and harvest stages.

4.2.1.2 Second crop

The effect of application of different rockphosphate and their different level on biometric observation are given in Tables 29 and 30. The number of leaves showed a steady decrease from MT stage to harvest in both the soils. The trend was similar in both soils. The SSP applied twice had number of leaves comparable to

Table 27. Biometric observation of crop I as influenced by the treatments (Laterite)

Treatment		No. of leaves			No. of tillers			Height of plant (cm)			Dry weight of plant (g)		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	11.30	7.57	8.52	3.50	5.50	3.50	39.47	55.24	52.74	9.06	13.23	35.66
2	TRP-P_2	11.28	7.50	8.00	3.00	3.50	2.00	45.74	55.64	54.62	10.06	16.26	31.24
3	TRP-P_3	12.81	8.58	8.52	3.50	3.50	3.50	41.71	48.24	47.70	10.55	23.30	35.22
4	SSP-P_1	11.30	7.57	8.03	3.50	4.00	3.00	43.61	44.07	45.16	8.49	15.27	29.91
5	SSP-P_2	12.29	8.58	8.52	3.00	4.00	2.50	43.20	52.84	51.04	9.55	15.27	31.05
6	SSP-P_3	12.23	8.58	8.52	4.00	4.50	3.00	47.75	61.83	59.84	9.03	18.80	32.65
7	DAP-P_1	11.30	8.05	8.52	3.50	3.50	2.50	45.25	55.09	54.16	8.55	13.72	28.32
8	DAP-P_2	12.29	8.09	8.03	3.50	3.00	3.00	46.27	57.25	56.24	10.55	14.77	27.67
9	DAP-P_3	13.31	8.09	8.03	3.50	3.50	2.50	46.75	57.91	56.55	11.56	19.26	30.49
10	MRP-P_1	10.74	7.57	7.52	3.00	3.50	2.00	39.73	53.27	52.26	9.06	19.30	28.12
11	MRP-P_2	11.28	7.57	8.03	3.50	4.00	2.50	38.69	48.19	48.19	9.06	13.72	28.85
12	MRP-P_3	11.09	7.57	8.52	3.00	4.00	2.50	39.73	52.15	51.20	8.55	18.30	31.92
13	Control	10.78	7.57	8.03	3.50	3.50	3.00	44.24	49.77	49.77	7.54	8.70	29.08
14	SSP(P_2+P_2)	11.76	8.09	8.03	3.50	4.00	3.00	46.23	57.32	55.82	10.06	16.26	35.64
	Source												
	TRP	11.58	7.82	8.32	3.33	4.17	3.00	42.07	52.72	51.41	9.84	17.16	32.89
	SSP	11.73	8.18	8.33	3.50	4.17	2.83	44.64	52.22	51.47	8.98	16.22	30.18
	DAP	12.08	8.02	8.17	3.50	3.33	2.67	45.91	56.52	55.43	10.14	15.64	27.88
	MRP	10.84	7.52	8.00	3.17	3.83	2.33	39.23	50.96	50.33	8.83	16.82	28.60
	CD(0.05)	-	-	-	-	-	-	1.1276	-	-	-	0.1053	-
	Level												
	P_1	10.97	7.67	8.09	3.43	4.00	2.83	42.82	52.04	51.31	8.73	14.02	29.87
	P_2	11.55	7.87	8.12	3.25	3.63	2.50	43.19	53.14	52.20	9.76	14.79	28.56
	P_3	12.11	8.13	8.37	3.50	3.88	2.88	43.67	54.55	53.39	9.84	19.63	31.35
	CD(0.05)	-	-	-	-	-	-	-	-	-	0.217	0.0782	0.926

Table 28. Biometric observation of crop I as influenced by the treatments (Kuttanad)

Treatment		No. of leaves			No. of tillers			Height of plant (cm)			Dry weight of plant (g)		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	15.86	11.08	9.52	5.50	6.00	5.00	49.73	56.44	55.09	11.56	18.72	38.10
2	TRP-P_2	16.30	11.59	10.52	6.00	5.00	5.00	50.13	62.36	59.84	13.57	30.89	38.21
3	TRP-P_3	16.36	10.10	10.03	5.50	5.50	4.00	47.56	59.59	59.20	13.53	30.89	44.28
4	SSP-P_1	16.30	8.58	8.52	5.50	5.50	4.00	39.21	49.93	49.47	10.51	28.29	34.79
5	SSP-P_2	15.08	9.53	9.00	5.00	5.00	4.50	45.76	49.19	48.24	14.05	26.32	34.23
6	SSP-P_3	17.36	10.10	10.03	4.00	4.50	3.50	56.24	61.85	50.49	14.58	27.87	46.32
7	DAP-P_1	19.87	9.06	8.52	5.50	5.50	3.00	51.80	57.32	56.81	9.55	18.72	36.21
8	DAP-P_2	18.89	9.58	9.52	5.50	5.50	4.50	50.77	57.11	56.18	12.56	24.85	42.46
9	DAP-P_3	16.34	9.58	9.52	6.00	5.50	3.50	52.21	55.24	55.24	19.08	24.34	42.76
10	MRP-P_1	18.32	9.06	9.00	4.50	5.00	4.50	47.70	53.62	53.62	12.07	22.32	38.93
11	MRP-P_2	16.68	9.06	8.52	3.00	4.00	4.00	45.08	53.27	56.31	13.53	21.46	41.68
12	MRP-P_3	17.36	9.58	9.52	5.00	4.00	4.00	48.76	51.29	50.79	12.07	26.84	39.69
13	Control	13.31	8.58	8.52	3.00	4.50	4.50	43.20	55.82	55.82	9.06	14.19	35.59
14	SSP(P_2+P_2)	17.85	9.58	9.52	5.00	5.50	4.00	45.63	58.74	60.60	15.08	19.78	42.35
	<u>Source</u>												
	TRP	15.93	10.84	10.00	5.67	5.50	4.67	48.94	59.19	57.78	12.82	26.26	38.79
	SSP	15.99	9.33	9.15	4.83	5.00	4.00	46.38	53.15	49.20	12.93	27.24	35.87
	DAP	18.08	9.35	9.16	5.67	5.50	3.67	51.39	56.33	55.86	13.40	22.33	39.14
	MRP	17.20	9.17	8.99	4.17	4.33	4.17	46.97	52.51	53.32	12.50	23.26	38.84
	CD(0.05)	-	-	-	-	-	-	1.1276	-	-	-	0.1053	-
	<u>Level</u>												
	P_1	16.56	9.24	8.91	4.83	5.33	4.17	45.82	55.00	54.89	11.17	19.88	36.23
	P_2	16.43	9.85	9.35	4.88	4.88	4.50	47.66	55.03	54.74	13.37	25.50	37.60
	P_3	16.58	9.77	9.75	5.13	4.88	3.75	50.86	56.60	53.58	14.65	27.16	41.67
	CD(0.05)	-	-	0.0107	-	-	-	-	-	-	0.0217	0.0782	0.926

other treatments. The statistical analysis of data showed no significant difference in number of leaves due to different P sources or due to different doses.

The number of tillers showed no uniform trend during MT and PI stage. But in harvest stage it was decreased to a lower value in both soils. The doses of applied P sources gave no linear relationship to number of tillers. The statistical analysis showed that there was no significant difference due to type of P source or dose. The different factors showed interaction with each other.

Height of plant showed an increase from MT stage to PI stage and then decreased to a low value at harvest stage in both laterite and Kuttanad soils. In laterite soil during maximum tillering stage TRP treatments were having maximum height while in Kuttanad soil in maximum tillering stage DAP treatments gave maximum height. The different P sources and doses do not found to have any significant difference with height of plant except in maximum tillering stage. The different factors viz., soil type, source and dose interacted with each other at different stages.

Dry weight of plant

It was found that dry weight of the plant showed an increase from MT stage to panicle initiation and harvest stages in both laterite and Kuttanad soils. In laterite soil the SSP and TRP had a slightly higher dry weight compared to DAP and MRP in MT stage. However, in PI and at harvest similar effects were observed for various treatments. In Kuttanad soil the TRP showed higher dry weight in MT and harvest stages, but DAP showed higher value in PI stage. The values were 23.1,

Table 29. Biometric observation of crop II as influenced by the treatments (Laterite)

Treatment		No. of leaves			No. of tillers			Height of plant (cm)			Dry weight of plant (g)		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	10.64	9.77	8.14	2.50	3.00	2.50	44.76	52.53	41.68	7.12	7.85	22.07
2	TRP-P_2	9.05	9.77	8.17	2.00	2.50	2.50	37.72	61.83	56.07	8.69	10.87	26.37
3	TRP-P_3	14.50	13.14	9.63	4.50	4.50	4.50	44.69	59.79	57.63	9.70	13.98	36.39
4	SSP-P_1	12.74	11.28	9.68	3.50	3.50	3.50	44.53	61.37	57.30	7.61	12.45	28.75
5	SSP-P_2	12.17	11.30	8.67	2.50	3.00	3.00	38.90	49.19	46.21	8.56	7.78	22.56
6	SSP-P_3	12.17	11.30	8.67	3.00	3.00	3.00	39.73	49.27	46.83	9.70	16.02	25.88
7	DAP-P_1	9.53	9.24	8.17	2.50	3.50	3.50	45.25	61.32	58.03	6.56	6.74	24.07
8	DAP-P_2	10.15	9.77	9.68	2.50	3.00	3.00	40.03	61.34	60.71	7.12	9.89	23.67
9	DAP-P_3	9.37	8.12	7.12	2.50	3.00	3.00	45.25	59.33	57.63	6.60	13.94	30.30
10	MRP-P_1	11.69	11.28	9.68	3.50	3.50	3.50	44.69	60.32	57.59	6.56	12.37	24.95
11	MRP-P_2	11.69	11.76	8.67	3.50	3.50	3.50	45.25	54.81	51.97	7.61	8.81	22.60
12	MRP-P_3	8.08	7.20	6.64	2.00	2.00	2.00	46.23	53.23	54.54	7.29	15.00	26.08
13	Control	8.93	8.57	8.04	2.50	2.50	2.50	43.24	54.75	52.70	4.89	9.89	20.98
14	SSP(P_2+P_2)	11.09	9.01	7.58	3.50	3.50	3.50	48.19	57.32	53.00	8.56	17.00	29.77
	<u>Source</u>												
	TRP	10.82	10.64	8.51	3.00	3.33	3.17	42.10	57.69	50.29	8.01	10.47	27.38
	SSP	11.87	11.09	8.88	3.00	3.17	3.17	40.82	52.78	48.92	8.14	11.54	25.12
	DAP	9.25	8.85	8.17	2.50	3.17	3.17	43.27	60.43	57.66	6.35	9.71	25.40
	MRP	9.96	9.78	8.16	3.00	3.00	3.00	45.21	55.82	53.61	6.73	11.63	23.68
	CD(0.05)	-	-	-	-	-	-	1.1276	-	-	0.3835	0.2007	1.014
	<u>Level</u>												
	P_1	10.22	9.62	8.40	3.00	3.25	3.17	44.89	57.59	51.92	6.37	10.48	24.36
	P_2	10.23	10.41	8.65	2.63	3.00	3.00	40.20	56.31	52.33	7.48	9.01	23.05
	P_3	10.38	9.59	7.84	3.00	3.13	3.13	43.71	54.99	52.82	7.76	14.35	28.81
	CD(0.05)	-	-	-	-	-	-	-	-	-	-	0.1486	1.112

Table 30. Biometric observation of crop II as influenced by the treatments (Kuttanad)

Treatment		No. of leaves			No. of tillers			Height of plant (cm)			Dry weight of plant (g)		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	20.44	17.36	14.23	7.00	7.00	7.00	45.63	57.78	59.13	21.04	18.32	54.54
2	TRP-P_2	20.48	18.32	13.20	7.00	7.00	7.00	51.28	62.35	62.26	24.06	31.05	54.28
3	TRP-P_3	20.44	17.36	15.74	7.00	7.50	7.50	59.84	73.36	62.26	26.73	32.71	57.08
4	SSP-P_1	21.21	15.33	12.21	9.50	8.50	7.00	43.84	67.84	62.26	21.52	31.17	50.68
5	SSP-P_2	18.39	16.30	12.13	6.50	6.50	6.50	51.20	63.85	62.26	24.54	31.60	48.85
6	SSP-P_3	19.33	15.33	12.70	5.50	5.50	5.50	50.29	62.81	62.26	15.05	32.73	50.93
7	DAP-P_1	25.53	19.39	15.23	8.50	8.50	8.50	48.78	67.87	31.52	18.33	26.63	50.40
8	DAP-P_2	19.88	16.87	13.22	6.50	6.50	6.50	55.82	70.34	69.42	8.56	27.64	53.19
9	DAP-P_3	22.94	17.85	11.69	6.00	7.00	7.00	57.83	72.90	73.06	20.05	32.46	54.22
10	MRP-P_1	16.83	16.34	10.69	5.50	5.00	5.00	54.27	62.86	63.81	19.46	30.19	43.39
11	MRP-P_2	20.75	16.36	11.18	7.00	7.00	7.00	55.31	56.44	70.89	20.16	33.68	48.62
12	MRP-P_3	15.67	15.33	11.18	4.50	5.50	5.50	55.82	72.90	73.06	18.49	33.72	52.67
13	Control	15.31	13.31	13.49	5.00	5.50	5.50	46.09	60.85	64.27	17.17	24.55	41.44
14	SSP(P_2+P_2)	15.31	15.82	13.20	5.00	13.00	6.00	45.25	62.07	60.19	26.71	34.64	59.89
	Source												
	TRP	19.82	17.43	14.22	7.00	7.17	7.17	51.73	63.93	60.04	23.11	26.50	54.42
	SSP	19.01	15.41	12.21	7.17	6.83	6.33	48.15	64.55	61.08	19.45	31.34	49.30
	DAP	22.06	17.77	13.20	7.00	7.33	7.33	53.80	70.07	53.24	14.55	28.39	51.79
	MRP	17.10	15.77	10.88	5.67	5.83	5.83	54.92	63.47	67.82	18.67	32.02	46.97
	CD(0.05)	-	-	-	-	-	-	1.1276	-	-	0.3835	0.2007	1.014
	Level												
	P_1	18.25	15.93	12.97	6.75	7.92	6.50	46.99	62.83	54.13	19.79	26.89	48.74
	P_2	19.17	16.68	12.26	6.75	6.75	6.75	53.13	62.78	64.68	17.88	30.41	49.95
	P_3	18.82	16.18	12.61	5.75	6.38	6.38	55.59	70.04	66.01	19.07	32.35	52.75
	CD(0.05)	-	-	-	-	-	-	-	-	-	-	0.1486	1.112

31.34 and 54.42 respectively. The statistical analysis of data showed that the different treatments had significant effect on dry weight in all the three stages. But the level gave significant difference only in PI stage.

The Biometric observations like number of leaves, number of tillers and height of plants showed no difference with the application of phosphatic fertilizer in both crops. Statistically it was not significant with the different types and levels of sources. But the two types of soils showed significant difference which may be attributed to inherent physio-chemical characters of two type of soils.

In laterite soil during I crop the dry weight was maximum for TRP in panicle initiation stage and was comparable for different treatments in other stages. During 2nd crop the dry weight was maximum for TRP and SSP treatments. In Kuttanad soil during I crop the dry weight was maximum for SSP in panicle initiation stage. But was comparable in stages for all the sources. Thus the dry weight of plants clearly reflected the high residual activity of TRP. The higher dry weight for TRP in laterite soil during I and 2nd crop can be attributed to higher uptake of major nutrients by these treatments. Similar results were recorded by Patil *et al.* (1995). The dry weight was found to be varying in a linear way to the level of applied phosphorus.

4.2.2.1 First crop soil analysis

The chemical analysis of soil used in pot culture was carried out in three stages of plant growth namely MT stage, PI stage and harvest stage. The available

Table 31 . Available N, P, K - Ist crop (Laterite soil) (ppm)

Treatment		Available N			Available Phosphorus			Available Potassium		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	333.20	252.00	280.00	9.62	6.31	5.87	61.08	48.59	75.53
2	TRP-P_2	260.40	274.40	254.80	9.01	5.17	6.70	48.06	66.09	55.53
3	TRP-P_3	296.80	235.20	291.20	15.18	6.19	8.71	40.53	36.00	60.54
4	SSP-P_1	268.80	260.40	280.00	8.50	4.57	5.70	38.04	37.00	60.03
5	SSP-P_2	358.10	235.20	260.40	8.67	7.50	8.21	61.05	57.57	56.54
6	SSP-P_3	254.80	243.55	280.00	16.01	9.03	10.55	44.49	48.57	62.99
7	DAP-P_1	240.60	229.60	263.20	7.68	7.67	6.20	46.02	36.47	61.03
8	DAP-P_2	266.00	333.20	235.20	9.18	8.01	7.70	63.08	60.59	57.05
9	DAP-P_3	263.20	274.40	288.40	16.52	10.74	9.05	45.02	62.08	58.05
10	MRP-P_1	277.20	266.00	235.20	8.18	4.72	4.52	81.11	84.13	82.07
11	MRP-P_2	271.60	271.60	324.80	7.84	7.33	4.36	54.07	45.97	67.04
12	MRP-P_3	198.80	204.40	288.40	8.17	8.70	6.20	45.54	64.58	60.54
13	Control	257.60	224.00	285.60	5.50	4.26	4.36	67.03	40.48	58.54
14	SSP(P_2+P_2)	187.60	254.80	263.20	8.34	9.21	8.21	59.08	51.04	55.53
						Mean				
	Source									
	TRP	296.80	253.87	275.33	10.95	5.78	6.97	49.14	48.65	63.28
	SSP	293.99	246.38	273.47	10.56	6.66	7.87	46.88	46.90	59.75
	DAP	256.60	279.07	262.27	10.51	8.57	7.53	50.70	51.52	58.65
	MRP	249.20	247.33	282.80	8.06	6.60	4.94	58.40	62.91	69.27
	CD(0.05)	7.76	3.18	8.63	1.06	1.29	1.1006	1.0614	1.0627	1.0504
	Level									
	P_1	279.95	252.00	264.60	8.46	5.59	5.51	54.21	48.40	68.98
	P_2	289.02	278.60	268.80	8.65	6.79	6.53	56.18	56.99	58.82
	P_3	253.40	239.39	287.00	3.45	8.36	8.44	43.80	51.40	60.46
	CD(0.05)	6.72	2.75	7.48	1.0495	1.2404	1.0863	1.0529	1.0540	1.0434

nitrogen, available phosphorus, available potassium, calcium, magnesium and pH was determined in each stage. The results are discussed below:

Available nitrogen

Laterite soil

The data on available N present in the soil during critical stages of plant growth are given in Tables 31 and 32. The data showed a slight decreasing trend from maximum tillering (MT) stage to panicle initiation stage and then increased in harvest stage. The values ranged from 187.6 ppm (SSP-P_2+P_2) to 358.1 ppm of SSP (P_2). In maximum tillering stage the control showed a comparable value with DAP and TRP, but the TRP and SSP gave higher mean N content. In panicle initiation stage DAP showed a higher nitrogen content followed by TRP. The SSP and MRP were comparable but were significantly different from control.

In Kuttanad soil the available nitrogen (Table 32) content showed a slight variation only. The content remained almost steady for SSP and TRP. But for MRP and DAP the available N content showed an increase. The mean available N content was maximum for TRP and SSP in MT stage compared to MRP and DAP. But in panicle initiation stage the MRP had highest N content and in harvest SSP and DAP gave highest N content. It was noticed that the dose of the P gave an inverse relationship with the nitrogen content of soil.

