# UTILIZATION OF PHOSPHORUS FROM GREEN MANURE BY RICE


By

**PUSHPA JOSEPH**


**THESIS**

Submitted in partial fulfilment of the requirement for the degree of

## Master of Science in Agriculture


Faculty of Agriculture
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## DECLARATION

I hereby declare that the thesis entitled '**Utilization of Phosphorus from Green Manure by Rice**' is a bonafide record of research work done independently 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.

Vellanikkara

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# CERTIFICATE

Certified that this thesis entitled '**Utilization of Phosphorus from Green Manure by Rice**' is a record of research work done independently by **Ms.Pushpa Joseph** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.


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# CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms.Pushpa Joseph**, a candidate for the degree of **Master of Science in Agriculture** with major in **Agronomy**, agree that the thesis entitled '**Utilization of Phosphotus from Green Manure by Rice**' may be submitted by Ms.Pushpa Joseph, in partial fulfilment of the requirement for the degree.

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*PUSHPA JOSEPH*

*Dedicated to my*
*beloved grand parents*

## CONTENTS

## LIST OF TABLES

## LIST OF ILLUSTRATIONS

# Introduction

# INTRODUCTION

In recent years there is tremendous renewal of interest in the age old practice of green manuring not only from the point of view of sustaining soil productivity but also the energy crises and escalating prices of fertilizers. The unbalanced and continuous use of fertilizers in the intensive cropping system is leading to decreases in crop yields, imbalance of nutrients in soil and adverse effect on soil physical and biological properties. The integrated use of organic manures, biofertilizers and chemical fertilizers will help to maintain optimum crop yields and long term soil productivity. The crop yields are higher when both chemical and organic sources are used as compared to either chemical fertilizers or organic manures.

There is vast scope for increasing nutrient supply from the soil through organic manures, green manures, biofertilizers and adoption of proper cropping systems. There is however not much scope for reducing the consumption of chemical fertilizers since the level of crop productivity is not only to be maintained, but is to be increased in coming years which is presently not possible without the use of chemical fertilizers. Hence the organic sources of nutrients should be considered as a supplement to chemical fertilizers and not as their substitutes.

Phosphorus is one of the essential plant nutrients and often its deficiency becomes a major constraint for successful crop production. However fertilizer phosphorus is a costly input and its relative poor utilization by individual crop and fixation-immobility phenomenon in the soil are some of the principal factors which have prompted attention towards most efficient management of fertilizer phosphorus.

The incorporation of green manures to soil influence P uptake by plants in two ways, (1) by the direct contribution of P contained in green manures and (2) by the indirect effect on the availability of inorganic P present in the soil and applied as fertilizer. A sound knowledge of the extent of substitution of inorganic P fertilizer by green manure and influence of green manure on availability of applied and native soil P may help to have a modified schedule of P application to rice after a legume.

The present study was undertaken (i) to assess the contribution of phosphorus released from labelled green manure to the P nutrition of rice, (ii) to study the effect of incorporation of green manure on the utilization of applied fertilizers and native soil phosphorus and (iii) to investigate the effect of incorporation of green manure on the dry matter yield of rice.

# Review of Literature

# REVIEW OF LITERATURE

The role of green manure crops in improving soil fertility has been well recognized and this practice is prevalent in countries like India, China, Philippines and Thailand. The advantages of green manuring include increases in organic matter content and available plant nutrients and improvement in the microbiological and physical properties of the soil. The role of green manures in supplying plant nutrients, particularly N is well documented. Apart from the N addition, a well grown green manure crop can add phosphorus equivalent to 75 to 100 kg of superphosphate. Several workers have reported a solubilizing effect of decomposing organic matter on soil phosphorus. This review focuses on research on green manures in improving soil fertility and properties of wet land rice soils with special reference to the availability of phosphorus.