The statistical analysis of the data showed a significant difference with soil treatment and dose. The different factors were found to interact with each other in all stages of crop growth. The control was found to have significant difference with other treatments in maximum tillering and harvest stages.

Table 32. Available N, P, K - Ist crop (Kuttanad) (ppm)

Treatment		Available N			Available Phosphorus			Available Potassium		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	352.80	364.00	317.20	4.1670	2.89	2.99	88.12	89.11	114.09
2	TRP-P_2	313.60	316.40	313.60	4.6659	1.92	2.17	87.12	101.11	88.55
3	TRP-P_3	352.80	313.60	344.40	4.8331	2.72	2.01	103.14	139.18	93.04
4	SSP-P_1	366.80	302.40	386.50	5.1689	4.43	2.68	75.08	135.66	89.59
5	SSP-P_2	383.60	347.20	389.20	3.8311	4.09	3.35	77.53	96.96	-123.12
6	SSP-P_3	252.00	361.30	319.20	4.3355	4.94	3.51	84.03	94.63	101.98
7	DAP-P_1	280.00	344.40	378.00	2.6634	2.72	3.18	108.14	130.18	90.55
8	DAP-P_2	277.20	369.60	336.00	6.5011	4.26	2.32	91.13	129.16	101.57
9	DAP-P_3	243.60	288.40	380.80	5.3217	4.10	3.02	112.16	109.14	83.99
10	MRP-P_1	288.40	347.20	378.00	2.6634	1.80	3.35	115.13	117.67	81.54
11	MRP-P_2	240.80	344.40	389.20	4.4977	2.21	4.02	108.63	141.18	111.09
12	MRP-P_3	280.00	352.20	271.80	3.4955	2.55	3.18	104.77	126.66	98.56
13	Control	243.60	369.60	294.00	2.6634	0.96	2.32	94.88	152.43	140.57
14	SSP(P_2+P_2)	280.00	344.40	305.20	4.0051	2.0465	3.35	106.14	116.16	103.02
						Mean				
	<u>Source</u>									
	TRP	339.73	331.33	325.07	4.5425	2.44	2.35	92.43	107.73	97.90
	SSP	334.13	336.97	364.93	4.4078	4.41	3.14	78.75	107.46	103.93
	DAP	266.93	334.13	364.93	4.5129	3.57	2.80	103.67	122.31	91.69
	MRP	269.73	347.93	346.33	3.4696	2.13	3.49	109.32	128.01	96.23
	CD(0.05)	7.76	3.18	8.63	1.0575	1.2837	1.1006	1.0614	1.0627	1.0504
	<u>Level</u>									
	P_1	322.00	339.50	364.90	3.5124	2.77	3.03	95.16	116.52	93.14
	P_2	303.80	344.40	357.00	4.7769	2.88	2.86	90.58	115.50	105.24
	P_3	282.10	328.88	329.05	4.4391	3.38	2.86	100.35	116.03	94.08
	CD(0.05)	6.72	2.75	7.48	1.0495	1.2404	1.0863	1.0529	1.0540	1.0434

Available phosphorus

The data of available phosphorus in soil during different critical stages of plant growth are given in Tables 31 and 32. The available phosphorus content of soil applied with MRP and DAP was found to decrease with the advancement of crop from MT stage to PI stage and increased upto harvest. But in the case of SSP and TRP the available phosphorus content decreased till PI stage and then increased up to the harvest stage. The mussooriephos was found to be low in available phosphorus content in MT and harvest stages, compared to other sources. But in PI stage the MRP and TRP were comparable in available P content and was inferior to other sources. The doses were found to be having a linear relationship with the content of phosphorus in PI and harvest stage.

The data in Kuttanad soil (Table 32) showed a steady decrease from MT to harvest stage for all sources except MRP. In the case of MRP the content in soil was least during PI stage (2.13 ppm) which increased to 3.49 ppm on harvest stage. In maximum tillering stage, the available phosphorus content was higher for TRP in comparison with MRP, but DAP and SSP were comparable with both the sources. In PI stage the SSP had higher P content compared with TRP and MRP and was comparable with DAP. In harvest stage MRP had higher P content in comparison with TRP. The control showed a low content of phosphorus compared to various sources. The control had the lowest value in PI stage of 0.96 ppm. The dose of applied sources had a varying effect on available P content on all stages. The different levels also showed a decrease from MT to PI stage and an increase on harvest stage.

The statistical analysis of data showed a significant difference in available phosphorus content of soil at various stages of crop growth. But interaction was also found to be significant at various stages due to different factors. So the effect cannot be assigned to phosphorus sources alone. The control was found to have significant difference with the other treatments in all stages of crop growth. The two type of soils used showed significant difference between them.

Available potassium

The data of available potassium on laterite soil during critical stages of plant growth is given in Tables 31 and 32. In laterite soil the data showed a decrease in available K content from MT stage to PI stage and there after showed a higher value at harvest in the case of TRP. But in all other cases K content increased linearly with the period. It was maximum in soil applied with MRP in all the three stages. The contents for the different stages were 58.4 ppm 62.91 ppm and 69.27 ppm respectively.

In Kuttanad soil the available K content during different stages of crop growth showed an increase from MT stage to PI stage. There after the treatments decreased in their content. The different sources showed a marked difference in this parameter. The content was highest with MRP in MT and PI stages but in harvest stage the highest available potassium content was with SSP. The sources showed significant difference with each other in all stages except in PI stage where, TRP and SSP were comparable. The doses behaved irregularly corresponding to available potassium content.

The statistical analysis of data showed that the available potassium content of soil showed significant difference with the type of P source, level of applied P source and soil. The data also revealed significant interaction between different sources at all stages of crop growth. So the effect cannot be interpreted as a result of a main factor alone. The control showed significant difference with other treatments.

Available calcium

The data on available calcium content in soil at different critical period are given in Tables 33 and 34. In laterite soil a slight increase in available calcium content was observed from MT stage to PI stage and harvest stage. The different sources did not show much difference in their effect on available calcium content. The different levels also did not show to affect the available calcium content in a wider scale except in MT stage where SSP and TRP had a higher content of calcium than MRP. In all other stages the different sources were comparable.

In Kuttanad soil the available calcium content of soil (Table 34) showed an increase from MT stage to panicle initiation stage and harvest. The mean available calcium content in soil do not showed any variation due to different P sources. In PI stage the levels were found to have a linear relation with calcium content.

The statistical analysis of data showed significant difference in available calcium content due to P source in MT stage. The dose showed significant difference in PI stage only. The different factors showed interaction in PI and harvest stages.

Table 33. Available Ca, Mg, pH - Ist crop (Laterite soil)

Treatment		Available Ca (ppm)			Available Mg (ppm)			pH		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_I	13	12	16	6.5	5.5	2.6	5.90	6.00	6.10
2	TRP-P_2	13	12	15	5.5	4.6	4.6	5.70	6.00	6.25
3	TRP-P_3	13	13	15	5.2	6.2	3.6	6.00	6.00	6.03
4	SSP-P_I	12	11	15	3.3	3.6	3.9	5.90	5.90	6.00
5	SSP-P_2	13	12	14	3.0	3.3	3.0	5.90	5.95	6.23
6	SSP-P_3	15	13	10	3.0	3.9	4.6	5.70	5.95	6.00
7	DAP-P_I	11	10	13	3.6	4.3	3.6	5.90	6.13	6.00
8	DAP-P_2	11	10	14	3.9	4.6	3.0	6.10	6.20	6.23
9	DAP-P_3	12	11	10	4.9	6.2	3.9	5.82	6.00	6.30
10	MRP-P_I	12	11	13	6.2	6.8	3.6	6.10	5.65	6.00
11	MRP-P_2	13	12	14	4.3	3.9	3.6	5.90	6.10	5.50
12	MRP-P_3	11	13	14	3.6	4.6	3.5	5.68	5.82	5.95
13	Control	11	12	14	3.6	4.3	3.9	6.18	6.20	6.35
14	SSP(P_2+P_2)	14	13	13	4.6	6.2	3.9	5.90	6.20	5.90
					Mean					
	Source									
	TRP	13	12	15	5.7	5.4	3.6	5.87	6.00	6.13
	SSP	13	12	14	3.1	3.6	3.8	5.83	5.93	6.08
	DAP	12	12	14	4.1	5.0	3.5	5.94	6.11	6.18
	MRP	11	10	14	4.7	5.1	3.6	5.89	5.86	5.80
	CD(0.05)	1.1	-	-	0.39	0.41	0.37	0.058	-	0.196
	Level									
	P_I	12	11	14	4.9	5.0	3.4	5.95	5.92	6.03
	P_I	12	11	14	4.2	4.1	3.5	5.90	6.06	6.00
	P_3	13	12	14	4.2	5.2	3.9	5.80	5.94	6.07
	CD(0.05)	-	-	-	0.34	0.36	0.32	0.050	-	-

Table 34 . Available Ca, Mg and pH - Ist crop (Kuttanad soil)

Treatment		Available Ca (ppm)			Available Mg (ppm)			pH		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	23	31	33	7.8	7.8	9.1	4.90	5.45	5.00
2	TRP-P_2	25	32	37	7.8	10.1	9.1	4.70	4.75	5.15
3	TRP-P_3	26	37	36	7.5	7.8	10.1	4.60	4.70	4.93
4	SSP-P_1	23	31	33	6.8	7.8	7.8	4.70	4.80	5.00
5	SSP-P_2	24	35	36	7.1	9.5	9.5	4.70	5.10	5.05
6	SSP-P_3	25	39	35	7.8	7.5	9.8	4.75	4.97	4.97
7	DAP-P_1	24	36	35	7.1	6.8	9.1	4.80	5.10	5.00
8	DAP-P_2	22	37	36	6.8	6.2	8.8	4.90	5.15	4.95
9	DAP-P_3	24	36	38	6.8	10.4	6.8	4.75	4.75	4.90
10	MRP-P_1	24	33	37	7.1	7.5	7.8	4.88	4.75	4.90
11	MRP-P_2	25	36	37	7.1	7.1	7.8	4.60	4.90	5.05
12	MRP-P_3	32	35	36	7.8	10.4	10.1	4.63	5.05	4.90
13	Control	23	33	33	6.2	5.5	8.1	4.97	5.00	5.00
14	SSP(P_2+P_2)	25	35	33	7.5	8.5	9.1	4.90	4.97	4.95
						Mean				
	Source									
	TRP	24	33	35	7.7	8.6	9.4	4.73	4.97	5.03
	SSP	24	34	34	7.2	8.2	9.0	4.72	4.96	5.01
	DAP	23	36	36	6.9	7.8	8.2	4.82	5.00	4.95
	MRP	24	35	37	7.3	8.3	8.6	4.70	4.90	4.95
	CD(0.05)	1.1	-	-	0.39	0.41	0.37	0.058	-	0.196
	Level									
	P_1	24	32	34	7.2	7.5	8.5	4.82	5.03	4.97
	P_2	24	35	36	7.2	8.2	8.8	4.72	4.97	5.05
	P_3	25	36	36	7.5	9.0	9.2	4.68	4.87	4.93
	CD(0.05	-	1.1	-	0.34	0.36	0.32	0.050	-	-

Available Magnesium

Laterite soil

The data on available magnesium content in soil at critical stages of plant growth are given in Tables 33 and 34. The data showed varied behaviour in available magnesium content of soil from MT stage to PI stage and harvest stages. In MT stage mean Mg content was maximum in TRP (5.7 ppm) while in harvest stage the content was comparable among different sources. The doses gave irregular behaviour corresponding to magnesium content of soil in different stages of plant growth.

Kuttanad soil

The data of available Mg showed an increasing trend with the advancement of crop. The doses showed a linear relationship with available Mg content. The highest magnesium content was associated with TRP in MT and harvest stages and was on par with SSP and MRP in panicle initiation stage. The contents of TRP in different stages were 7.7, 8.8 and 9.4 per cent respectively. The control when compared with other treatments showed a lower value.

The statistical analysis of data showed significant difference in available Mg content of soil with P sources, level and soil. There was interaction between different sources and at different periods of crop. The control was found significantly different from other sources in MT and PI stages.

pH

The data of variation of pH on different periods of crop growth are given in Tables 33 and 34. In laterite soil the pH generally showed an increasing trend from MT to harvest. In maximum tillering stage DAP had a higher value compared to SSP and TRP. In PI stage different sources were comparable. In harvest stage MRP had a higher value compared to all other sources.

In Kuttanad soil pH showed an increase from MT stage to PI stage and then gave irregular variation. The mean pH was maximum in DAP treatments in MT stage. While in PI and harvest stages, different sources were on par. The TRP gave a variation from 4.73 in MT stage to 4.97 in PI stage and 5.03 in harvest stages.

The statistical analysis of the data showed significant difference with P source in MT and harvest stage. The levels resulted in significant difference in MT stage only . Control and SSP applied twice showed significant variation in MT stage. The change in pH observed for the various type of phosphatic fertilizer may be attributed to the variation in the liming effect of fertiliser material.

4.2.2.2 Second crop

The results of chemical analysis of soil used in second crop are discussed below.

Available nitrogen

The data of available N in laterite soil at different critical stages of plant growth are given in Tables 35 and 36. The content showed a decrease from MT stage to PI stage in all treatments. The statistical analysis of data showed that the type of P sources showed significant difference in the available N content in PI and harvest stages. The mean available N content in soil treated with different sources showed a higher value for MRP in PI stage and for SSP in harvest stage (225.87 and 254.8 ppm, respectively). The different sources showed a comparable N content in MT stage. The doses of applied P sources did not show any specific gradation with the available N content of soil.

In Kuttanad soil the available N content showed the similar trend as that of laterite soil. The mean available N content was comparable for different sources in MT stage. But in the other two stages MRP had the maximum available N (380.8 and 358.4). The control had significant difference with other treatments.

The doses showed significant difference in all the three stages. The different factors like treatment, dose and soil were found to have significant interaction between themselves in different stages of plant growth. The control showed significant difference with other treatments in MT and PI stages. While the SSP applied twice showed significant difference in all stages.

Available P

The data on available phosphorus content in different critical stages of plant growth are given in Tables 35 and 36. In laterite soil the available P content

Table 35. Available N, P, K - 2nd crop (Laterite soil) (ppm)

Treatment		Available N			Available Phosphorus			Available Potassium		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	291.20	148.50	170.80	9.70	6.73	7.07	42.10	37.61	44.64
2	TRP-P_2	209.50	159.60	224.00	9.73	7.24	9.08	24.00	28.60	41.14
3	TRP-P_3	257.60	114.80	240.80	8.05	8.76	8.74	16.49	17.95	22.53
4	SSP-P_1	243.65	148.40	252.00	9.89	6.73	7.40	47.75	33.59	44.64
5	SSP-P_2	232.00	165.15	271.60	10.06	7.74	9.08	51.67	40.62	45.64
6	SSP-P_3	291.20	126.00	240.80	12.40	8.76	8.57	44.15	26.02	43.63
7	DAP-P_1	263.20	241.05	238.00	8.32	5.72	7.73	40.13	38.12	32.61
8	DAP-P_2	243.65	224.00	198.80	8.38	6.23	6.39	35.11	27.08	47.65
9	DAP-P_3	277.20	181.90	274.40	9.89	8.23	7.90	43.63	22.53	42.10
10	MRP-P_1	280.00	229.60	198.80	6.70	5.72	8.35	42.14	38.12	31.05
11	MRP-P_2	240.80	235.20	240.80	7.19	6.40	6.56	35.11	29.04	45.15
12	MRP-P_3	238.00	212.80	252.00	8.38	10.11	8.74	45.16	19.41	50.14
13	Control	193.15	226.70	224.00	5.03	5.39	2.33	37.61	28.49	41.62
14	SSP(P_2+P_2)	383.60	263.80	221.20	19.61	11.95	20.19	44.11	36.60	47.13
					Mean					
	Source									
	TRP	252.77	140.97	211.87	9.09	7.47	8.19	24.48	26.76	34.50
	SSP	255.62	146.52	254.80	10.68	7.64	8.27	47.61	32.79	44.52
	DAP	261.35	215.65	236.07	8.80	6.60	7.26	39.37	28.12	40.20
	MRP	252.93	225.87	230.53	7.36	7.13	7.77	40.48	27.73	41.17
	CD(0.05)	-	9.5	4.15	1.1311	-	-	1.0998	1.0998	1.0825
	Level									
	P_1	269.51	191.89	214.90	8.51	6.16	7.57	42.80	36.71	37.59
	P_2	231.49	195.99	233.80	8.72	6.82	7.61	35.07	30.54	44.71
	P_3	266.00	158.88	252.00	9.49	8.86	8.42	34.52	21.20	37.85
	CD(0.05)	13.24	8.23	3.6	-	-	-	1.0857	1.0857	1.0709

showed a decrease from MT stage to PI stage and then an increase from PI stage to harvest. The SSP was followed by TRP, DAP and MRP respectively in MT stage. While in other stages they were comparable. The dose of applied P source was found to have no relationship with the available phosphorus content in crop soil.

In Kuttanad soil the available P content of crop soil showed a regular decrease from MT stage to harvest stage. In MT stage DAP had a value lower than TRP but the other sources were comparable to each other. In the other two stages all the sources were comparable. The different factors like soil, P source and level were found to have a significant interaction between each other in different stages of plant growth. The control and SSP applied twice was found significantly different from TRP in MT stage only.

Available Potassium

The data of available potassium in laterite soil are given in Tables 35 and 36. The data showed an irregular variation with the advancement of crop. The single superphosphate treatments were found to have maximum K content in soil in all the three stages of crop growth. In all the stages TRP gave the lowest values. In MT and PI stages the doses were found to have a negative effect on available K content.

In Kuttanad soil the data showed an irregular variation with the advancement of crop (Table 36). The DAP gave the highest available potassium in MT stage. But in PI and harvest stages the TRP gave the highest available K. The doses do not show any regular pattern with the available K content. The TRP and

Table 36. Available N, P, K - 2nd crop (Kuttanad soil) (ppm)

Treatment		Available N			Available Phosphorus			Available Potassium		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	394.80	302.40	243.60	4.68	3.01	3.64	64.20	88.30	61.19
2	TRP-P_2	341.60	313.60	310.70	4.52	3.20	3.00	31.10	59.71	47.65
3	TRP-P_3	350.00	350.00	344.40	5.01	3.35	2.69	37.61	34.05	38.12
4	SSP-P_1	352.80	364.00	347.20	4.15	3.20	3.00	28.56	38.12	28.08
5	SSP-P_2	341.60	355.60	302.40	3.82	2.95	3.15	24.34	47.16	53.18
6	SSP-P_3	369.60	324.80	252.00	3.14	2.12	2.35	76.22	36.60	47.65
7	DAP-P_1	355.60	333.20	294.00	4.19	2.95	2.61	45.15	40.62	24.07
8	DAP-P_2	383.60	389.20	282.80	4.27	3.87	3.52	95.21	42.51	41.04
9	DAP-P_3	380.80	378.00	392.00	2.50	2.86	3.00	39.13	41.62	32.43
10	MRP-P_1	366.30	386.40	389.20	4.52	3.70	3.52	50.14	39.13	41.62
11	MRP-P_2	372.40	380.80	383.60	4.01	3.87	3.50	48.13	44.15	36.01
12	MRP-P_3	358.40	375.20	302.40	3.26	3.01	2.51	36.07	41.62	43.63
13	Control	355.60	372.40	333.20	2.99	2.95	2.35	31.97	43.05	45.60
14	SSP(P_2+P_2)	369.90	380.80	324.80	3.14	3.20	3.52	26.93	44.59	38.09
					Mean					
	<u>Source</u>									
	TRP	362.13	322.00	299.57	4.7146	3.16	3.07	42.08	56.28	47.97
	SSP	354.67	348.13	300.53	3.6649	2.70	2.80	37.47	40.28	41.34
	DAP	373.33	366.80	322.93	3.5367	3.17	3.00	55.07	41.48	31.68
	MRP	365.70	380.80	358.40	3.8789	3.48	3.12	44.21	41.48	40.19
	CD(0.05)	-	9.5	4.15	1.1311	-	-	1.0998	1.0998	1.0825
	<u>Level</u>									
	P_1	367.38	346.50	318.50	4.36	3.18	3.14	45.02	47.96	36.12
	P_2	359.80	349.80	319.88	4.13	3.42	3.26	43.04	47.82	43.87
	P_3	364.70	357.00	322.70	3.36	2.77	2.61	44.73	38.23	39.93
	CD(0.05)	13.24	8.23	3.6	-	-	-	1.0857	1.0857	1.0709

SSP contents showed an increase up to PI stage and decreased thereafter. In DAP and MRP it was slightly increasing.