## 2.1 Green manuring in rice-based cropping systems

Green manuring is a cheap and feasible alternative for substituting inorganic fertilizers. Rice based cropping system is particularly amenable for green manuring (Abrol and Palaniappan, 1988). Majority of rice-growing areas in India were applied with green manure regularly in the past. Many factors have limited wider acceptance of green manuring in rice culture. The most important factor is that the farmers are reluctant to use one season entirely for raising a green manure crop which has neither cash nor food value (John *et al.*, 1992). The use of green manures received a further set back with the increase in cropping intensity and the low cost and ready availability of fertilizers in the last several decades; but with the advent of high yielding cultivars, increases in the cost of fertilizers, and the concern for pollution and conservation of energy, green manures have again become very popular (Kulkarni and Pandey, 1987).

### 2.1.1 Green manure crops

The use of green manures in rice-based cropping systems is primarily found in irrigated environments. The identification of flood tolerant, stem nodulating legumes has increased research interest in green manures for environments prone to waterlogging (Rinaudo *et al.*, 1988).

Ladha *et al.* (1988) have listed several characteristics that makes a leguminous green manure ideal for wet land rice ecosystem. Although several legume species have been used as green manure crops in different countries, it has been difficult to find one that possesses all the needed characteristics. More often, green manure crops are sown and turned under in the same field. Interplanting of green manure crops with wet land rice is also practiced. Both root as well as stem nodulating leguminous crops are used for *in situ* incorporation.

#### 2.1.1.1 Green manure crops for *in situ* incorporation

##### 2.1.1.1.1 Root nodulating crops

Sunnhemp (*Crotolaria juncea*) and *Sesbania aculeata* Syn. *cannabina* are the most widely grown green manure crops in India (Abrol and Palaniappan, 1988; Garrity and Flinn, 1988). Sesbania species are well adapted for use as a green manure before rice because of their ability to withstand waterlogging and flooding, to grow on fine textured soils and to tolerate soil salinity (Evans and Rotar, 1987). Sunnhemp is less tolerant to salinity, acidity and excess water than *S. aculeata* but it performs better in low rainfall and limited soil moisture areas (Vachhani and Murty, 1964; Panse *et al.*, 1965). Cluster bean (*Cyamopsis tetragonoloba*) and cowpea (*Vigna unguiculata*) are fairly drought tolerant and can be used as both vegetable and green manure crop (Singh *et al.*, 1981). In South India, *Tephrosia purpurea* under drought conditions and pillipesara (*Phaseolus trilobus*) in erosion-prone areas were found promising (Palaniappan *et al.*, 1990). *Sesbania speciosa* can grow as a perennial plant and is more drought tolerant than *S. aculeata* (Patnaik *et al.*, 1957).

Milkvetch (*Astragalus sinicus*) is the chief green manure grown in winter season in China. *Sesbania cannabina* is an important summer green manure. *Aeschynomene indica* has been introduced as a green manure for late rice in China (Liu, 1988).

Green manure crops commonly used in Japan are *Astragalus sinicus*, *Glycine max* and *Medicago denticulata* (Watanabe, 1984). In Thailand *S. aculeata*, *C. juncea*, *Cajanus cajan* and *S. rostrata* are the important green manure crops for wetland rice (Arunin *et al.*, 1988). Important green manures used in Philippines are *S. cannabina*, *S. rostrata*, *V. unguiculata*, *V. radiata* and *C. juncea* (Morris *et al.*, 1986, 1989; Meelu and Morris, 1988).

2.1.1.1.2 Stem nodulating crops

Among the stem-nodulating legumes, *S. rostrata* and *Aeschynomene afraspera* have received particular attention. These are characterized by profuse stem nodulation, fast growth and more active nitrogen fixation than most root nodulating legumes. Also, these are less affected by excess water than root-nodulated ones and are able to nodulate and fix nitrogen with levels of nitrogen high enough to inhibit root nodulation (Rinaudo *et al.*, 1988). The stem-nodulating legumes usually show a high sensitivity to climatic variations, particularly to temperature and photoperiod (Dreyfus *et al.*, 1985). *S. rostrata* grows well in saline and alkaline soils. Although *S. rostrata* has performed better in south India (Palaniappan *et al.*, 1990) and Thailand, it did not do well in north India (Mahapatra and Sharma, 1989).

2.1.1.2 Green leaf manures

Green leaf manures are preferred when raising green manure crops *in situ* is not possible, especially in areas with limitations such as lack of irrigation water and due to loss of main crop growing season. Woody species of the genera Glyricidia, Leucaena and Sesbania, which are widely used in food crop systems in the tropics, are the important green leaf manures. Some other legumes that produce large amounts of green matter for incorporation in wetland rice include *Aeschynomene americana, Phaseolus trilobus* and *Flamingo congestis* (Vachhani and Murty, 1964; Brewbaker and Glover, 1988; Nair, 1988). Species of sesbania (mostly *S. sesban*) are used for *in situ* green manure as well as green leaf manure (Arunin *et al.*, 1988; Palm *et al.*, 1988; Rao *et al.*, 1989).

Samad and Sahadevan (1952) and Raju (1952) have listed a number of tree species and other plants used extensively for green leaf manure in the southern Indian states. Some of the important ones are *Cassia auriculata, Melia azadirachta, Calotropis gigantea, Tephrosia purpurea, T. candida, Glyricidia maculata* and *Cassia tora*. Wild legumes available from the uncropped land and forest area such as *Tephrosia purpurea* and *T. pumila* can also be used as green manure in wet land rice (Singh, 1971).

2.1.1.3 Time of incorporation of green manures

Traditionally, green manures were grown in fallow fields and incorporated two to four weeks before sowing of the following crop. This practice is, however, not feasible in the context of intensive agriculture when there is a fallow period of only 40-60 days before transplanting of rice. Iso (1954) reported that the effectiveness of green manure was hindered by too early and too late ploughing-in before the transplanting of rice. The best time to plough-in would be 15 days before transplanting. Joachim (1940) suggested that green manure crops should be incorporated at the time of puddling, so that larger quantities of $NH_4^+$-N are made available to the plant at the period of active crop growth. While studying the possibility of green manuring in rice-based cropping systems, Beri *et al.* (1989) showed on the basis of yield response, that a 2-week delay between incorporation of green manure and transplanting of rice was not only unnecessary, but also disadvantageous. Williams and Finfrock (1962) and Vachhani and Murty (1964) had demonstrated that green manure could be incorporated even at the time of transplanting rice seedlings. The reason for low efficiency of green manure when incorporated for a longer period before transplanting rice or flooding could be the loss of green manure N released during aerobic decomposition through ammonia volatilization, nitrification - denitrification and leaching after flooding of rice fields (Williams and Finfrock, 1962; Chapman and Myers, 1987 and Ishikawa, 1988).

Swarup (1987) showed in field experiments that allowing decomposition of sesbania green manure for one week under flooded conditions in sodic soils significantly improved rice yields over simultaneous incorporation and transplanting of rice, possibly through improvement of physico-chemical properties of sodic soils. Wen (1984) reported that it is better to turn under green manure crop about 15 days before transplanting rice seedlings so that plants do not suffer damage from the decomposition products of the green manure. Increases in paddy yield with soil incorporation of green manure rather than surface application were reported by van de Goor (1941) in Indonesia.

2.1.1.4 Application rate of green manure

High amounts of green manure can be unfavourable, even harmful, to plant growth because the nutrients are released faster and are more concentrated.

The result is ineffective tillering and lodging. Through anaerobic decomposition of excessive organic matter added through green manure, the soil redox potential drops, harmful substances such as organic acids are formed and rice plant roots suffer injury. Singh *et al.* (1988) observed a progressive increase in rice yield with increasing rates of *S. aculeata* upto 35 t/ha (fresh matter) on coarse textured soils. From the data reported by Reddi *et al.* (1972) it was found that 28.5 t/ha of Glyricidia green leaf manure was required to obtain maximum yield of rice.