The statistical analysis of data showed that the available K content of soil showed significant variation with source, soil type and dose. The different factors showed interaction at various stages. The control showed significant variation with other sources in MT and PI stages. The SSP applied twice gave significant difference with other sources in MT and PI stages.

Available Calcium

The data of available calcium during critical stage of plant growth in laterite and Kuttanad soils are given in Tables 37 and 38. The data showed irregular variation with the crop stages. There was not much difference between different P sources in different stages. The effect was not significant at various stages. The mean values ranged from 12 to 14 ppm for different sources at different stages. The levels gave a slight increase in available calcium with increase in levels.

In Kuttanad soil the available calcium content showed irregular behaviour as in the case of laterite (Table 38). The doses were found to show a linear relationship with available calcium content in Kuttanad soil.

The statistical analysis of data showed nonsignificance with type of P sources and doses. The levels were also did not have any significant effect on available calcium content of soil. There was no interaction between different effects. The control and SSP-P_2 had same effect as that of other treatments.

Table 37. Available Ca, Mg, pH - 2nd crop (Laterite soil)

Treatment		Available Ca (ppm)			Available Mg (ppm)			pH		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	13	13	11	4.3	6.8	6.8	6.20	6.20	6.50
2	TRP-P_2	13	14	13	4.6	4.3	6.2	6.20	6.25	6.55
3	TRP-P_3	15	10	13	3.9	4.3	5.8	6.13	6.20	6.15
4	SSP-P_1	12	11	13	7.5	3.9	5.2	6.30	6.30	7.00
5	SSP-P_2	12	15	10	7.5	3.6	5.8	6.30	6.20	6.32
6	SSP-P_3	15	15	13	5.5	4.3	5.8	6.30	6.15	6.53
7	DAP-P_1	13	13	13	4.2	4.9	6.2	6.30	5.85	5.90
8	DAP-P_2	13	13	14	7.1	3.6	6.2	6.15	5.95	6.30
9	DAP-P_3	13	14	15	6.5	3.9	5.3	6.10	5.80	5.82
10	MRP-P_1	13	12	12	6.2	8.2	6.5	6.40	6.10	6.00
11	MRP-P_2	13	11	13	4.5	4.3	4.9	6.23	5.70	5.60
12	MRP-P_3	14	15	14	5.2	3.6	5.8	6.40	5.50	6.00
13	Control	12	12	14	4.9	3.6	4.6	6.50	6.15	6.25
14	SSP(P_2+P_2)	13	12	14	4.3	3.6	4.6	6.20	5.45	5.85
						Mean				
	<u>Source</u>									
	TRP	14	12	12	4.3	5.1	6.3	6.18	6.22	6.40
	SSP	13	13	13	6.8	3.9	5.6	6.30	6.22	6.62
	DAP	13	13	14	5.9	4.1	5.9	6.18	5.87	6.01
	MRP	13	12	13	5.3	5.3	5.7	6.34	5.77	5.87
	CD(0.05)	-	-	-	1.438	1.524	0.473	-	0.0923	0.1668
	<u>Level</u>									
	P_1	13	12	12	5.5	5.9	6.2	6.30	6.11	6.35
	P_2	13	13	13	5.9	3.9	5.7	6.22	6.03	6.19
	P_3	14	13	13	5.3	4.0	5.7	6.23	5.91	6.13
	CD(0.05)	-	-	-	1 246	0.455	0.410	-	0.0800	-

Table 38. Available Ca, Mg, pH - 2nd crop (Kuttanad soil)

Treatment		Available Ca (ppm)			Available Mg (ppm)			pH		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	36	36	33	7.8	10.4	11.5	4.97	4.90	5.20
2	TRP-P_2	35	36	34	9.5	10.0	7.4	4.88	4.65	5.13
3	TRP-P_3	36	34	33	6.8	9.0	7.4	4.80	4.85	4.82
4	SSP-P_1	31	34	29	5.9	9.5	7.8	4.85	4.80	5.00
5	SSP-P_2	37	36	33	6.2	7.5	9.0	4.80	4.60	5.20
6	SSP-P_3	33	39	35	9.1	12.5	10.5	5.10	4.60	5.28
7	DAP-P_1	35	34	31	6.5	8.5	12.0	4.90	4.45	4.82
8	DAP-P_2	33	35	29	5.5	10.5	9.5	4.90	4.68	5.10
9	DAP-P_3	37	35	32	8.2	11.0	12.5	4.95	4.72	5.23
10	MRP-P_1	33	34	33	10.0	10.5	8.1	4.88	4.90	5.20
11	MRP-P_2	31	34	33	11.2	7.5	6.8	4.80	4.70	4.50
12	MRP-P_3	33	35	36	12.0	10.5	9.0	4.90	4.82	5.08
13	Control	30	31	35	9.0	6.5	7.8	4.80	4.90	5.43
14	SSP(P_2+P_2)	35	36	38	7.5	7.0	10.5	5.00	4.72	5.15
						Mean				
	Source									
	TRP	36	35	33	8.0	9.8	8.8	4.88	4.80	5.05
	SSP	34	36	32	7.1	9.8	9.1	4.92	4.67	5.16
	DAP.	35	35	30	6.7	10.0	11.3	4.92	4.62	5.05
	MRP	32	34	34	11.1	9.5	8.0	4.86	4.81	4.93
	CD(0.05)	-	-	-	1.438	0.473	0.473	-	0.0923	0.1668
	Level									
	P_1	34	34	31	7.6	9.7	9.9	4.90	4.76	5.06
	P_2	34	35	32	8.1	8.9	8.2	4.84	4.66	4.98
	P_3	34	36	34	9.0	10.8	9.9	4.94	4.75	5.10
	CD(0.05)	-	-	-	-	0.458	0.410	0.1254	0.0800	0.1445

Magnesium

The data of available magnesium in laterite soil are given in Tables 37 and 38. The data showed inconsistent variation with different treatments. The mean Mg content showed a linear increase in the case of TRP, while other sources showed a mixed reaction. The mean available Mg content was higher in SSP compared to TRP and MRP during MT stage. In PI stage different sources were on par and in harvest TRP performed better than SSP and MRP. The doses gave a decreased value of available Mg with increase in dosage.

In Kuttanad soil, the Mg content showed an irregular behaviour. The highest magnesium content was for MRP (11.1 ppm) in MT stage, while it was DAP (11.3 ppm) which gave highest value in harvest stage. The doses showed a general increasing trend with the crop.

The statistical analysis of data showed that the Mg content of soil showed significant difference with type of P source. The levels affected Mg content in PI and harvest stages. The soil, P source and levels were found to show interaction in PI and harvest stages. The control showed significant difference with other treatments in MT, PI and harvest stages. The SSP(P_2+P_2) showed difference with other sources in PI and harvest stages.

pH

The data on variation of pH in different period of crop growth are given in Tables 37 and 38. In laterite soil the pH showed mixed variation. The TRP gave a direct increase in pH (6.15 to 6.40) while other sources showed a decrease in pH from MT to PI stage and then showed an increase. The pH was found to be comparable for all treatments in MT stage. In PI stage SSP and TRP had a higher pH than DAP and MRP and in harvest stage SSP had the highest pH.

In Kuttanad soil pH showed a decrease from MT stage to panicle initiation stage and then increased. In MT stages all sources were on par, while in PI stage TRP and MRP had a higher pH than DAP and SSP. The doses did not result in any specific trend of variation of pH. The statistical analysis of data showed that the pH of the soil showed significant difference with P sources in PI and harvest stages and with levels in PI stage. Control showed significant variation with other treatments in PI and harvest.

The difference in pH observed with P sources might be due to the variation in the liming effect of concerned fertilizer. The initial decrease in pH with water soluble sources of phosphorus viz., SSP and DAP may be due to the rapid release of phosphoric acid. The calcium released in later stages accounts for the increase in pH observed at the harvest stage.

The available N content of soil applied with different treatments showed a variable response in the first crop. It has been observed that, in both soils the content showed a decrease in N from maximum tillering to harvest. This is expected as more of N is absorbed from the soil by growing rice crop. Thus it was noticed that maximum uptake was in PI stage and this accounted for decrease of N content in PI stage during first crop. Thus the rockphosphate had a higher value of available N in 1st crop season. While in 2nd crop the available N content of soil was maximum with water soluble sources. This may be due to the fact that by the time of 2nd crop dissolution of rockphosphate may be higher and so the release of P may be higher which resulted in higher phosphorus uptake and increased crop growth which resulted in higher N uptake. So the value of N in rockphosphate applied soil was less by 2nd crop. This results are in confirmity with the findings of Manjaiah *et al.* (1995).

It was also found that the N content of soil showed irregular variation with doses of applied P. This variation may be due to inherent soil characters, presence of other nutrients, pH etc.

During 1st crop available P content showed significant variation due to sources and level of P in all three stages. But in 2nd crop the difference was there only in MT stage due to type of P sources. The data showed that the mean available P content in laterite soil was comparable for DAP, SSP and TRP in 1st crop. For 2nd crop the available P content was maximum with SSP followed by TRP and DAP in MT stage. But was comparable for all sources in other stages. This high P release by water soluble sources may be due to breaking of $CaPO_4$ to Ca^{2+} and PO_4^{2-} ions or due to low uptake by crop (Manjaih *et al.*, 1995, Regi and Jose, 1986).

In Kuttanad soil during 1st crop the availability of phosphorus was higher for TRP than MRP in MT stage. But in PI stage the SSP gave highest P availability and in harvest stage all sources performed similarly. During 2nd crop the rockphosphate gave higher P value, this high value may be due to high amount of P released by the rockphosphate during later periods. Similar results were obtained by Minhas and Kich (1974).

It was found that in Kuttanad soil the available phosphorus content increased till the 2nd dose and then decreased. The low response to higher dose may be due to precipitation of insoluble phosphate. Mahima Raja *et al.* (1995) reported a decrease in available P content above a level of 100 kg/ha and below that there was an increase in P content with levels. But in laterite soil the level showed a linear relation with available phosphorus content.

The treatment SSP(P_2+P_2) was having a higher P content than all other sources in both soils. This is due to high P release when SSP applied twice - once at the beginning of 1st crop and 2nd in the 2nd crop.

Available potassium content showed significant difference with different P sources in all the stages. The mean value of potassium in soil showed a low value for SSP treatments in initial stages of first crop which may be due to increased uptake of potassium by the crop. During 2nd crop season the content of available potassium in soil was least with rockphosphate source. The low value of available potassium clearly indicated maximum uptake.

The dose of applied phosphorus showed irregular variation in K availability in Kuttanad and laterite soils in 1st crop. In 2nd crop in laterite soil, as the P level increased there was a decrease in soil potassium content which may be due to high uptake of potassium with higher P dose. Similar results were obtained by Singh *et al.* (1988).

In laterite soil the calcium content showed only slight difference with different sources. During MT stage of 1st crop the mean content was maximum with TRP and SSP and minimum with MRP while in 2nd crop the contents were almost similar. The variation observed may be due to change in calcium percentage in applied P sources. In Kuttanad soil also different sources did not show any impact on calcium content of soil. In laterite soil the calcium content showed a decrease from MT to PI stage and then an increase to harvest stage. This may be due to increased uptake by crop in the initial stage and then due to break down of the insoluble calcium phosphate. In Kuttanad soil the Ca content increased from MT to harvest stage in 1st crop due to high release of free calcium in low pH soils.

In laterite soil mean magnesium content was higher in rockphosphate applied treatments in both crops. But in Kuttanad soil during 1st crop the Mg content was more in treatment applied with Tunisia rockphosphate and in 2nd crop the magnesium contents was more with DAP and MRP. This higher Mg contents of soil may be due to the high Mg content in rockphosphate. The statistical analysis showed that Mg content differed significantly due to P sources, levels and soils. The Mg content do not show a linear relationship with dose. The variation in the chemical composition of the fertilizer accounts for the differences in the content of available Mg in the two soils.

4.2.3 Nutrient uptake

4.2.3.1 First crop

The uptake of nutrient at critical stages of plant growth was estimated by analysis of the crop. The nutrients N, P, K, Ca and Mg were estimated to asses the uptake of nutrients. The data are presented in Tables 39 to 42 and the results are discussed below:

Table 39 . Nutrient uptake of N, P, K during Ist crop (Laterite)

Treatment		Nitrogen (g pot^{-1})			Phosphorus (mg pot^{-1})			Potassium (g pot^{-1})		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	0.22	0.25	0.52	11.84	14.64	36.19	0.17	0.17	0.34
2	TRP-P_2	0.24	0.27	0.45	14.70	26.45	40.90	0.16	0.17	0.30
3	TRP-P_3	0.21	0.42	0.50	18.08	31.57	53.77	0.16	0.20	0.25
4	SSP-P_1	0.19	0.27	0.42	15.09	15.74	29.35	0.13	0.17	0.21
5	SSP-P_2	0.21	0.28	0.43	20.53	35.50	37.20	0.15	0.17	0.28
6	SSP-P_3	0.19	0.34	0.42	21.65	40.81	45.78	0.12	0.22	0.28
7	DAP-P_1	0.15	0.25	0.32	12.51	18.77	35.08	0.12	0.18	0.22
8	DAP-P_2	0.19	0.28	0.31	16.54	15.75	35.04	0.15	0.15	0.22
9	DAP-P_3	0.21	0.36	0.30	23.75	31.43	35.96	0.16	0.18	0.23
10	MRP-P_1	0.16	0.33	0.62	11.60	22.63	23.73	0.14	0.17	0.19
11	MRP-P_2	0.14	0.26	0.29	11.54	12.93	28.06	0.13	0.14	0.23
12	MRP-P_3	0.16	0.21	0.31	12.49	15.37	34.03	0.13	0.18	0.29
13	Control	0.13	0.15	0.29	8.66	5.37	21.99	0.11	0.09	0.28
14	SSP(P_2+P_2)	0.20	0.31	0.38	18.20	10.18	29.78	0.12	0.15	0.25
						Mean				
	Source									
	TRP	0.22	0.31	0.49	14.27	21.50	42.52	0.16	0.18	0.30
	SSP	0.20	0.30	0.43	18.36	26.47	36.41	0.13	0.19	0.25
	DAP	0.18	0.30	0.31	16.56	19.62	34.95	0.14	0.17	0.22
	MRP	0.16	0.27	0.41	11.56	15.41	27.98	0.13	0.16	0.24
	CD(0.05)	0.0205	0.0603	-	-	-	1.2344	0.0236	0.0529	0.0374
	Level									
	P_1	0.17	0.26	0.42	12.27	12.24	28.50	0.13	0.15	0.25
	P_2	0.20	0.27	0.37	15.03	19.35	34.52	0.15	0.16	0.26
	P_3	0.20	0.33	0.38	17.91	25.99	41.12	0.14	0.20	0.26
	CD(0.05)	0.0205	0.0522	-	1.3244	1.5845	1.1993	0.0205	0.0458	0.0324

Uptake of Nitrogen

In laterite soil, the nitrogen uptake showed an increasing trend from the MT stage to PI stage and harvest stage. The uptake values ranged from 0.126 g pot^{-1} in MT stage (control) to 0.62 g (MRP-P_1) at the harvest stage. The mean value of N uptake in soil applied with different sources were comparable for different sources in all the 3 stages. The uptake of nitrogen was found to have linear relation with dose of applied P source.

In Kuttanad soil the data of uptake of nitrogen (Table 40) showed an increase upto PI stage and then decreased. In MT and PI stages the mean uptake of N was higher for TRP and SSP compared to DAP and MRP. In PI stage DAP had a low content compared to other sources and in harvest stage the different sources were comparable. As the level of applied P increased the nitrogen uptake was also found to increase. The statistical analysis of nutrient uptake in soil showed that a significant difference was there with soil, treatment and dose. The increased uptake of phosphorus by the rice crop may enhances better plant growth and this inturn may cause more uptake of N, since the content of water soluble phosphorus and the rate of dissolution of each sources were different, there could be a difference in the uptake of N.

Uptake of phosphorus

In laterite soil the data of uptake of phosphorus during critical stages of plant growth are given in Table 39. The data of uptake of phosphorus content in different stages showed an increasing trend. The minimum uptake in every stage of crop growth was associated with control. The mean content of P uptake was

Table 40. Nutrient uptake of N, P, K during Ist crop (Kuttanad)

Treatment		Nitrogen (g pot^{-1})			Phosphorus (mg pot^{-1})			Potassium (g pot^{-1})		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	0.24	0.35	0.40	20.89	20.72	50.86	0.21	0.28	0.35
2	TRP-P_2	0.30	0.58	0.40	37.12	48.57	64.73	0.22	0.48	0.34
3	TRP-P_3	0.26	0.60	0.45	41.08	50.73	68.96	0.23	0.45	0.39
4	SSP-P_1	0.21	0.49	0.38	16.18	42.92	38.63	0.18	0.40	0.28
5	SSP-P_2	0.27	0.46	0.35	40.01	44.01	50.51	0.23	0.40	0.32
6	SSP-P_3	0.29	0.42	0.42	39.70	55.83	67.88	0.23	0.42	0.40
7	DAP-P_1	0.16	0.28	0.47	18.76	22.79	42.98	0.16	0.26	0.30
8	DAP-P_2	0.21	0.38	0.47	27.05	31.87	54.82	0.16	0.29	0.42
9	DAP-P_3	0.27	0.44	0.45	32.61	44.14	65.48	0.34	0.23	0.37
10	MRP-P_1	0.20	0.47	0.38	30.16	20.41	45.18	0.18	0.20	0.31
11	MRP-P_2	0.24	0.34	0.38	32.24	38.20	55.32	0.24	0.23	0.45
12	MRP-P_3	0.25	0.59	0.40	33.87	46.36	61.94	0.18	0.32	0.43
13	Control	0.16	0.24	0.38	14.80	14.92	28.19	0.16	0.18	0.36
14	SSP(P_2+P_2)	0.32	0.30	0.00	31.41	26.84	49.79	0.26	0.18	0.39
					Mean					
	<u>Source</u>									
	TRP	0.27	0.51	0.42	30.86	34.62	60.30	0.22	0.40	0.36
	SSP	0.26	0.46	0.38	28.73	44.10	50.39	0.21	0.42	0.33
	DAP	0.21	0.37	0.46	24.81	29.65	53.02	0.22	0.26	0.37
	MRP	0.23	0.47	0.39	31.20	30.86	53.08	0.20	0.25	0.40
	CD(0.05)	0.0236	0.0603	0.1182	-	-	1.2344	0.0236	0.0524	0.0374
	<u>Level</u>									
	P_1	0.21	0.36	0.34	20.50	21.69	41.29	0.19	0.25	0.33
	P_2	0.26	0.44	0.40	32.73	37.17	55.40	0.21	0.35	0.38
	P_3	0.27	0.51	0.43	35.54	45.40	65.16	0.25	0.35	0.40
	CD(0.05)	0.0205	0.0520	-	1.3244	1.5845	1.1993	0.0205	0.0458	0.0324

comparable for different sources in initial periods and was maximum for TRP in harvest stage (42.5 mg pot^{-1}). The uptake of P showed linear increase with level of applied phosphorus.