### 2.1.2 Green manuring and productivity of rice

In Taiwan, Lin *et al.* (1951) used black bean as green manure and got an yield increase of 10 per cent over the control. Green manuring of dhaincha equivalent to 45 kg N/ha gave 20 per cent more yield than the control and the response was 8.8 kg grain per kg N (Rao and Ghosh, 1952). Smith *et al.* (1962) reviewed the early work and concluded that green manuring with *S. aculeata* and sunnhemp increased rice yield by 21 to 44 per cent. Coarse textured soils low in organic matter and nitrogen showed greater response to green manuring than the high-fertile soils. In a large number of field experiments in Japan, Yamazaki (1957) found that incorporation of 22.5 t/ha of milkvetch increased rice yield by 1.9 t/ha (82.6 per cent over control). In China, Gu and Wen (1981) observed that in low fertile soils, rice yields with green manuring increased by 78 per cent compared with 21.6 per cent in the high fertile soils. In the United States, Westcott and Mikkelsen (1987) found that application of 120 kg N/ha through vetch green manure increased rice yield by 2.4 t/ha (43.3 per cent) over the control. Zoysa *et al.* (1990) reported that green leaf manures incorporated before transplanting can significantly increase rice yields.

Smith *et al.* (1987) presented three possibilities for understanding the yield responses of wetland rice to green manuring. The first is that there is yield benefit from the green manure at low N rates, suggesting that the only significant effect of the green manure is to increase N supply to the rice crop. Secondly green manure provides benefits beyond N supply. This can be found in the works of Chatterjee *et al.* (1979), Tiwari *et al.* (1980), Rekhi and Meelu (1983), Beri *et al.* (1989), John *et al.* (1989) and many others. The beneficial effects may include more favourable physical, chemical and biological conditions of the soil amended with green manure. A third case exists when sufficient N fertilizers are applied and rice yields following green manuring are lower than those with no green manuring. The yield reduction could be due to excessive N causing lodging in rice, root toxicity due to accumulation of toxic chemicals released from green manure (Ishikawa, 1988) or Fe and Mn toxicity due to increased reduction in the presence of green manure (Katyal; 1977).

### 2.1.3 Green manuring on fertility and chemical properties of soil

Green manure by contributing organic matter may prevent leaching loss, render unavailable forms of nutrients into available forms and increase permeability and drainage capacity of soil besides ensuring steady supply of N throughout the growth period (Rao *et al.*, 1961). Agboola (1974) highlighted the capacity of green manure to recycle leached plant nutrients. This was accomplished by the absorption of nutrients from the lower depths by roots of legumes and translocation of them to the leaves. van de Goor (1941) stated yield increases following green manuring are not only due to the supply of N but P and K. Several workers have reported a solubilizing effect of decomposing organic matter on P, K and trace elements (Lockett, 1938; Copeland and Merkle, 1941; Shrikhande, 1948). Kute and Mann (1969) and Debnath and Hajra (1972) observed increased K availability and Nagarajah *et al.* (1986) reported an increased soil solution P due to green manuring. This may be due to the release of carbondioxide and weakacids which can act on insoluble soil minerals as reported by Rogers and Giddens (1957) and Agboola (1974) and also due to the release of these minerals from green manure (Nagarajah *et al.*, 1986). Tiwari *et al.* (1980) obtained an increased available NPK content for green manured plots over fallow.

Broadbent and Norman (1946), Chapman and Liebig (1947) and Furoc and Morris (1982) observed an increased rate of decomposition of native organic matter, releasing more nitrogen, when easily decomposible organic matter is added. Consequent upon the decomposition of any organic matter added to soil, the native soil organic matter also begins to decompose and in this process more quantities of nutrients are liberated for use by the plant, this is so called priming action reported by Lohins (1926).

Incorporation of green manures increased porosity, hydraulic conductivity, water-holding capacity and aggregate stability of the soil under rice (Darra *et al.*, 1968; Biswas *et al.*, 1970; Havanagi and Mann, 1970; Jiao *et al.*, 1986; Liu, 1988).

Application of sesbania green manure under waterlogged conditions to acid, non-calcareous and gypsum-amended sodic soils helped in rapidly achieving near neutral soil pH - the commonly observed effect of submerging a soil. Short-term variations in pH due to application of organic manure do not necessarily reflect the overall long-term changes. But may have a marked effect on plant growth (Khind *et al.*, 1987).

Several studies have shown that green manures caused drastic reduction in Eh of waterlogged soils dif- fering in pH, organic matter and easily reducible Fe and Mn contents (Katyal, 1977; Thind and Chahal, 1983; Sadana and Bajwa, 1985; Khind *et al.*, 1987). The magnitude of depression was more pronounced during the early stage of submergence. More reduction has been reported in noncalcareous than the calcareous or sodic soils. In an acid soil with a low organic matter content, green manuring reduced Eh within one to two days of flooding from +200 mV to -200 mV (Yu, 1985).