The uptake of phosphorus in critical stages of plant grown in Kuttanad soil is given in Table 40. The uptake showed an increase from MT stage through PI to harvest. The mean value was maximum with TRP (60.30 mg pot^{-1}) in harvest stage. It was found that as the dose of applied phosphorus increased from 22.5 to 45 and 67.5 kg the uptake was increased from 20.5 to 35.4 mg pot^{-1} in MT stage, 21.69 to 45.4 mg pot^{-1} in PI stage and 41.29 to 65.16 mg pot^{-1} for harvest stage. The control had shown much difference with other sources in various stages of crop growth.

Statistical analysis of data showed that the treatments had significant difference in P uptake in harvest stage. The difference was attributed to the variation in the composition as well as to the rate of dissolution of the fertilizers used. But the different doses showed significant difference with each other in all the three stages. The different factors had no interaction. So the uptake of P from TRP was higher in comparison with other sources in harvest stage.

Potassium

In laterite soil uptake of potassium during critical stages of plant growth showed an increasing trend from MT stage to harvest. The different sources as well as doses showed marked difference in their effect on uptake of K. Of the different sources TRP gave the highest uptake in harvest stage (0.30 g pot^{-1}) while in MT and

Table 41 . Nutrient uptake of Ca and Mg during Ist crops (Laterite) (mg pot^{-1})

Treatment		Ca			Mg		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	23.68	45.89	91.23	16.24	25.08	76.78
2	TRP-P_2	24.02	31.73	106.88	17.95	46.74	63.07
3	TRP-P_3	27.61	60.98	105.55	18.80	49.85	93.80
4	SSP-P_1	22.01	46.58	127.93	15.32	28.93	56.85
5	SSP-P_2	20.80	46.59	132.75	30.00	44.99	59.32
6	SSP-P_3	29.31	57.42	140.18	15.03	50.19	58.01
7	DAP-P_1	22.31	41.65	85.32	17.78	32.88	61.60
8	DAP-P_2	25.19	38.54	89.48	24.59	24.10	56.68
9	DAP-P_3	35.24	50.29	108.09	28.30	31.42	66.15
10	MRP-P_1	23.66	38.51	84.06	16.24	28.79	60.84
11	MRP-P_2	26.52	35.70	86.04	21.26	20.66	62.11
12	MRP-P_3	22.31	55.86	109.43	20.13	27.29	65.16
13	Control	16.41	26.35	87.16	14.68	12.84	60.09
14	SSP(P_2+P_2)	35.00	35.44	153.16	17.95	26.65	58.87
				Mean			
	Source						
	TRP	24.94	44.10	99.43	16.14	38.58	74.13
	SSP	23.67	49.37	131.49	15.53	39.69	55.25
	DAP	26.95	42.72	92.37	21.61	28.37	58.53
	MRP	24.01	42.02	91.09	17.58	24.55	59.77
	CD(0.050	1.1276	-	1.2766	0.9381	0.4348	0.9567
	Level						
	P_1	23.15	37.90	100.13	14.72	24.38	59.07
	P_2	23.93	37.28	100.48	19.28	31.90	57.05
	P_3	28.12	55.28	113.05	18.48	37.73	66.70
CD(0.05)		1.1094	1.1993	1.2344	0.6858	0.3202	0.6994

PI stage the uptake was comparable for different sources. It was found that uptake of potassium gave a linear relationship with the dose in PI stage.

In Kuttanad soil the uptake of potassium showed an increase from MT stage to PI stage and harvest stage for MRP and DAP. But for TRP and SSP the K content showed an increase upto PI stage and decreased then. The different sources had difference in the uptake of potassium. In the case of TRP and SSP the maximum uptake was in panicle initiation stage (0.40 and 0.42 g pot^{-1}). But in the case of MRP and DAP the uptake was maximum in harvest stage. The statistical analysis showed that the potassium uptake by crop was significantly affected by source, dose and soil. The levels showed a linear relationship with uptake.

Calcium

The data of uptake of calcium in critical stages of plant growth in Ist crop are given in Tables 41 and 42. The calcium content showed an increasing trend from MT stage to harvest stages. The mean uptake of calcium content was maximum for DAP in MT stage. While in PI and harvest stage the highest uptake was with SSP treatment. The control showed difference with other treatments ensuring that the P application resulted in a higher uptake of calcium.

In Kuttanad soil also the uptake of calcium was found to be increased with the stages of crop growth. The uptake of calcium was maximum with TRP in MT stage, with SSP in PI stage and with DAP in harvest period. The control was found to have much difference with other sources.

Table 42. Nutrient uptake of Ca and Mg during Ist crops (Kuttanad) (mg pot^{-1})

Treatment		Ca			Mg		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	42.99	43.45	122.37	23.41	32.27	133.38
2	TRP-P_2	31.61	72.28	138.33	33.13	64.59	117.48
3	TRP-P_3	31.44	76.60	159.59	33.10	78.93	155.89
4	SSP-P_1	24.35	96.63	111.41	22.96	64.42	104.91
5	SSP-P_2	32.72	98.14	139.96	30.27	74.76	76.94
6	SSP-P_3	33.96	110.27	177.75	34.06	71.31	110.20
7	DAP-P_1	24.20	46.05	165.84	26.59	34.69	82.91
8	DAP-P_2	29.02	58.03	157.97	27.50	36.84	121.89
9	DAP-P_3	48.40	56.87	157.83	48.01	41.83	137.81
10	MRP-P_1	28.12	52.09	142.52	33.19	32.10	89.03
11	MRP-P_2	34.22	49.28	153.37	35.89	39.51	83.96
12	MRP-P_3	27.88	62.67	163.03	32.08	49.88	90.37
13	Control	21.67	32.81	118.08	19.98	20.56	85.68
14	SSP(P_2+P_2)	35.18	46.05	155.30	39.68	39.72	118.03
				Mean			
	Source						
	TRP	34.83	61.48	137.15	27.73	55.41	130.82
	SSP	29.91	100.34	138.33	26.97	68.60	93.14
	DAP	32.27	52.76	158.06	31.29	36.63	109.03
	MRP	29.82	53.76	150.42	31.61	39.03	84.30
	CD(0.05)	1.1276	-	1.2766	0.9381	0.4348	0.9567
	Level						
	P_1	28.44	49.14	132.16	25.13	34.99	97.33
	P_2	31.70	66.25	144.65	29.34	51.24	94.93
	P_3	34.50	73.12	161.56	34.10	57.96	117.66
	CD(0.05)	1.1094	1.1993	1.2344	0.6858	0.3202	0.6994

The statistical analysis of the data showed that the uptake of calcium showed significant difference in MT and harvest stages due to P sources. The doses of applied P sources showed a linear relation with calcium uptake. The different factors like soil, type of P sources and levels showed interaction in various stages. The control was found significantly different with rest of treatments. The variation in the composition of the rockphosphate and the inherent properties of the soil account for the change in uptake of calcium.

Magnesium

The uptake of Mg in critical stages of plant growth in laterite soil are given in Tables 41 and 42. The uptake of magnesium was found to be increasing from MT stage to harvest stage. The different P sources were found to have different effect on uptake of magnesium. The levels were found to have a linear relation with magnesium uptake except on 15th day. The Kuttanad soil also gave same trend with highest mean uptake of Mg associated with MRP and DAP in MT stage, SSP in PI stage (68.6 mg pot^{-1}) and TRP in harvest stage 130.08 mg pot^{-1}).

Statistical analysis of the data showed significant difference in uptake of Mg content due to soils, type of P sources and levels. The interaction between different factors was significant at different stages of crop. The control showed significant difference with other treatments only in MT stage.

Second crop

During 2nd crop the uptake of nitrogen, phosphorus, potassium, calcium and magnesium were estimated at MT, PI and harvest stage and results are discussed below.

Nitrogen

The data on nitrogen uptake during different stages of crop in laterite soil are given in Table 43 and 44. The uptake was not in any particular pattern for different treatments. Anyhow in harvest stage uptake was found to be higher compared to other two stages. The mean value of different P sources was found increasing in the order of MT < PI < Harvest. The different P sources were comparable in uptake of N in MT and PI stage and in harvest stage TRP resulted in (0.49 g pot^{-1}) higher uptake. The uptake generally showed an increasing trend with dose.

In Kuttanad soil also the N uptake by different treatments were of inconsistent nature. In MT, PI and harvest stages all the sources performed similarly and were on par. It was found that as the doses increased there was an increase in uptake except in PI stage.

The statistical analysis of data showed that the type of P sources showed significant difference in N uptake in MT and harvest stages and the doses in PI and harvest stages. The different factors showed interaction in harvest stage. The control showed significant difference with other treatments in PI stage. The SSP applied twice was significantly different from all other treatments. Thus the results were same as that of the first crop.

Uptake of phosphorus

In laterite soil the phosphorus uptake (Table 43 and 44) was found to be increased from MT to harvest. The maximum uptake of phosphorus was obtained

Table 43 . Nutrient uptake of N, P, K during 2nd crop (Laterite)

Treatment		Nitrogen (g pot^{-1})			Phosphorus (mg pot^{-1})			Potassium (g pot^{-1})		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	0.16	0.15	0.38	9.94	11.09	19.42	0.14	0.13	0.19
2	TRP-P_2	0.20	0.27	0.44	11.11	13.37	24.46	0.13	0.12	0.24
3	TRP-P_3	0.24	0.22	0.63	12.42	26.64	34.75	0.17	0.17	0.31
4	SSP-P_1	0.25	0.24	0.37	6.35	16.66	26.60	0.14	0.12	0.26
5	SSP-P_2	0.22	0.16	0.34	8.15	8.90	21.30	0.14	0.11	0.16
6	SSP-P_3	0.18	0.25	0.38	16.04	16.53	25.03	0.26	0.34	0.20
7	DAP-P_1	0.13	0.11	0.27	5.76	9.25	20.52	0.12	0.11	0.21
8	DAP-P_2	0.18	0.18	0.34	6.91	11.51	22.31	0.14	0.15	0.24
9	DAP-P_3	0.11	0.24	0.54	7.45	19.64	27.76	0.19	0.22	0.31
10	MRP-P_1	0.17	0.24	0.32	4.85	18.37	22.33	0.15	0.22	0.29
11	MRP-P_2	0.18	0.17	0.29	6.64	15.84	19.79	0.11	0.12	0.15
12	MRP-P_3	0.19	0.21	0.32	7.24	17.56	24.75	0.19	0.19	0.23
13	Control	0.15	0.17	0.25	3.81	11.79	16.89	0.12	0.15	0.21
14	SSP(P_2+P_2)	0.15	0.32	0.32	12.69	35.27	30.81	0.168	0.23	0.23
	Mean									
	<u>Source</u>									
	TRP	0.20	0.21	0.49	10.86	15.45	25.07	0.15	0.14	0.25
	SSP	0.22	0.21	0.36	9.18	13.18	23.84	0.18	0.19	0.21
	DAP	0.14	0.18	0.39	6.52	12.49	22.98	0.15	0.16	0.25
	MRP	0.18	0.21	0.31	6.02	16.83	21.85	0.15	0.17	0.22
	CD(0.05)	0.1182	0.0626	0.0603	1.3513	1.3513	1.2760	-	0.0614	0.0488
	<u>Level</u>									
	P_1	0.17	0.20	0.32	6.47	14.95	21.92	0.15	0.16	0.23
	P_2	0.20	0.19	0.35	7.82	11.83	21.54	0.13	0.14	0.20
	P_3	0.18	0.23	0.47	9.92	19.23	27.33	0.20	0.23	0.26
	CD(0.05)	0.1024	0.0542	0.0522	1.2962	-	1.2344	0.1024	0.0532	0.0422

Table 44 . Nutrient uptake of N, P, K during 2nd crop (Kuttanad)

Treatment		Nitrogen (g pot^{-1})			Phosphorus (mg pot^{-1})			Potassium (g pot^{-1})		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	0.45	0.35	0.42	22.92	56.53	47.34	0.33	0.24	0.34
2	TRP-P_2	0.50	0.41	0.43	37.28	72.73	58.17	0.42	0.42	0.40
3	TRP-P_3	0.54	0.58	0.50	41.69	92.17	65.42	0.39	0.35	0.34
4	SSP-P_1	0.46	0.47	0.46	24.71	59.21	41.47	0.42	0.43	0.37
5	SSP-P_2	0.48	0.48	0.44	31.02	70.58	53.61	0.39	0.39	0.44
6	SSP-P_3	0.38	0.49	0.49	51.44	87.49	58.53	0.41	0.42	0.38
7	DAP-P_1	0.36	0.44	0.41	21.19	57.06	52.17	0.31	0.30	0.40
8	DAP-P_2	0.21	0.48	0.42	28.41	74.05	57.41	0.28	0.35	0.40
9	DAP-P_3	0.41	0.54	0.41	42.51	78.93	65.64	0.40	0.42	0.41
10	MRP-P_1	0.41	0.45	0.37	27.62	56.63	39.58	0.32	0.31	0.32
11	MRP-P_2	0.43	0.47	0.36	26.76	70.05	50.52	0.36	0.37	0.30
12	MRP-P_3	0.42	0.53	0.41	43.72	79.23	68.55	0.37	0.41	0.35
13	Control	0.39	0.35	0.32	14.72	13.57	34.96	0.33	0.27	0.28
14	SSP(P_2+P_2)	0.61	0.62	0.44	56.91	121.91	62.62	0.30	0.35	0.44
	Mean									
	Source									
	TRP	0.49	0.45	0.45	32.15	70.72	55.62	0.38	0.34	0.36
	SSP	0.44	0.48	0.46	33.26	69.88	49.90	0.40	0.42	0.40
	DAP	0.33	0.49	0.42	28.80	67.77	57.26	0.33	0.36	0.40
	MRP	0.42	0.48	0.38	31.12	66.45	50.78	0.35	0.36	0.32
	CD(0.05)	0.1180	0.0626	-	1.3513	1.3513	1.2766	0.1182	0.0614	0.0488
	Level									
	P_1	0.45	0.45	0.40	24.89	49.83	44.73	0.33	0.32	0.36
	P_2	0.40	0.46	0.41	29.84	70.00	53.90	0.36	0.38	0.39
	P_3	0.44	0.54	0.45	43.54	82.11	63.32	0.39	0.40	0.37
	CD(0.05)	0.1024	0.0542	0.0522	1.2962	1.2962	1.2344	0.1024	0.0532	0.0422

for Tunisia rockphosphate in MT and harvest stage of crop (10.86 and 25.07 mg pot^{-1}). In PI stage MRP gave highest uptake of phosphorus. The levels of applied phosphorus showed a linear relationship with P uptake. In harvest stage the P uptake increased from 21.92 mg to 27.32 mg for the different levels of phosphorus.

The data on phosphorus uptake during different stages of crop in Kuttanad soil are given in Table 44. The data showed an increase from MT to PI stage and thereafter a decrease in harvest stage. In MT and PI stages the uptake by SSP and TRP were higher than MRP and DAP. In harvest stage DAP (57.26 mg pot^{-1}) gave the highest P uptake. With the doses the P uptake increased from 24.89 to 43.54 mg pot^{-1} in MT stage 49.83 to 82.11 mg pot^{-1} in PI stage and 44.73 to 62.32 mg pot^{-1} in harvest stage.

The statistical analysis of the data showed significant difference in uptake with type of P sources and levels in all the three stages. The treatment SSP applied twice gave significant difference in uptake of phosphorus with other sources.

Potassium

The data on uptake of potassium in laterite soil during critical stage of plant growth are given in Table 43 and 44. The data showed a decrease in uptake from MT to PI stage and gave a higher value in harvest stage. It was also observed that the uptake of K showed a decrease when dose increased from 22.5 to 45 kg ha^{-1}. However, when the level increased, the uptake of K increased with dose. All the sources were comparable on their effect in K uptake in all the three stages.

The uptake of potassium content in Kuttanad soil showed inconsistent result at various stages. The different sources were comparable at MT stage of crop growth. In PI stage except TRP all other sources were comparable and in harvest stage MRP was lower to SSP and DAP. As the dose of applied phosphorus increased the uptake of potassium also found to be increased in PI stage. The statistical analysis of the data showed that the uptake of K differed in all the stages due to different P sources and levels of applied P. The control differed from other sources. SSP (P_2+P_2) showed significant difference with various other treatments.

Calcium

In laterite soil the data (Table 45 and 46) showed an increase in calcium uptake from MT stage to harvest stage. The TRP found to gave a higher uptake of calcium in all the critical stages of plant growth (34.35, 40.06 and 128.85 mg pot^{-1} respectively). The doses were found to have a linear relation with calcium uptake and highest level recorded a value of 32.61, 49.30 and 132.69 mg pot^{-1} for MT, PI and harvest stage.

The data of uptake of calcium during critical stages of IInd crop in Kuttanad soil are given in Table 46. The data showed an increase from MT stage to harvest stage. Of the different P sources TRP gave the highest value in MT and harvest stages (105.65 and 281.29 mg pot^{-1}) while in PI stage SSP and MRP gave higher uptake. The dose of applied P source was found to have a linear relation with uptake in PI and harvest stage. But in MT stage the behaviour was different.

The statistical analysis of data showed that calcium uptake showed a significant difference due to type of P sources and levels in all the stages. Different

Table 46. Nutrient uptake of Ca and Mg during 2nd crops (Kuttanad) (mg pot^{-1})

Treatment		Ca			Mg		
No.	Notation	MT	PI	Harvest	MT	PI	Harvest
1	TRP-P_1	101.79	54.46	247.01	42.08	38.16	154.11
2	TRP-P_2	104.72	80.40	303.48	60.36	72.56	153.17
3	TRP-P_3	122.68	85.14	303.83	67.18	76.52	152.57
4	SSP-P_1	93.45	81.07	238.01	48.39	73.91	170.77
5	SSP-P_2	94.12	95.40	252.58	54.08	73.97	151.70
6	SSP-P_3	69.92	99.30	264.17	37.37	84.95	192.22
7	DAP-P_1	70.85	80.44	238.97	43.11	62.27	183.52
8	DAP-P_2	75.42	83.56	230.42	18.76	64.64	221.88
9	DAP-P_3	87.13	97.54	280.89	45.02	75.87	239.85
10	MRP-P_1	92.45	91.45	223.97	43.69	62.97	111.61
11	MRP-P_2	77.32	87.59	204.30	50.39	82.87	135.21
12	MRP-P_3	80.06	95.28	207.66	55.24	70.37	132.05
13	Control	66.41	68.45	179.42	38.39	57.38	131.68
14	SSP(P_2+P_2)	134.15	104.77	310.41	73.85	89.95	197.96
	<u>Source</u>			Mean			
	TRP	105.65	71.15	281.30	55.72	60.24	143.70
	SSP	82.16	90.53	249.44	46.07	76.59	161.03
	DAP	74.88	85.88	247.25	34.21	66.60	203.06
	MRP	80.21	90.34	210.19	49.38	70.94	117.39
	CD(0.05)	-	1.2344	1.1865	0.0898	0.2497	2.1936
	<u>Level</u>						
	P_1	87.20	77.43	234.53	47.32	62.15	145.94
	P_2	83.76	85.45	242.99	43.77	72.34	152.81
	P_3	84.61	92.94	259.33	50.27	75.79	165.28
	CD(0.05)	-	1.1993	1.1591	0.667	0.1846	1.5871

factors like type of P sources and levels were found to have interaction with soil and each other in PI stage. The control and SSP (P_2+P_2) showed significant difference with other sources in PI and harvest stage.