Katyal (1977) and Sadana and Bajwa (1985) observed higher and sharper peaks of $P_{CO_2}$ in the soil amended with green manure. $CO_2$ produced during decomposition of green manure can directly influence the photosynthetic process of rice plants (Shivashankar and Vlassak, 1978).

Katyal (1977), Sadana and Bajwa (1985) observed that addition of organic matter into soil caused a sharp increase in EC within 14 days of flooding. Sudden increase in EC may cause the death of rice plants.

During decomposition of a green manure several organic compounds accumulate in waterlogged soils. Ishikawa (1988) showed that organic acids can accumulate in significant amounts during decomposition of milkvetch green manure under waterlogged conditions. Organic acids can retard root elongation, restrict nutrient uptake, and reduce shoot weight (Watanabe, 1984).

## 2.2 Effect of green manuring on availability of phosphorus

The incorporation of organic materials into a soil influences the phosphorus uptake by plants in various ways; by the direct contribution of phosphorus contained in green manures, and by the indirect effect on the availability of native P and applied fertilizer P.

### 2.2.1 Mineralization of P from green manures

Legume plants have the ability to utilize insoluble phosphates through the well-developed root system, and when used as green manures, upon mineralization, they release P in the available forms (Gu and Wen, 1981; Bin, 1983). Although the rate of decomposition of green manure is influenced by a number of soil and environmental factors, P mineralization is closely related to the analogous transformation of N (Thompson *et al.*, 1954). Phosphorus release would be most rapid under soil and climatic conditions favouring ammonification (Alexander, 1977).

Phosphorus content of the added organic matter is perhaps the most important factor in regulating the mineralization of P from green manures. Phosphorus content of green manure crops ranges from 0.20 to 0.34 per cent. Green leaf manures have lower P content than leguminous green manures. Phosphorus in residues high in total P was more readily available than P contained in residues low in total P. The critical level above which P mineralization takes place is about 0.2 per cent (Fuller *et al.*, 1956). Kaila (1954) following culture studies, suggested that net mineralization would take place if the phosphorus content of the organic matter exceeded 0.3 per cent.

There are several reports that mineralization of green manure P is dependent on the C:P ratio of the green manure. The critical C:P ratios for P mineralization to occur have, however, been found to vary from as low as 55 to as high as 300 (Barrow, 1960; Hannapel *et al.*, 1964; Blair and Boland, 1978). Enwezor (1976) observed immobilization of P in pea residues (C:P ratio 112) incubated under aerobic conditions for 12 weeks. Phosphorus content and C:P ratio of green manures would depend on age of the green manure crops and their species, and available P status of the soil. The total P content of 6 to 8 week old green manures is generally more than 0.3 per cent. The C:P ratio is around 100. This suggests that during decomposition of green manures, immobilization of soil P should not be expected. The data recorded by Blair and Boland (1978) suggested that P mineralization would be fast from young plants. Fuller *et al.* (1956) found that P contained in shoot material was more readily mineralized than P in roots.

Hundal *et al.* (1993) observed that grain yield and P uptake by rice were the highest in cowpea manured plots followed by dhaincha (*S. aculeata*) and sunnhemp (*Crotolaria juncea*). The higher rate of P release from cowpea treated soil might be due to higher P content (0.43%) and lower C:P ratio (79.6) of cowpea than those of dhaincha (0.35%, C:P ratio 101.4) and sunnhemp (0.38%, C:P ratio 103.5). The P content of added plant residue is the most important factor for determining mineralization (Fuller *et al.*, 1956; Dalal, 1979). Lower C:N ratio is observed in cowpea (11.1) than dhaincha (13.3) and sunnhemp (13.5) and it should be the prime factor for decomposition of green manure (Beri *et al.*, 1989). Soil conditions that favour the rapid decomposition of plant materials such as optimum N, proper aeration, moisture supply and temperature (30-45 °C) also increase the rate of mineralization of phosphorus from added organic matter.