Magnesium

The data on uptake of Mg in laterite soil are given in Tables 45 and 46. The data showed a decrease from MT stage to PI stage and then an increase in harvest stage. Of the different P sources - SSP gave maximum uptake in MT and PI stages of crop growth and TRP and DAP gave highest uptake in harvest stage. The level of applied phosphorus was found to have a linear relationship with Mg uptake.

In Kuttanad soil the data (Table 46) showed similar trend. The uptake of Magnesium was maximum with TRP in MT stage (55.72 mg pot^{-1}) SSP in PI and DAP in harvest stage. The doses of applied P source was found to have a linear relationship with Magnesium uptake except in MT stage.

The statistical analysis showed that the Mg uptake showed significant difference with various P sources in all stages. The levels differed in PI and harvest stages. The control and SSP applied twice had significant difference in all the crop stages.

In laterite soil during I crop the N uptake was found to be higher with TRP application and was followed by SSP. In 2nd crop the mean uptake due to different sources was comparable in MT and PI stages. But in harvest stage the TRP had higher uptake. In Kuttanad soil during Ist crop the TRP and SSP had higher N content in MT stage and DAP had a lower content in PI stage. But in 2nd crop except in MT stage all sources had comparable effect. The high N uptake with TRP in Kuttanad soil was due to low pH and high organicmatter content. The mineralisation of organic amendments and secretion of organic acid made more P available from TRP with better condition for uptake of nitrogen. Manjiah *et al.* (1995) observed similar results in soils of Sirsi using MRP.

The statistical analysis had shown that interaction between soil, treatment and dose was there in different stages. The increase of N uptake due to P application may be due to increased root growth, better root CEC, extensivity of root hairs, and surface area resulting in higher uptake.

The uptake of phosphorus was found to be significantly affected by application of phosphatic fertilizer. The different doses and sources had affected the uptake of phosphorus in a significant way. In laterite soil during I crop the uptake of phosphorus was comparable in different sources in initial phase and in harvest stage the uptake was maximum in TRP treatments. During 2nd crop the uptake was maximum in SSP and TRP treatments in all the different stages. In the initial period water soluble form of phosphorus wass the major source of P to the crops. But later on dissolution of rock phosphate occurred in a faster rate and that had contributed a portion of phosphorus to plant uptake. This is indicated by the higher uptake of phosphorus in the later period of crop in rock phosphate treatments. This clearly indicated that the rockphosphate had a higher residual effect than water soluble P sources. Similar results were obtained in acid soils of Kerala by Regi and Jose (1986), Subehia and Minhas (1993).

In Kuttanad soil the uptake of P during Ist crop was found to be maximum for TRP in harvest stage and was comparable with different sources in

PI and MT stages. In 2nd crop the uptake of P in TRP and SSP was comparable in initial period and was higher than other sources. But in harvest stage DAP had a higher uptake. Similar results were obtained with TRP in Mudigre soil of Karnataka by Girish *et al.* (1995).

The high uptake of P during initial phase of Ist crop may be due to increased P availability of soil, and increased dry matter production (Rejkhowa *et al.*, 1996). The high uptake noted in alluvial soil can also be attributed to P requirement of soil, high clay content etc. The predominance of Fe^{++}, Al^{+++} resulted in increased P fixing capacity which contributed to the residual effect of phosphate source. The pool of phosphate will be increased by active iron and Al in the soil which might increase the uptake of phosphorus content in successive crop.

The application of phosphorus was found to have affected the K uptake increasingly as shown by significant difference between control and other treatments. In laterite soil during I crop the potassium uptake showed a maximum value with TRP treatments in harvest stage. While in 2nd crop uptake was comparable for different sources.

In Kuttanad soil the K uptake by rockphosphate was comparable with water soluble sources in MT, PI and harvest stages. The data also revealed an increase in uptake of potassium with applied P level in PI stage. Similar results were reported by Jaggi *et al.* (1995) in acid soils of Himachal Pradesh.

This may be due to more root growth resulted from increased uptake of phosphorus enabling the plant to explore under higher depth for absorption of nutrients.

The data revealed that in laterite soil calcium uptake in first crop was maximum with SSP and DAP treatments. Similar results were reported by Sadanandan and Hamza (1995) in acid soils. of Kerala. But in 2nd crop TRP was found to contribute a higher value initially. In Kuttanad soil during first crop highly different values were obtained for SSP and DAP. But in 2nd crop there was not much difference. The variation noticed in uptake may be attributed to change in soil environment causing dissolution of rock phosphate and release of calcium from the fertilizer.

The magnesium uptake showed significant difference with soil, P sources and levels in different stages of crop growth. In laterite soil the magnesium uptake during Ist crop was maximum for DAP in MT stage and TRP in harvest stage. But in 2nd crop the SSP gave higher effect in initial stage and TRP in harvest stage. In Kuttanad soil the magnesium uptake during I and 2nd crop was without any consistant order. The different sources gave higher uptake in different periods. The difference may be attributed to changes in soil and environment causing dissolution of rock phosphate. The uptake of magnesium in berry was found in similar pattern in soils of Kerala by Sadanandan and Hamza (1995).

Leaching loss of nutrients in crop

The leaching loss of major nutrients like N, P and K were estimated during 1st and 2nd crop. The data of variation of loss of N, P and K in leachate during different period of crop growth (15th, 30th, 40th and 60th) days were schematically presented in Figs.27 to 29. The data are presented in Tables 47 to 50.

Table 47. Leachate loss of NPK during Ist crop (Laterite)

Treatment		N (%)				P (ppm)				K (ppm)			
No.	Notation	15	30	45	60	15	30	45	60	15	30	45	10
		(Period in days)											
1	TRP-P_1	0.0031	0.0027	0.0027	0.0032	0.1084	0.0312	0.0312	0.0312	0.8485	0.8485	0.9165	0.4000
2	TRP-P_2	0.0027	0.0024	0.0024	0.0028	0.3216	0.0716	0.0571	0.0441	1.0954	1.2649	0.9798	0.6325
3	TRP-P_3	0.0027	0.0028	0.0024	0.0028	0.1367	0.0679	0.0624	0.0624	0.5657	1.1832	0.8944	0.8000
4	SSP-P_1	0.0020	0.0027	0.0031	0.0031	0.1458	0.1487	0.0760	0.0312	0.4899	0.8944	1.0583	1.0954
5	SSP-P_2	0.0017	0.0023	0.0024	0.0024	0.3819	0.1264	0.0883	0.0312	0.8000	0.8944	0.5292	1.1314
6	SSP-P_3	0.0017	0.0023	0.0024	0.0024	0.1869	0.1090	0.0698	0.0312	0.6000	1.2961	1.2649	0.8944
7	DAP-P_1	0.0014	0.0032	0.0035	0.0031	0.2708	0.2422	0.0605	0.0312	0.9798	0.8485	1.4697	0.7746
8	DAP-P_2	0.0027	0.0024	0.0031	0.0024	0.0626	0.0493	0.0544	0.0271	2.1166	0.8485	1.1314	0.6928
9	DAP-P_3	0.0024	0.0035	0.0031	0.0020	0.0825	0.0605	0.0542	0.0716	0.4899	1.1314	0.9798	0.6928
10	MAP-P_1	0.0017	0.0035	0.0031	0.0027	0.0716	0.0766	0.0612	0.0542	0.5657	0.9798	0.8944	0.7746
11	MAP-P_2	0.0014	0.0032	0.0027	0.0024	0.0480	0.0825	0.0612	0.0312	0.6000	0.4472	1.0583	0.7746
12	MAP-P_3	0.0021	0.0020	0.0028	0.0028	0.0542	0.0624	0.0766	0.0493	0.6928	0.8944	1.1314	0.9798
13	Control	0.0025	0.0020	0.0031	0.0028	0.1103	0.1304	0.0440	0.0222	0.6928	1.0954	1.1832	0.5657
14	SSP(P_2+P_2)	0.0017	0.0017	0.0020	0.0031	0.0856	0.0716	0.0470	0.0158	0.5657	0.9165	1.1314	0.6000

Table 48. Leachate loss of NPK during Ist crop (Kuttanad)

Treatment		N (%)				P (ppm)				K (ppm)			
No.	Notation	15	30	45	60	15	30 (Period in days)	45	60	15	30	45	10
1	TRP-P_1	0.0027	0.0027	0.0021	0.0017	0.2620	0.0856	0.0698	0.0470	6.3498	0.3464	0.4899	0.5657
2	TRP-P_2	0.0017	0.0030	0.0017	0.0020	0.0987	0.0870	0.0383	0.0383	2.3917	1.0000	0.6325	0.8944
3	TRP-P_3	0.0024	0.0024	0.0023	0.0024	0.1084	0.0766	0.0698	0.0624	1.3416	1.0954	0.7746	0.9165
4	SSP-P_1	0.0017	0.0020	0.0019	0.0024	0.0418	0.0825	0.0605	0.0312	1.4832	0.8000	0.6928	0.7746
5	SSP-P_2	0.0014	0.0021	0.0021	0.0012	0.1326	0.0624	0.0542	0.0605	2.9933	0.4472	0.4000	1.0000
6	SSP-P_3	0.0028	0.0027	0.0027	0.0007	0.1710	0.0470	0.0470	0.0493	6.2032	0.9487	0.6000	0.8944
7	DAP-P_1	0.0030	0.0027	0.0024	0.0024	0.1484	0.2608	0.0605	0.0312	1.5100	0.6325	0.4899	1.0954
8	DAP-P_2	0.0034	0.0024	0.0023	0.0017	0.0935	0.0383	0.0383	0.0542	4.2048	0.5657	0.4899	0.8485
9	DAP-P_3	0.0033	0.0024	0.0030	0.0032	0.0605	0.0565	0.0493	0.0441	2.1166	0.8944	0.6000	1.0000
10	MRP-P_1	0.0023	0.0014	0.0014	0.0017	0.0809	0.0441	0.0383	0.0358	2.1909	1.0954	0.6928	1.0000
11	MRP-P_2	0.0027	0.0017	0.0017	0.0022	0.0883	0.0383	0.0312	0.0156	4.0988	0.8000	0.3464	1.0000
12	MRP-P_3	0.0027	0.0021	0.0021	0.0024	0.0760	0.0766	0.0467	0.0856	4.7329	0.8944	0.6000	0.6928
13	Control	0.0031	0.0017	0.0017	0.0014	0.0605	0.0312	0.0312	0.0441	1.7664	0.8944	0.6000	0.8000
14	SSP(P_2+P_2)	0.0021	0.0030	0.0027	0.0007	0.2090	0.1039	0.0418	0.0450	3.5327	0.6000	0.4899	0.4000

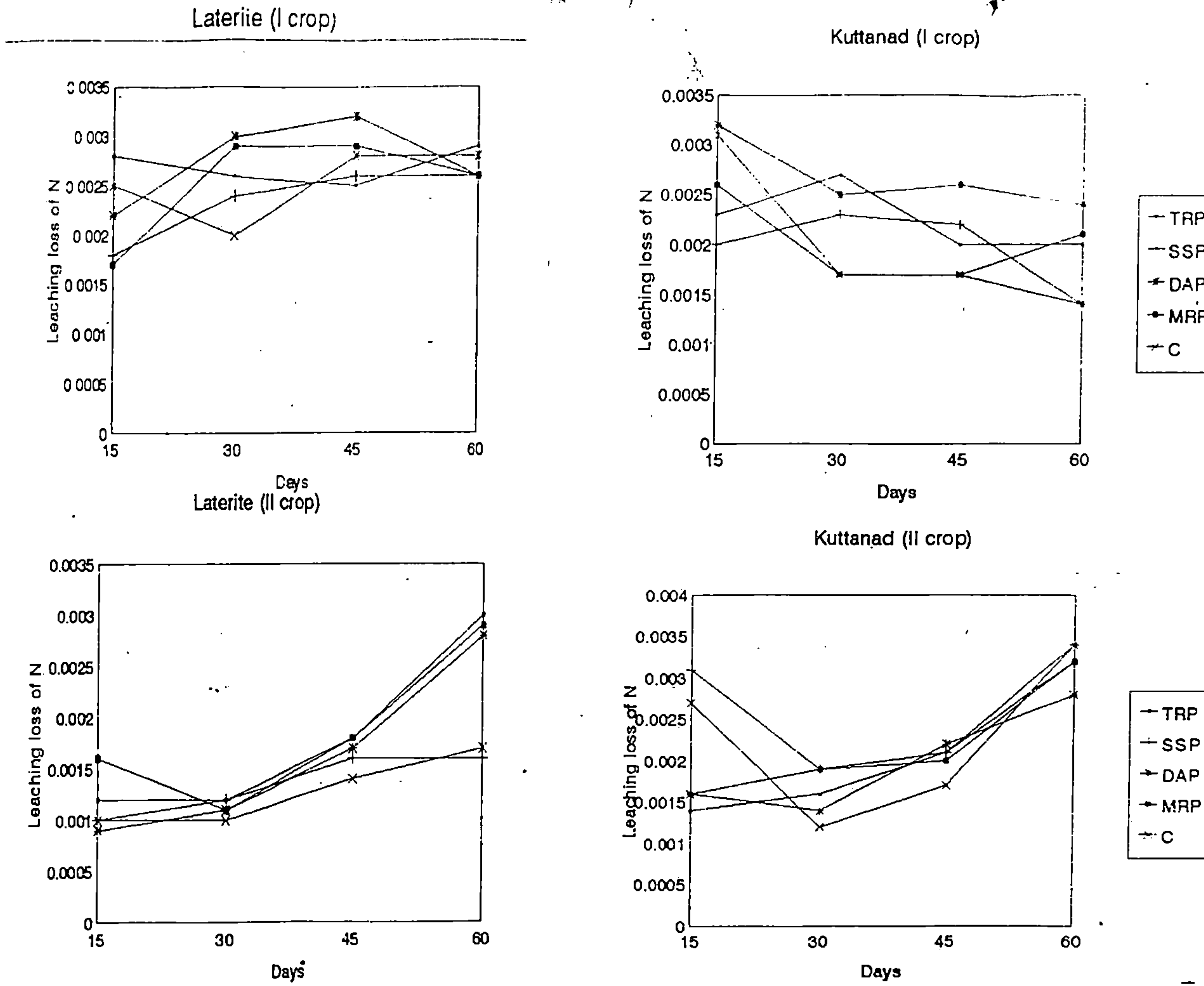


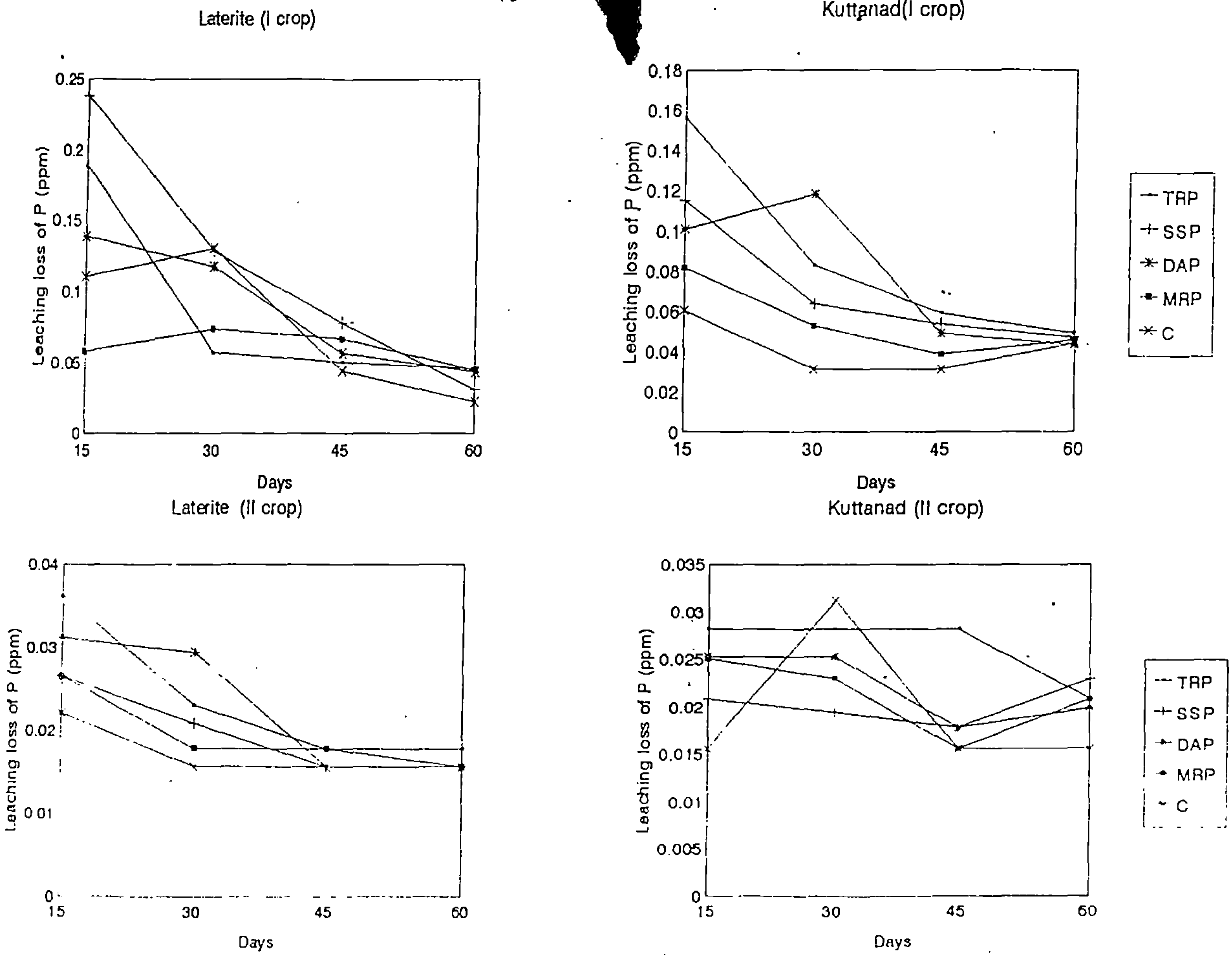
Fig. 27 Leachate loss of Nitrogen in potculture as affected by different treatments

Table 49. Leachate loss of NPK during 2nd crop (Laterite)

Treatment		N (%)				P (ppm)				K (ppm)			
No.	Notation	15	30	45	60	15	30	45	60	15	30	45	10
						(Period in days)							
1	TRP-P_1	0.0016	0.0010	0.0017	0.0028	0.0387	0.0312	0.0156	0.0156	0.8000	0.8944	0.6325	1.0954
2	TRP-P_2	0.0014	0.0010	0.0021	0.0034	0.0387	0.0221	0.0221	0.0156	1.2649	0.9798	0.8485	0.9798
3	TRP-P_3	0.0007	0.0017	0.0017	0.0027	0.0312	0.0156	0.0156	0.0221	1.2649	0.8000	0.8000	0.6928
4	SSP-P_1	0.0006	0.0012	0.0014	0.0022	0.0221	0.0156	0.0156	0.0156	0.4000	0.7746	0.6000	0.8000
5	SSP-P_2	0.0014	0.0014	0.0014	0.0024	0.0418	0.0156	0.0156	0.0156	0.5657	0.5657	0.6928	0.6928
6	SSP-P_3	0.0010	0.0010	0.0021	0.0003	0.0156	0.0312	0.0156	0.0156	0.4899	0.8000	0.8485	0.8485
7	DAP-P_1	0.0010	0.0010	0.0017	0.0024	0.0221	0.0312	0.0156	0.0156	0.5657	0.8944	0.6928	0.5657
8	DAP-P_2	0.0007	0.0010	0.0017	0.0028	0.0221	0.0221	0.0156	0.0156	3.4641	1.1489	0.8944	0.6000
9	DAP-P_3	0.0010	0.0014	0.0017	0.0031	0.0493	0.0349	0.0156	0.0156	0.5657	0.8944	0.9798	1.3856
10	MRP-P_1	0.0014	0.0014	0.0017	0.0031	0.0190	0.0156	0.0156	0.0156	0.6928	0.6928	0.6325	0.4000
11	MRP-P_2	0.0010	0.0010	0.0017	0.0030	0.0383	0.0156	0.0156	0.0156	1.1832	0.9798	0.8000	0.5657
12	MRP-P_3	0.0024	0.0010	0.0021	0.0026	0.0221	0.0221	0.0221	0.0156	0.8000	0.8944	0.6928	0.7746
13	Control	0.0010	0.0010	0.0014	0.0017	0.0221	0.0156	0.0156	0.0156	0.8944	0.9798	0.7746	0.6325
14	SSP(P_2+P_2)	0.0007	0.0007	0.0014	0.0021	0.0221	0.0221	0.0156	0.0156	0.6928	0.8000	0.6928	0.5657

Table 50. Leachate loss of NPK during 2nd crop (Kuttanad)

Treatment		N (%)				P (ppm)				K (ppm)			
No.	Notation	15	30	45	60	15	30	45	60	15	30	45	10
						(Period in days)							
1	TRP-P_1	0.0012	0.0014	0.0017	0.0031	0.0312	0.0312	0.0312	0.0156	0.8000	0.8000	0.5657	0.2000
2	TRP-P_2	0.0017	0.0017	0.0024	0.0037	0.0221	0.0221	0.0312	0.0156	0.6000	0.4899	0.2828	0.2000
3	TRP-P_3	0.0014	0.0017	0.0024	0.0028	0.0312	0.0312	0.0221	0.0312	0.6000	0.4899	0.4899	0.2000
4	SSP-P_1	0.0035	0.0017	0.0021	0.0024	0.0312	0.0221	0.0156	0.0312	0.4899	0.4899	0.3464	0.2449
5	SSP-P_2	0.0038	0.0021	0.0017	0.0037	0.0156	0.0221	0.0156	0.0221	1.3856	0.4899	0.2828	0.2449
6	SSP-P_3	0.0021	0.0020	0.0024	0.0041	0.0156	0.0139	0.0221	0.0156	1.3416	0.4899	0.4000	0.2449
7	DAP-P_1	0.0014	0.0017	0.0028	0.0034	0.0221	0.0221	0.0156	0.0156	0.4899	0.4000	0.4000	0.2000
8	DAP-P_2	0.0017	0.0014	0.0021	0.0027	0.0156	0.0156	0.0156	0.0221	1.0583	0.4899	0.2828	0.2000
9	DAP-P_3	0.0017	0.0012	0.0017	0.0024	0.0383	0.0383	0.0221	0.0221	0.8944	0.6000	0.2000	0.4000
10	MRP-P_1	0.0021	0.0020	0.0021	0.0042	0.0312	0.0312	0.0156	0.0156	1.2649	0.4899	0.3464	0.2828
11	MRP-P_2	0.0012	0.0021	0.0024	0.0031	0.0221	0.0221	0.0156	0.0156	1.0954	0.4899	0.2000	0.2000
12	MRP-P_3	0.0014	0.0017	0.0014	0.0024	0.0221	0.0156	0.0156	0.0312	0.8000	0.4000	0.2000	0.2449
13	Control	0.0027	0.0012	0.0017	0.0034	0.0156	0.0312	0.0156	0.0156	1.1489	0.4899	0.2000	0.2000
14	SSP(P_2+P_2)	0.0037	0.0028	0.0020	0.0024	0.0221	0.0221	0.0312	0.0312	0.4899	0.4899	0.2828	0.2449


Laterite (I crop)
Leaching loss of P (ppm)
Days
Kuttanad(I crop)
Leaching loss of P (ppm)
Days
TRP
SSP
DAP
MRP
C
Laterite (II crop)
Leaching loss of P (ppm)
Days
Kuttanad (II crop)
Leaching loss of P (ppm)
Days
TRP
SSP
DAP
MRP
C

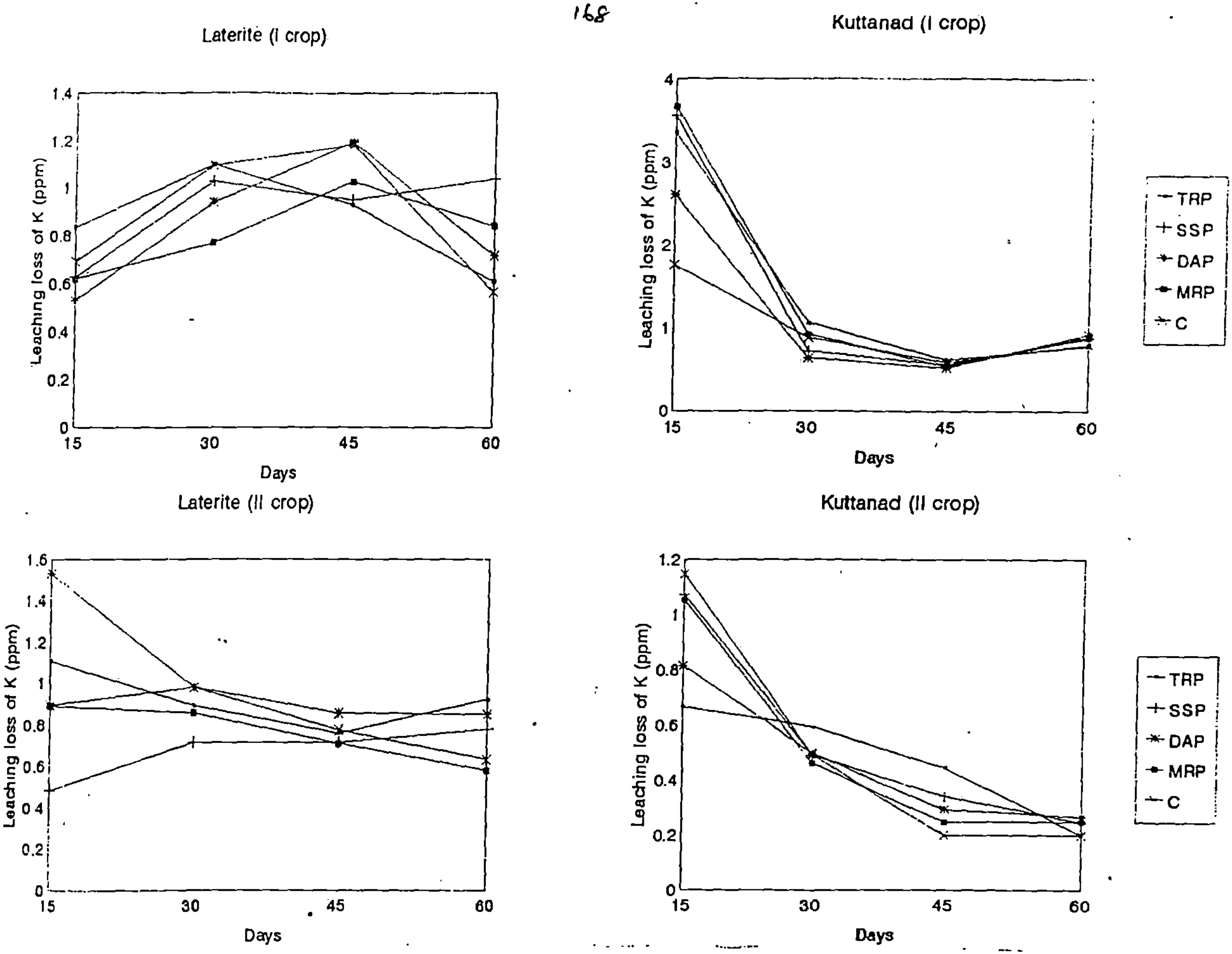


Fig. 2.8 Leachate loss of

Of the three elements maximum leaching loss was for nitrogen. The loss of N in laterite and Kuttanad soil varied in the range of 10 to 30 per cent during 1st and 2nd crop of rice. The loss of phosphorus in 1st and 2nd crop of rice in both Kuttanad and laterite soil was very negligible. The loss ranged from 0.02 to 0.12 ppm. The loss of potassium in 1st and 2nd crop of rice in different soil varied between 0.4 to 4.0 ppm and it did not show any clear trend with the source or dose.

4.2.4 Grain and straw yield

4.2.4.1 First crop

Laterite

The data on grain and straw yield with the application of different phosphate sources at different levels in first crop of rice are given in Table 51. The data showed that in laterite soil the control and different sources did not show any variation in their grain and straw yield. All the sources were on par. The different treatments gave grain yield of TRP-P_1 (17.55 g pot^{-1}), TRP-P_3 (17.05 g pot^{-1}) and SSP (P_2+P_2) 16.97 g pot^{-1}. In the case of straw yield SSP (P_2+P_2) gave 18.67 g.pot^{-1} and TRP-P_3 gave (18.17 g pot^{-1}). The control and SSP (P_2+P_2) application were not significantly different from other treatments.

The effect of different sources in comparison with control is illustrated in Figs.30 and 31. The straw yield was found to be decreasing from 15.64 to 14.71 g pot^{-1} as level of P increased from 22.5 to 45 kg ha^{-1}. The grain yield do not show any variation when dose increased from 1st to 2nd level. But as the dose increased to 67.5 kg ha^{-1} the straw yield was found to be increased to 16.65 g pot^{-1}).

Table 51.Grain and straw yield g pot^{-1} as influenced by treatments in first crop of rice

Treatment No.	Notation	Laterite		Kuttanad	
		Straw	Grain	Straw	Grain
1	TRP-P_1	18.11	17.55	18.67	19.43
2	TRP-P_2	15.38	15.86	18.16	20.05
3	TRP-P_3	18.17	17.05	22.18	22.10
4	SSP-P_1	15.16	14.75	18.16	16.63
5	SSP-P_2	15.66	15.39	17.67	16.56
6	SSP-P_3	17.17	15.48	25.16	21.16
7	DAP-P_1	14.65	13.67	18.15	18.06
8	DAP-P_2	14.15	13.52	24.03	18.43
9	DAP-P_3	16.16	14.33	22.69	20.07
10	MRP-P_1	14.15	13.97	19.68	19.25
11	MRP-P_2	14.15	14.70	21.69	19.99
12	MRP-P_3	15.66	16.26	19.65	20.04
13	Control	14.13	14.95	19.05	16.54
14	SSP(P_2+P_2)	18.67	16.97	21.69	20.66
	CD(0.05)	-	-	21.72	-
			Mean		
	<u>Sources</u>				
	Control	14.13	14.95	19.05	16.54
	TRP	17.08	15.81	19.51	19.28
	SSP	15.88	14.30	20.07	15.80
	DAP	14.87	13.01	21.43	17.71
	MRP	14.54	14.06	20.26	18.58
	CD(0.05)	-	-	-	-
	<u>Level</u>				
	P_1	15.64	14.23	19.09	17.14
	P_2	14.71	13.85	20.17	17.43
	P_3	16.65	14.70	22.23	19.44
	CD(0.05)	0.044	1.541	0.044	1.54

Fig.30 Grain and straw yield of I crop of rice as influenced by sources of P (laterite)

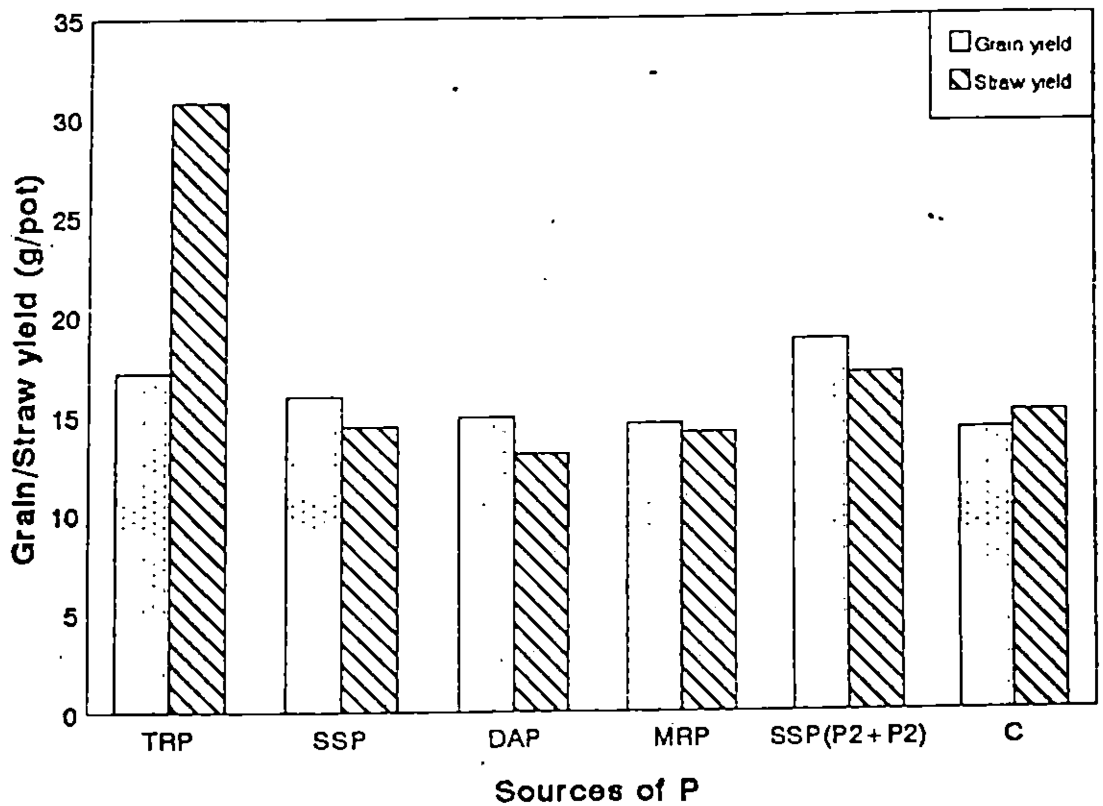
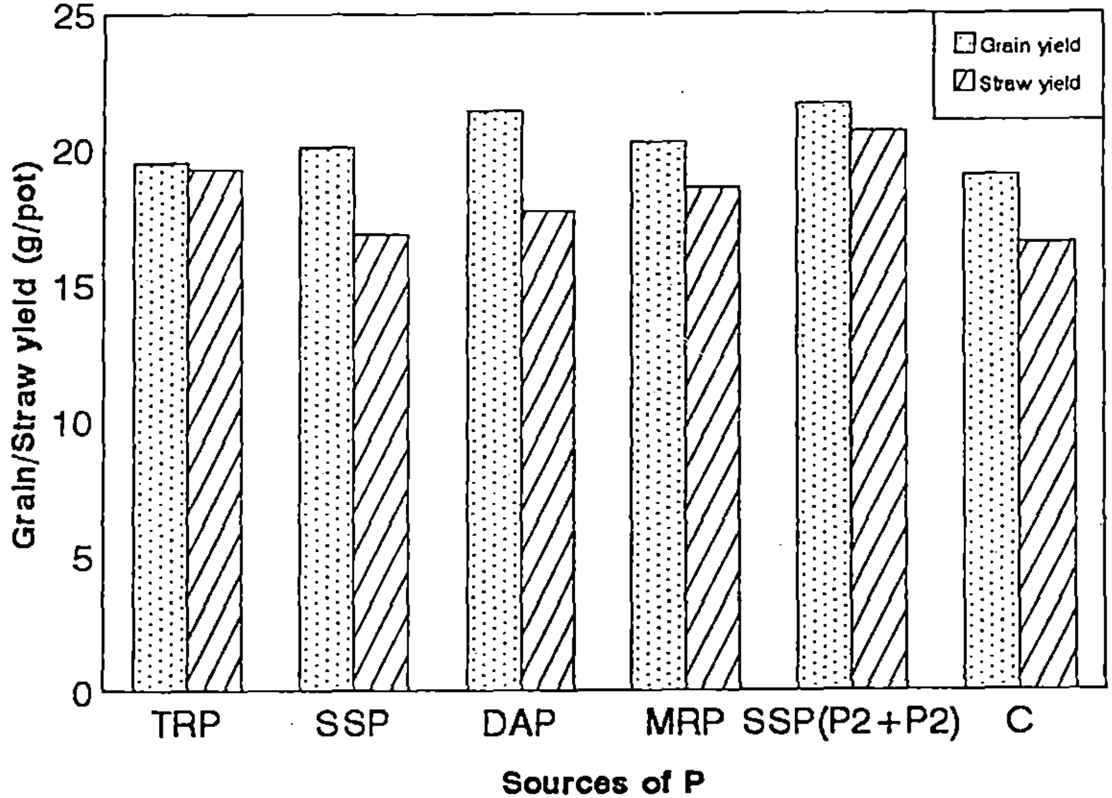


Fig.3: Grain and straw yield of I crop of rice as influenced by sources of P (Kuttanad)



In Kuttanad soil also the grain and straw was not affected by different sources. As the level increased from 22.5 to 45 kg the yield of grain did not vary. But when the level increased to 67.5 the grain yield also increased. The straw yield was found to have a linear relationship with the level of applied P. The straw yield for the three different levels applied were 19.09, 20.07 and 22.23 g pot^{-1} and grain yield was 17.14, 17.43 and 19.44 g pot^{-1}, respectively. The single super phosphate applied twice had similar values as that of other treatments for straw and grain yield. In general the grain yield in first crop season was low due to rodent attack.

The statistical analysis showed that there was no significant difference between any treatments. The control and SSP (P_2+P_2) had same effect as that of other treatments. The two soils showed a difference in their effect on yield and Kuttanad soil had higher yield.

4.2.4.2 Second crop

The data on yield of crop in laterite soil during 2nd crop are given in Table 52.

In 2nd crop season the yield of straw obtained for different treatments were TRP-P_3 (19.58 g pot^{-1}), DAP-P_3 (15.28 g pot^{-1}). The mean yield of straw increased in the order of TRP > DAP > MRP > SSP. The grain yield during 2nd crop was comparable for different sources. The different P sources did not affect the yield.

Comparing the levels it was found that as the dose of phosphorus increased from 22.5 kg to 45 kg there was a decrease in yield. When dose again increases to 67.5 kg ha^{-1} the yield also increased. Thus maximum yield was obtained at the dose of 67.5 kg. The grain yield with different doses of fertilizers were 13.1 g for Ist level 12.47 g for 2nd level and 15.49 g for 3rd level. The straw yield was 11.26 g for Ist level 10.58 g 2nd level and 13.32 g for 3rd level.

The effect of different P sources on yield is compared in the Fig.32 and 33.

In Kuttanad soil the straw yield obtained are TRP-P_1 and TRP-P_3 (24.53 g each) followed by TRP-P_2 (23.02 g pot^{-1}), SSP-P_1 (22.52 g pot^{-1}) and DAP-P_1 (22.51 g pot^{-1}) respectively. The grain yield was maximum for the treatment SSP (P_2+P_2) and the order of mean grain yield for different sources, TRP, DAP, MRP and SSP were 30.75, 29.64, 29.16 and 27.98 g pot^{-1} respectively. The mean value of straw yield was in the order of TRP > DAP > SSP > MRP. In Kuttanad soil the dose was found to have a linear relation with yield.

The statistical analysis of data showed that there was no significant difference in the grain yield of crop due to different type of P sources. But level of applied phosphorus was found to have significant effect on yield. The control showed similar effect to other treatments while the SSP applied twice gave a significantly higher yield compared to other treatments. The two soils showed a significant difference on their effect on yield and Kuttanad soil performed well.