### 2.2.2 Availability of soil P

Several studies have shown that the availability of P can be increased through the incorporation of green manures in to the soil both under laboratory (Blair and Boland, 1978; Singh *et al.*, 1981; Hundal *et al.*, 1987; Yadvinder-Singh *et al.*, 1988) and field conditions (Chatterjee *et al.*, 1979; Yadav and Singh, 1986). The effects of green manure on P transformations in soils are expected to be markedly different under upland and waterlogged conditions. In waterlogged soils, green manuring increases the availability of P through the mechanisms of reduction, chelation and favourable changes in soil pH (Hundal *et al.*, 1987). Soil reduction has been shown to cause marked changes in the amount of plant available P (Ponnamperuma, 1972) and sometimes the P-sorption properties of the soil (Patrick and Khalid, 1974; Khalid *et al.*, 1977). P is more soluble between pH 5.5 and 7.5. The decomposing green manures release organic acids and $CO_2$, both tending to lower the soil pH in neutral and alkaline soils and raise solubility of calcium phosphate.

The effect of green manuring in increasing the availability of P was more pronounced in strongly acidic and alkaline soils than in normal soils. Singh *et al.* (1981) reported that pH changes in an acid soil amended with organic residues were significantly correlated with available P. Saha and Mandal (1979) reported that the significant increase in available P with the addition of organic matter may be attributed to the mineralization of organic P and solubilization of inorganic phosphorus by the action of microorganisms and organic decomposition products.

Prabhakar *et al.* (1972) observed that the addition of *Glyricidia maculata* green manure increased the availability of native soil P by 26 to 37 per cent. Increased availability of P by green manuring in waterlogged soils may also be caused by the increase in labile P or decrease in buffering capacity, but both of these effects are mainly mediated through changes in the iron chemistry of the soils (Singh and Rai, 1973; Hundal *et al.*, 1988).

Dalal (1977) found that organic sources (crop residues, FYM, water hyacinth compost, azolla etc.) affect P availability in soil through mineralization of organic P, liberation of Ca bound P through $CO_2$ formation and complexing of Fe and Al phosphates through increased microbial activity. Kaila (1954) observed an increase in the mineralization of organic and inositol P with increase in pH of the soils due to reduction in sorption of organic P compounds by hydroxides of Fe and Al, thereby subjecting them to mineralization.

The effects of green manure on P-transformations are expected to be smaller under upland than waterlogged conditions. In a laboratory incubation study, Singh (1988) observed that green manuring with sesbania did not appreciably increase the available P content of a sandy loam soil. Singh and Rai (1975) and Bajpai *et al.* (1980) have reported slightly greater build-up of inorganic P due to green manuring in normal than in saline and alkaline soils, possibly because of greater microbial activity in the former. On the contrary, Singh *et al.* (1981) found that the effect of green manuring in increasing the availability of P has been more pronounced in strongly acidic and alkaline than in normal soils.

Rao *et al.* (1962) and Subbiah and Mannikar (1964) have reported that green manure crops could tap subsoil P and make it available to the shallow rooted crops. In the study carried out by Subbiah and Mannikar (1964), sesbania was found to derive about 77 per cent of the fertilizer phosphorus from the subsoil (20 to 30 cm). The soil having the lowest amount of available P had the highest fertilizer P recovery from the subsoil. Deep penetration of the legume rooting system also allows exudates to exist at greater soil depths. Upon decomposition, microbial metabolites of these exudates may serve as solubilizing and/or chelating agents for plant nutrients fixed in the unavailable forms. Yawalkar *et al.* (1972) had summarised from a few studies on P nutrition that greater amounts of phosphorus are taken by legumes and are converted into organic forms. Since P in organic form becomes more easily available after decomposition in soil, application of P to green manure crop indirectly increases the P availability to succeeding crop. Beri and Meelu (1980) suggested that P application to green manure crops in soils of low P status was beneficial to the following rice crop for its higher biomass production, N accumulation and yield, compared to P application to rice. However, Murthy and Vachhani (1964) observed no beneficial effect for P application to rice either directly or indirectly through green manure at CRRI, Cuttack, may be due to high native P status of soil.