It was thus found that rockphosphate release available phosphorus similar to water soluble sources and it was indicated by similar yield for both types of sources. This comparative performance of rockphosphate may be due to rapid dissolution of rockphosphate which was caused by high acidity, clay content,

Table 52.Grain and straw yield g pot^{-1} as influenced by treatments in second crop of rice

Treatment No.	Notation	Laterite		Kuttanad	
		Straw	Grain	Straw	Grain
1	TRP-P_1	10.35	11.72	24.53	30.01
2	TRP-P_2	12.84	13.53	23.02	31.16
3	TRP-P_3	19.58	16.81	24.53	32.55
4	SSP-P_1	14.34	14.41	22.52	28.16
5	SSP-P_2	8.28	14.28	22.52	26.33
6	SSP-P_3	10.85	15.03	19.99	30.94
7	DAP-P_1	10.55	13.52	21.98	28.42
8	DAP-P_2	11.73	11.94	22.99	30.20
9	DAP-P_3	15.28	15.02	22.51	31.71
10	MRP-P_1	13.22	11.73	17.46	25.93
11	MRP-P_2	10.88	11.72	17.46	30.16
12	MRP-P_3	9.83	16.25	19.48	33.19
13	Control	9.30	11.68	15.43	26.01
14	SSP(P_2+P_2)	11.85	17.92	19.94	39.95
	CD(0.05)	3.142	-	3.142	3.296
			Mean		
	Source				
	Control	9.3	11.68	15.43	26.01
	TRP	13.73	13.65	23.67	30.75
	SSP	10.78	14.34	21.32	27.98
	DAP	12.17	13.23	22.15	29.64
	MRP	11.00	12.68	17.81	29.16
	CD(0.05)	0.1685	-	0.1685	-
	Level				
	P_1	11.26	13.10	19.83	28.91
	P_2	10.58	12.47	21.05	28.90
	P_3	13.32	15.49	21.20	31.55
	CD(0.05)	0.1241	1.234	0.1241	1.234

Fig.32 Grain and straw yield of II crop of rice as influenced by sources of P (laterite)

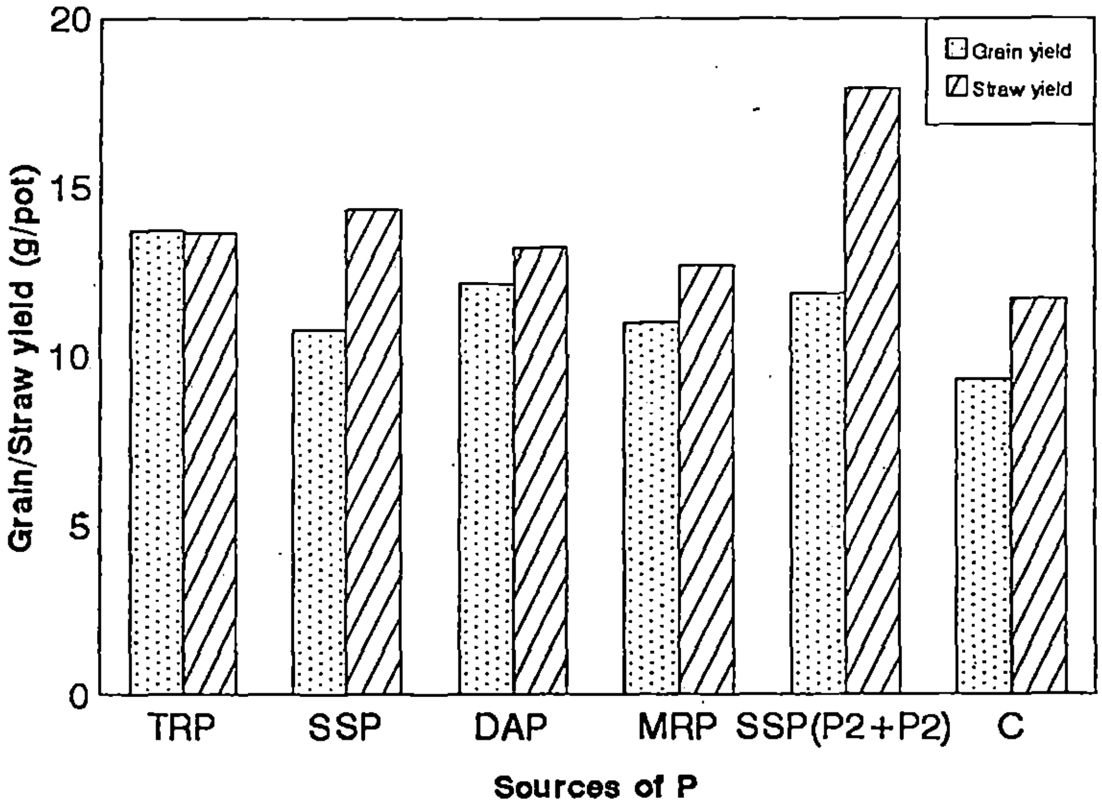
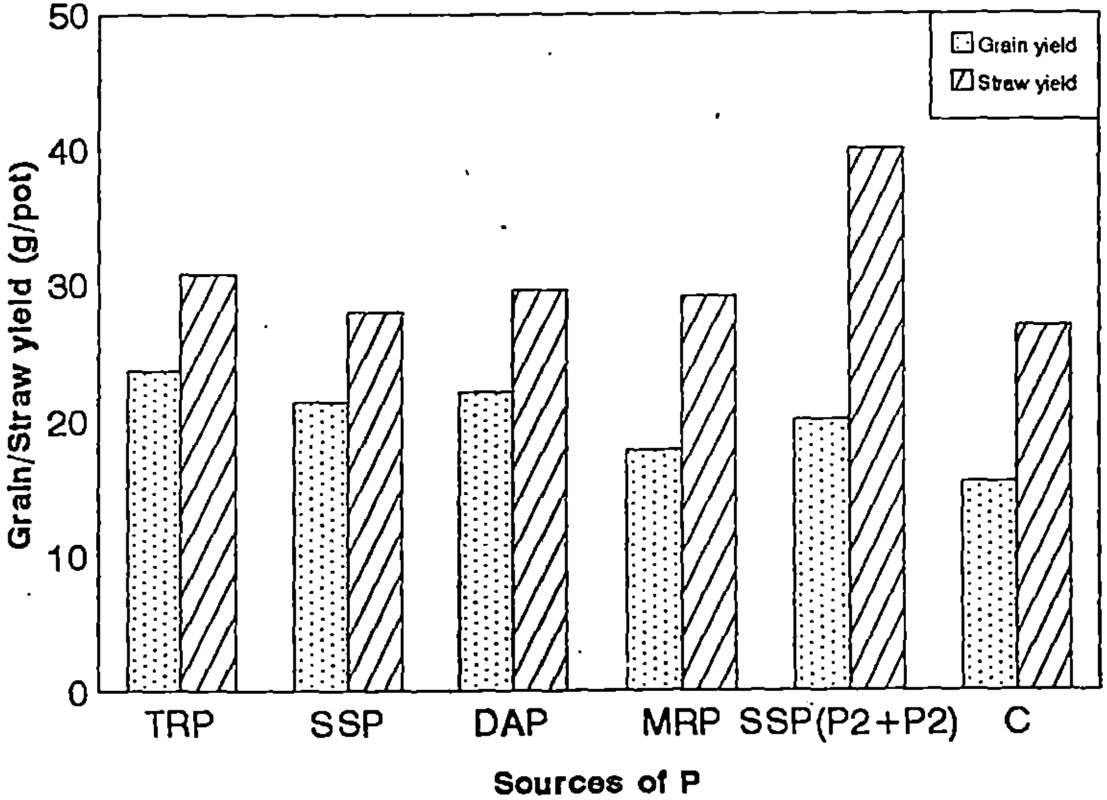


Fig.33 Grain and straw yield of II crop of rice as influenced by sources of P (Kuttanad)



organic matter content prevailed in these type of soils. The increased yield may also be due to supply of other elements namely, Ca and Mg present in the Tunisia rockphosphate. Among the two rockphosphates the TRP had higher dissolution. The rapid dissolution can be attributed to high surface area, sedimentary nature and CO_3 apatite type. All these aspects may be responsible for the rapid dissolution, increased uptake of nutrients and there by resulting in more grain and straw yield. Similar response was obtained for rockphosphate (mussoorie rockphosphate) in laterite soil and Karapadam soils of Kerala by Nair and Padmaja (1982).

Statistically there was no difference between different P sources and interaction was there between different factors. The yield was found to increase with level of applied P in the case of straw and grain in both soils.

In the second crop the grain and straw yield was found slightly higher in Kuttanad soil while it was slightly less in laterite soil. This may be due to the fact that in laterite soil the availability of P from applied sources and the native P sources were high during Ist crop which resulted in exhausting of P reserve. While in Kuttanad soil the applied P undergone easy fixation in the form of Fe and Al-P and there by increased the pool of labile phosphorus which subsequently released to meet the P requirement of 2nd crop.

During 2nd crop in laterite soil the straw yield was found to be maximum for treatment TRP - P_3. The control had minimum straw yield. The mean value of straw yield showed a higher value for rockphosphate treatment compared to water soluble sources. Similar results were obtained by Geethakumari and Mohammedkunju (1984) in Pattambi soils of Kerala using cowpea.

In Kuttanad soil the trend was similar with mean straw yield maximum in TRP followed by DAP and SSP. The higher straw yield of TRP in laterite and Kuttanad soil may be due to the high residual effect of rockphosphate.

The grain yield in laterite soil showed no difference for different P sources. The highest yield was by treatment SSP(P_2+P_2) which differed significantly from all other treatments. The similar results were obtained by Nair (1978) using Mussoorie rockphosphate.

In Kuttanad soil the grain yield had no difference with different sources. The comparative grain yield for rockphosphate with water soluble phosphates in 2nd crop of rice was mainly due to its residual effect. This findings is in confirmity with the observation of Nair and Padmaja (1982) in Kayal and Karapadam soils.

It was clearly observed that in both crops in Kuttanad soil, the TRP had a numerically higher grain yield though it was statistically not significant. But in 2nd crop the grain yield of TRP was less compared to (SSP P_2+P_2) by a percentage difference of around 20 per cent. So the application of SSP in succeeding crops can be reduced or skipped according to the economy of production.

The residual effect of the applied P source was calculated using the formula

$$\text{Residual effectiveness} = \frac{\text{The yield of source not applied with SSP - control}}{\text{The yield source applied again with SSP - control}} \times 100$$

The residual effect of different sources in different soils were calculated. It was found that in laterite soil residual effectiveness was very less (TRP - 31.56%, SSP - 42.61%, DAP - 24.83% and MRP - 16.2%). The SSP had the maximum residual effect. But in Kuttanad soil the different source had residual effect. TRP - 75 per cent, SSP - 31 per cent, DAP - 50 per cent and MRP - 51 per cent. So the application of SSP to succeeding crop can be reduced by 3/4th if TRP is applied for a rice crop.

The present study clearly emphasised the high residual effect of TRP as compared to MRP and TRP was found well suited for Kerala soils. The high performance of Tunisia rockphosphate (Gafsa) in different types of soil make it suitable as a substitute of SSP for direct application in acid soils of Kerala.

SUMMARY

Study on the suitability of Tunisia rockphosphate for direct application in acid soils of Kerala was conducted at the College of Horticulture, Vellanikkara during the period 1993-95 to evaluate the effectiveness of TRP as a source of phosphorus compared to SSP, DAP and MRP in acid soils of Kerala and to study the pattern of release of P from all the above sources. The investigation consisted mainly of two parts, an incubation study and a continuous pot culture experiment for two seasons. In order to ascertain the pattern of release of P and the transformation it undergoes, an incubation experiment was conducted for a period of eight months. The different sources of phosphatic fertilizers used in the study also compared with two treatments, ie. no P treatment (control) and continuous application of SSP in both crops. The pot culture experiment was conducted using rice variety Triveni and crop was raised in Mundakan and Punja season to assess residual effect of different P sources. The salient features of the results are summarised below:

1. Available nitrogen content of soil decreased with period of incubation irrespective of the treatments and it varied from 280 to 170 ppm in laterite soil and from 535 to 290 ppm in Kuttanad soil with advancement of incubation.

2. Available phosphorus slightly increased with period of incubation and reached a peak content for the water soluble phosphates on 60th to 90th days while for rockphosphate it was on 90th to 120th days irrespective of soil types.

3. Of 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 acid + 0.06 N HCl) more available P was extracted by Mathew's triacid and it was found to be of same trend for both soils.

4. The available P content (Bray-I) was comparable for the treatments with SSP, DAP and TRP in laterite soil during incubation and was higher than MRP.

5. The available phosphorus content of soil showed an increase with increase in the level of application from 22.5 to 67.5 kg P_2O_5 ha^{-1} in laterite soils.

6. The available potassium content showed a decrease with period of incubation. In laterite soil the potassium content ranged from 29.0 ppm to 48.5 ppm. While in Kuttanad alluvium it ranged from 89.51 ppm to 151.5 ppm. The maximum was observed on 45th day.

7. The calcium content of soil registered maximum value on 90th day of incubation after which it declined.

8. The Mg content showed a slight increase till 45th day of incubation and then decreased gradually.

9. The Kuttanad soil recorded higher values for various available nutrients N, K, Ca and Mg compared to laterite soil.

10. Transformation and fixation of available P as Fe-P, Al-P and Calcium phosphate were maximum in Kuttanad soil compared to laterite soil.

11. Al-P was the most dominant fraction in laterite soil while Fe-P was the most dominant fraction in Kuttanad soil. The content ranged between 51 to 174 ppm in laterite soil and 54 to 293 ppm in Kuttanad soil. Al-P content showed a steady increase throughout incubation.

12. Fe-P also showed a steady increase through out the incubation. In Kuttanad soil Fe-P was the most dominant fraction through out incubation. The content varied between 310 to 475 ppm. While in laterite soil the content ranged between 35 to 115 ppm.

13. Ca-P content showed a steady increase till 120th day of incubation and there after decreased in both the type of soils. The calcium phosphate content of Kuttanad soil was higher than laterite soil.

14. The different sources of phosphorus did not record any significant difference in biometric observation during 1st and 2nd crops.

15. With the advancement of crop growth, available N content of soil showed clear cut decrease. But all other nutrients registered stabilized value. pH showed a slight increase in both crops.

16. The available P content of soil showed a decrease with advancement of crop. During 2nd crop season the rockphosphates registered a higher available phosphorus content.

17. The nutrient uptake of different elements increased with the advancement of crop. While the soil status of N, P, K, Ca and Mg remained almost stable or slightly reduced.

18. The uptake of phosphorus was found to be maximum with TRP followed by SSP in 2nd crop. While in first crop the maximum uptake of phosphorus was shown by SSP in initial stage but in harvest stage TRP registered highest uptake.

19. There was no marked difference in leaching losses between various sources in both crops. Among the nutrients maximum leachate loss was recorded for N followed by K and P through out the period of crop growth.

20. The grain yield did not show difference with the sources during both the crops. All the four sources did not show any significant difference. But the levels of phosphorus were found to have an impact on yield.

21. The straw yield was comparable for different sources in laterite and Kuttanad soils during 1st crop. While in 2nd crop the TRP gave the highest yield for Kuttanad soil and was comparable with other sources in laterite soils.

22. With increase in the level of application there was increase in yield of grain and straw.

23. The residual effect of applied P source was found to be maximum for TRP followed by MRP and DAP. The residual effect was prominant only in Kuttanad soil.

24. Comparison of the different sources with SSP(P_2+P_2) treatment showed significant difference in P uptake, straw and grain yields during second crop. The source with the highest residual effect ie. TRP showed 20 per cent reduction in yield compared to SSP(P_2+P_2) treatment.

References

REFERENCES

Anderson, D.L., Kussow, W.R. and Gorey, R.B., 1985. Phosphate rock dissolution in soils: Indication from plant growth studies. *Soil Sci. Soc. Am. J.* 49:918-925

Anonymous, 1993. *Package of Practices Recommendations*. Kerala Agric. Univ., Thrissur

Anonymous, 1996. Stragies for sustaining higher rice productivity. *Fert. News* 41:13

Atanansu, N. 1971. A comparative study on the effect of water and citrate soluble phosphatic fertilizers on yield and P uptake on tropical and subtropical soils. *J. Indian Soc. Soil Sci.* 19:119-127

Banerjee, B.K. 1979. Characterisation of rockphosphate. *Phosphorus in soils, crop and Fertilizers. Bull Indian Soc. Soil Sci.* 12:149-160

Biswas, A.K. and Narayanaswami, G. 1995. Release of phosphorus from different rockphosphate by incubation with pyrites. *J. Indian Soc. Soil Sci.* 43:394-399

Chakraborty, T., Majumber, S.K. and Bhattcharjee, R.K. 1986. Rock phosphate as direct fertilizer for wheat. *Nationall Seminar on Rock phosphate in Agriculture*, held at TNAU, Coimbatore, p.102-108

* Chang, S.C. and Chu, W.K. 1961. The fate of soluble phosphate applied to soils. *J. Soil Sci.* 12:286-293

Chaudhary, M.L. and Mishra, B. 1980. Factors affecting transformation of rockphosphate in soils. *J. Indian Soc. Soil Sci.* 28:295-301

Chien, S.H., Leon, L.A. and Te Jeda, H.R. 1980. Dissolution of North Carolina phosphate rock in acid Colombian soils as related to soil properties. *Soil Sci. Soc. Am. J.* 44:1267-1271

Cooke, G.W. 1978. Experimental work in the United Kingdon on the agricultural value of rock phosphates. *Seminar on Phosphate Rock for Direct Application*. IFDC, Muscle Shoals, Alabama, p.304-324

Dash, R.N., Mohanty, S.K. and Patnaik, S. 1980. Efficiency of indigenous rock-phosphates for rice. Annual Report, CRRI, Cuttack, p.100-102

Dash, R.N., Mohanty, S.K. and Patnaik, S. 1988. Influence of relativity of phosphate rocks on phosphorus utilization by Dhaincha (*Sesbania aculeate*). *J. Indian Soc. Soil Sci.* 36:375-378

Debnath, N.C. and Hajra, J.N. 1972. Inorganic transformation of added phosphorus in soil in relation to soil characteristics and moisture. *J. Indian Soc. Soil Sci.* 20:327-335

D'Souza, M.V., Shammukappa, D.R., Jayarama and Naidu, R. 1995. Gafsa rock-phosphate and its use in coffee soils as a phosphorus source. *Proceedings of National Symposium on the Use of Rockphosphate for Sustainable Agriculture*. Univ. Agric. Sci., Bangalore, p.225-229

Dwivedi, G.K., Dwivedi, M. and Pal, S.S. 1989. Relative efficiency of mussoorie rockphosphate and single super phosphate with lime on yield and phosphorus availability in maize-wheat and soybean-wheat relations in an inceptisol. *J. Indian Soc. Soil Sci.* 37:61-65

Geethakumari, V.L. and Mohammedkunju, U. 1984. Growth and yield of cowpea as influenced by different methods and source of phosphorus application. *Agric. Res. J. Kerala*, 22:87-90

Ghosh, S.K., Das, D.K. and Deb, D.L. 1973. Physical, chemical and minerological characterisation of Kari soils from Kerala. *Proc. Symp. on Acid Sulphate and Other Acid Soils of India*, Trivandrum, Organiser ISSS, p.25-28

Girish, M.A., Krishnappa, A.M., Siddaramappa, R. and Viswanath, D.P. 1995. Performance of Tunisia rockphosphate (Gafsaphos) under paleustults of Mudigere in Karnataka. *Proceedings of National Symposium on the Use of Phosphate Rock for Sustainable Agriculture*, Univ. Agric. Sci., Bangalore, p.237-342

Gopalakrishna, K., Devi, S.L., Nanjappa, H.V. and Mannure, G.R. 1986. Relative efficiency of different source of phosphorus on cereal based crop sequences. *Natl. Seminar on Rockphosphate in Agriculture* held at TNAU, Coimbatore, p.18-29

Gupta, A.P., Khanna, S.S. and Tomar, N.K. 1983. Residual efficiency of different phosphatic fertilizers by paddy (*Oryza sativa*) as influenced by levels of $CaCo_3$. *Trop. Pl. Sci. Res.* 1:43-47

Gupta, M.L. and Nayan, K. 1975. Transformation of soil inorganic phosphorus in red soils. *J. Indian Soc. Soil Sci.* 23:61-65

Hellums, D.T., Chien, S.H. and Touchton, J.T. 1989. Potential agronomic value of calcium in some phosphate rocks from South America and West Africa. *Soil Sci. Soc. Am. J.* 53:459-462

Hesse, P.R. 1971. *A Text Book of Soil Chemical Analysis*. Chemical Publishing Co. Inc., New York, p.106-125

*Hsu, P.H. and Jackson, M.L. 1960. Inorganic phosphate transformations by chemical weathering in soils as influenced by pH. *Soil Sci.* 90:16-24

Jackson, M.L. 1958. *Soil Chemical Analysis*. Prentice Hall Inc., U.S.A., p.498

Jacob, S. 1987. Characterisation of laterite soil from different parent materials in Kerala. M.Sc.(Ag.) thesis, Kerala Agric. Univ., Thrissur

Jaggi, R.C., Dixit, S.P. and Bhardwaj, S.K. 1995. Nutrient uptake and tuber yield of potato as influenced by phosphate and FYM in and acid alfisol. *J. Indian Soc. Soil Sci.* 43:391-394

Jaggi, T.N. and Luthra, K.L. 1983. Mussoorie phosphate rock as an economic but effective source of fertilizer phosphorus. *Ind. J. Agric. Chem.* 15:41-49

Jose, A.I. 1973. Studies on soil phosphorus in the South Indian soils of neutral-to-alkaline reaction. Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore, p.444

Kadrekar, S.B. and Talashilkar, S.C. 1977. Efficiency of applied phosphorus in relation to its saturation in laterite soils of Maharashtra. *Indian J. Agric. Chem.* 15:95-101

Kadrekar, S.B., Chavan, A.S., Talashilkar, S.C., Dhane, S.S. and Powar, S.L. 1983. Utility of rock phosphates to rice under submerged condition in lateritic soils of Maharastra. *Indian J. Agric. Chem.* 15:95-108

Kanabo, A.K. and Gilkes, R.J. 1988. The effect of moisture regime and incubation period on the dissolution of North Carolina phosphate rock in soil. *Aust. J. Soil Res.* 26:153-163

* Kanwar, J.S. and Grewal, J.S. 1958. Behaviour of different phosphatic fertilizers in Punjab soils. *J. Indian Soc. Soil Sci.* 6:215-222

Karanth, K.V. 1987. Utilization of mussoorie rockphosphate in acid soils of Maharastra. *Semi. Proc. on the use of rockphosphate in West Coast soils.* p.64-65

Khanna, S.S. and Chaudhury, M.L. 1979. Residual and cumulative effect of phosphatic fertilizers. Phosphorus in soil crops and fertilizers. *Bull. Indian Soc. Soil Sci.* 12:142-149

Koshy, M.M. and Thomas, P. 1972. *Soils of India and their Management.* Fertilizer Association of India, New Delhi, p.208-224

Krishnakumar, P.G. 1991. Taxonomy and fertility capability assessment of the soils in command areas of Edamalayar Project. M.Sc.(Ag.) thesis, Kerala Agric. Univ., Thrissur

Krishnappa, A.M., Krishnappa, M., Rao, B.V.V. and Perur, N.G. 1979. Residual effects of phosphates, phosphorus in soils, crops and fertilizers. *Bull. Indian Soc. Soil Sci.* 12:485-489

Krishnappa, M. 1987. Relative efficiency of different phosphatic fertilizers in relation to phosphorus availability and yield of paddy. *Seminar Proc. on the Use of Rockphosphate in West Coast soil*, p.39-42

Kulkarni, K.R. 1980. *Summary report.* All India Co-ordinated Agronomic Research Project, ICAR, Bangalore

Kumaraswamy, K. 1995. Efficacy of Mussoorie Rock Phosphate as phosphatic fertilizer for sugarcane. *Proceedings of National Symposium on the Use of Phosphate Rock for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore, p.71-75

Kumaraswamy, K. and Sreeramulu. 1992. Transformation of phosphorus in rice soil under different soil water regimes. *J. Indian Soc. Soil Sci.* 40:54-58

* Lehr, J.R. and McChellan, G.M. 1972. A revised laboratory reactivity scale of evaluating phosphate rocks for direct application. *National Fertilizer Centre,* TVA Bull. 5:43

Luthra, K.L., Sohu, S.K. and Awasthi, P.K. 1983. Role of rockphosphate in present day agriculture. *Indian agric. Chem.* 15:13-28

Mahapatra, I.C. and Patrick, W.H.(Jr.) 1969. Inorganic phosphate transformation in waterlogged soils. *Soil Sci.* 107:281-288

Mahimairaja, S. and Perumal, R. 1995. Effectiveness of Mussoorie Rock Phosphate with and without organics and biofertilizers in rice pulse cropping system. *Proceedings of National Symposium on the Use of Phosphate Rock for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore, p.126-132

Mandal, L.N. and Khan, S.K. 1972. Release of phosphorus from insoluble phosphatic materials in acidic low land rice soils. *J. Indian Soc. Soil Sci.* 20:19-25

Mandal, L.N., Khan, S.K. 1975. Influence of soil moisture regimes on transformation of inorganic P in rice soils. *J. Indian Soc. Soil Sci.* 23:31-37

Manjaiah, K.M., Channal, H.T. and Satyanarayana, T. 1995. Influence of rock-phosphate on nutrient dynamics at different stages of groundnut. *Proceedings of National Symposium on the Use of Phosphate Rock for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore, p.76-81

Manjunatha, K.V. and Shankar, M.A. 1995. Effect of phosphatic sources on growth and yield of mulberry. *Proceedings of National Symposium on the Use of Phosphate Rock for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore, p.82-86

Marwaha, B.C. and Kanwar, B.S. 1981. Utilisation of general rockphosphate as a direct phosphatic fertilizer a review. *Fert. News.*, p.10-20

Mathew, J.K. 1979. Evaluation of available phosphate reserve of soil by chemical methods, M.Sc(Ag) theses, Kerala Agric. Univ. Thrissufr.

Mathew, R.P. 1985. Suitability of rockphosphate for direct application in acid rice soils of Kerala. M.Sc.(Ag.) thesis, Kerala Agric. Univ., Thrissur

Mathur, B.S., Jha, K.K., Lal, S. and Srivastava, B.P. 1979. Utilization of phosphate rock deposite in acid soils of Chotanagpur, Bihar. *Phosphorus in soils, Crops and Fertilizers. Bull. Indian Soc. Soil Sci.* 12:505-515

Mehrotra, C.L. 1968. Relative efficiency of rockphosphate as compared to super phosphate. *Fert. News.*, 11:10-12

Minhas, R.S., Kich, M., 1974. Comparative availability of super phosphate and rockphosphate and their distribution on different inorganic phosphate fractions after adding heavy doses. *Fert. News.*, 19:12-16

Mishra, S.- and Gupta, R.P., 1978. Evaluation of mussoorie rockphosphate as a phosphorus sources for maize on acid soils of Kumaon hills. *Indian J. agric. Sci.*, 48:239-244

Motsara, M.R. and Datta, N.P. 1971. Rock phosphate as a fertilizer for direct application in acid soils. *J. Indian Soc. Soil Sci.*, 19:107-113

Nair, K.M. 1978. Studies on increasing the efficiency of rock phosphate in Kerala soils. M.Sc.(Ag.) thesis, Kerala Agric. Univ., Thrissur

Nair, K.M., Padmaja, P. 1982. Efficiency of primed rockphosphate for grain production in rice. *Agric. Res. J. Kerala* 20:31-36

Natarajan, K., Rajagopal, C.K. and Manickam, T.S. 1983. A study on mussorie rockphosphate as a straight phosphatic fertilizer. *Indian J. Agric. Chem.* 15:117-123

Pandurangaiah, K., Badiger, M.K. and Hanumappa, P. 1986. The comparative study on the use of mussoorie rockphosphate and single super phosphate on the yields of crops. *Proc. Natl. Seminar on Rockphosphate in Agriculture* held at Coimbatore, p.213-218

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agric. Workers* 4th ed. Indian Council of Agricultural Research, New Delhi, p.58-62

Patil, C.V., Satyanarayanan, C. Prakash, S.S. and Yeledhalli, N.A. 1995. Response of maize to direct and residual phosphorus from different sources. *Proceedings of National Symposium on the Use Phosphate Rock for Sustainable Agriculture*. Univ. Agric. Sci., Bangalore, p.5-9

Poojari, B.T., Krishnappa, K.M., Sharma, K.M.S., Jayakumar, B.V. and Panchakshariah, S. 1987. Efficiency of rockphosphate as a source of phosphorus in rice-groundnut cropping system in coastal Karnataka. *Semi. Proc. on the Use of Rock Phosphate in West Coast Soils.* p.58-65

Prakash, H.C., Badrinath, Krishnappa, A.M., Srinivasamurthy, C.A., Rao, B.K. and Siddaramappa, R. 1987. Influence of different sources of phosphorus with organic amendments on paddy. *Seminar Proc. on the Use of Rock phosphate in West Coast soils*. p.26-28

Ponnamperuma, F.N. 1955. Chemistry of submerged soil in relation to the growth and yield of rice. Ph.D. thesis, Cornella Univ.

Prasad, B. and Dixit, R.A. 1976. Fertilziers containing partially water or no water soluble phosphate. ICAR, New Delhi

* Puri, D.N. 1969. Groundnut responds well to super phosphate. *Fert. News*. 14:46-47

Rajkhowa, D.J. and Baroova, S.R. 1996. Relative agronomic efficiency of Udaipur rockphosphate on acid inceptisol. *J. Indian Soc. Soil Sci.* 44:278-281

Ramaswamy, S. and Arunachalam, G. 1983. Influence of Massorriephos in the main and residual crop of paddy in neutral soils. *Indian J. Agric. Chem.* 15:125-139

Raychaudhuri, S.P. 1980. Phosphorus and potasic fertilizers and their management. Soil Fertility - Theory and Practice (ed. Kanwar, J.S.) ICAR, New Delhi, p.371-398

Regi, P.M. and Jose, A.I. 1986. Phosphate rock for direct application in rice soils of Kerala. *Natl. Seminar on Rock phosphate in Agriculture* at TNAU, Coimbatore, p.93-101

Sadanandan, A.K. and Hamza, S. 1995. Use of phosphate rocks for sustainable spices production in India. *Proceedings of National Symposium on the use of Phosphate Rock for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore, p.42-48

Sahu, S.K. and Pal, S.S. 1983. Efficient utilization of rockphosphate in acid red soil (Inceptisol) under rice wheat farming system. *Indian J. Agric. Chem.* 45:57-94

Sarangamath, P.A.,Shinde, B.N. and Patnaik, S. 1975. Efficiency of water soluble, citric acid soluble and insoluble phosphate fertilizers for rice in different soils. *Indian J. Agric. Sci.* 15:106-111

Sarangamath, P.A., Shinde, B.N. and Patnaik, S. 1977. Effect of application of water and citrate soluble and P fractions and its relation with available P in different soils. *Indian J. Agric. Sci.* 47:309-313

Sharma, C.M. and Sangrai, A.K. 1993. Distribution and transformation of Indigenous rock phosphates in an acid alfisol. *J. Indian Soc. Soil Sci.* 41:447-451

Sharma, R.C., Grewal, J.S. and Sud, K.C. 1976. Relative suitability of different phosphatic fertilizers for potato on brown hill soils of Simla. *J. Indian Soc. Soil Sci.* 24:95-97

Sharma, P.K., Verma, S.P. and Bhumble, D.R. 1980. Transformation of added P into inorganic P fractions in some acid soils of Himachal Pradesh. *J. Indian Soc. Soil Sci.* 28:450-454

Shinde, B.H., Sarangamath, P.A. and Patnaik, S. 1978. P transformations from rockphosphate in acid soils and measures for increasing their efficiency for growing rice (*Oryza sativa*). *Pl. Soil* 49:449-459

Shivanna, M., Mruthunjaya, S. and Suseeladevi, L. 1995. Influence of maton rockphosphate and its combinations on Bray-1 P fraction in some soils of Karnataka. *Proceedings of National Symposium on the Use of Rock phosphate for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore

Shyamala, V.K., Suresh, P.R., Philip, V., Sudhakumari, B. and Punnoose, K.I. 1995. Comparison of dissolution pattern of rock phosphates and their evaluation in seedling nurseries of rubber. *Proceedings of National Symposium on the Use of Phosphate Rock for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore, p.182-185

Singaram, P. 1995. Effectiveness of rockphosphate and rockphosphate/super phosphate mixture for crops in a calcareous soil. *Proceedings of National Symposium on the Use of Phosphate Rock for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore, p.25-28

Singh, D. and Datta, N.P. 1973. Effect of particle size of rock phosphates on their fertilizer value for direct application to the soil. *J. Indian Soc. Soil Sci.* 21:315-318

Singh, D. and Datta, N.P. 1974. Saturation of soil with respect to phosphorus in relation to the efficiency of utilization of applied phosphorus from indigenous phosphate rocks. *J. Indian Soc. Soil Sci.* 22;125-129

Singh, D., Mannikar, N.D. and Srivas, N.C. 1976. Phosphate fertilizer value of indigenous rock phosphates and super phosphate for lucerne and their residual effect on guar. *J. Indian Soc. Soil Sci.* 24:186-191

Singh, D., Mannikkar, N.D. and Srivas, N.C. 1979. Comprative performance of indigenous rock phosphates and superphosphate in a forage legume cropping pattern. *J. Indian Soc. Soil Sci.* 27:170-173

Singh, R.K., Sengupta, M.B. and Gosami, N.N. 1988. Role of phosphate in saline soil in reaction to soil properties and crop growth. *J. Indian Soc. Soil Sci.* 36:765-770

Singh, R.S. and Ram, H. 1977. Effect of organic matter on the transformation of inorganic phosphorus in soils. *J. Indian Soc. Soil Sci.* 25:118-121

Singh, S. and Singh, S.B. 1975. Effect of waterlogging and organic matter on inorganic P fractions of soils. *J. Indian Soc. Soil Sci.* 24:88-90

Srinivasamurthy, C.A., Kumaraswamy, S., Badrinath, M.S. and Gowda, M.R. 1995. Studies on the effect of lime of application of rock phosphates on transformation and availability of phosphorus in low pH soils of Karnataka. *Proceedings of National Symposium on the Use of Phosphate Rock for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore, p.173-181

* Subbaiah, B.V. and Asija, C.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.* 25:259-260

Subehia, S.K. and Minhas, R.S. 1993. Phosphorus availability from Udaipur rockphosphate as influenced by different organic amendments. *J. Indian Soc. Soil Sci.* 41:96-99

Subramanian, C.K. and Manjunath, K.J. 1983. Response to mussoorie phosphate in Karnataka soils. *Indian J. Agric. Chem.* 15:81-86

Sushama, P.K., Suseeladevi, L. and Gopinathan, R. 1995. Phosphorus transformations in waterlogged coastal laterites. *Proceedings of National Symposium on the Use of Phosphate Rock for Sustainable Agriculture.* Univ. Agric. Sci., Bangalore, p.191-196

Tiwari, K.N., Pathak, A.N., Ram, N., Shukla, B.R., Upadhyay, R.L., Prasad, L. and Gangwar, B.R. 1979. Effect of rockphosphate, superphosphate and their mixtures on yield and phosphorus uptake by crops in soils of Uttar Pradesh. *Phosphorus in Soils, Crops and Fertilizers. Bull. Indian Soc. Soil Sci.* 12:527-539

Varadan, K.M., Sathyanarayana, T. and Havanagi, G.V. 1977. Some phosphate studies on Ragi. *J. Indian Soc. Soil Sci.* 25:388-390

Varghese, T., Thampi, P.S. and Money, N.S. 1970. Some preliminary studies on pokali saline soils of Kerala. *J. Indian Soc. Soil Sci.* 18:65-69

Venugopal, V.K. 1969. Cation exchange studies in Kerala soils. M.Sc.(Ag.) thesis, Kerala Agric. Univ., Thrissur

Vijayan, A.P. 1993. Behaviour of phosphorus in selected soil types of Kerala. M.Sc.(Ag.) thesis, Kerala Agric. Univ., Thrissur

* Wright, B.C. and Deech, M. 1960. Characterization of phosphate reaction products in acid soils by the application of solubility criteria. *Soil Sci.* 90:32-43

*Originals not seen

APPENDIX

Composition of Fertilizer used

Source	Total P_2O_5	Water soluble P_2O_5	Citrate soluble	Sulpur (in %)	Calcium
1. Gafsa	28.0	-	14.00	3.2	48.5
2. SSP	16.5	15.851	1.142	-	38.2
3. DAP	46.0	45.2	-	-	-
4. MRP	20.31	-	4.36	-	28.2

SUITABILITY OF TUNISIA (GAFSA) ROCKPHOSPHATE FOR DIRECT APPLICATION IN ACID RICE SOILS OF KERALA

By

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ABSTRACT OF A THESIS

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ABSTRACT

A study was conducted at College of Horticulture during the period 1993-95 so as to assess the suitability of Tunisia rockphosphate for direct application in acid rice soils of Kerala as a source of P compared with single superphosphate (SSP) diammonium phosphate (DAP) and Mussoorie rockphosphate (MRP). In addition to above sources a control treatment (with no P fertilizer) and another treatment with SSP of the rate of 45 kg P_2O_5 ha^{-1} given twice (conventional practice) were also included. The P release from all the sources was monitored with an incubation experiment. In order to evaluate the residual effect of fertilizers two continuous pot culture experiments were undertaken using Triveni variety of rice. The acids soils of Kerala namely Kuttanad alluvium and laterites were used for the study.

The soils showed variation in pH with submergence irrespective of the treatments. The different nutrients like N, K, Ca, Mg were higher in Kuttanad soil compared to laterite soil and was found to decrease with period of incubation. The available phosphorus content gradually increased with period of incubation and reached a peak at 60 to 90 days for water soluble phosphates and 90th to 120th day for rockphosphates. Comparing the two extractants, Mathew's triacid extracted more available P than that of Bray solution in both soil types. In general, Kuttanad alluvium recorded higher content of available nutrient as compared to laterite. The extent of fixation of P was higher in Kuttanad soil with Fe-P as dominant fraction while in laterite soil it was Al-P which was dominated.

While evaluating pot culture experiment the different nutrients showed a decrease in soil and increase in uptake with the advancement of crop. Of the different soils Kuttanad alluvium registered a higher yield compared to laterite soil. It was found that TRP registered a comparable uptake of phosphorus and gave a comparable yield of grain and straw with other sources in laterite and Kuttanad alluvium. The residual effectiveness of rockphosphate was found to be higher than that of water soluble sources and TRP gave the highest. Of the two different type of soils Kuttanad soil showed a higher residual effectivenes and resulted in higher yield for 2nd crop while laterite soil registered a lower yield.