### 2.3 Integrated use of organic manures and inorganic P

The crop yields are higher when there is a combined application of manures and chemical fertilizers. This is attributed to the proper nutrient supply as well as creation of better soil physical and biological conditions. The efficiency of fertilizer nutrients also increases when used in combination with organic manures. Stevenson (1982) stated that the combined use of fertilizers with manures can influence the form and availability of P in soils. Organic acids and other microbial product of decomposition may solubilise the insoluble P by interacting with P-binding cations and clay minerals. Sharma *et al.* (1991) in their tracer studies in a green house experiment on acid and alluvial soils with soybean showed that blending superphosphate with biogas slurry enhanced P utilization by 4.5 per cent in acid soil and 5.9 per cent in alluvial soil over superphosphate applied alone. Ramamoorthy *et al.* (1971) also noticed enhanced P utilization in cereals by the application of single superphosphate coated with biogas slurry. The beneficial effect of blending single superphosphate may be due to the fact that humus substances of biogas slurry surrounded single superphosphate and retarded its dissolution rate and thus reduced P fixation and increased the availability of phosphate over an extended period of time. Datta and Goswami (1962); Singh and Datta (1974); Rahate *et al.* (1979); Sharma *et al.* (1984); Hue (1991) and several others reported significant increase in available P content with the application of phosphatic fertilizers in combination with FYM.

Arunachalam (1959) stated that application of a high level of P (90 kg/ha) through a leguminous green manure, in conjunction with 34 kg of N/ha increased the paddy yield appreciably by 41 per cent. Bauer (1921) found increased phosphate uptake when mixtures of organic matter and rock phosphate were added to soils. Gerresten (1948) found that the action of micro-organisms increased the availability of the phosphate in rock phosphate, whereas Waksman (1938) reported an increase in the solubility of rock phosphate as a result of the action of certain constituents of humus. Ramankutty and Padmaja (1972) reported that in rice there was a definite increase in yield at 30 kg and 60 kg $P_2O_5$ only when applied in conjunction with 4 tonnes and 6 tonnes of green leaf per hectare. The yield was not increased with increased doses of superphosphate alone. Silva *et al.* (1985) and Kothandaraman and Ranjan (1986) found that the application of green manures in an acid soil increased the availability of P in rock phosphate and yield of beans, oats and rice.

# Materials and Methods

with deionised water and thereafter Hewitt's nutrient solution was used to give nutrients and water to the plants. Original Hewitt's solution with minor modifications suggested by De Waard (1969) was used.

The composition of complete nutrient solution is given in Table 1.

Analytically pure chemicals (AR grade) were used for the preparation of the solution. Every tenth day fresh nutrient solution was prepared by diluting aliquots of appropriate stock solutions to the desired concentrations. The pH of the final solution was adjusted to 5.0 by the addition of concentrated NaOH or HCl.

Iron was added separately to the pots as it caused precipitation when mixed with solution containing other nutrient elements. Stock solution of iron was prepared by dissolving the required quantity of $FeSO_4.7H_2O$ in distilled water and acidifying it with $H_2SO_4$ (0.5 ml $l^{-1}$) to avoid precipitation.

For the first 25 days, plants were watered with 300 ml of complete nutrient solution twice a week and subsequently at the rate of 250 ml every second day. Water was applied when required. When the plants were 15 days old, $^{32}P$ (carrier free) was applied with water at the rate of 30 $\mu$Ci $kg^{-1}$ sand. Application of $^{32}P$ (carrier free) was done with the help of a dispenser designed for the purpose of soil injection (Wahid *et al.*, 1988). During the subsequent period also, the same nutrient solution was used to provide nutrients and water to the plants. After 50 days, the shoots and roots were harvested and washed, then dried in the oven at 70°C for two days and ground.

The labelled plant material was used for the incubation study and pot culture experiment. The nutrient composition of the labelled plant material was estimated by the methods outlined by Jackson (1973). The relevant characteristics of the plant material is given in Table 2.

Table 1. Composition of complete nutrient solution

| Elements | meq $l^{-1}$ | mg pure element $l^{-1}$ |
|---|---|---|
| N | 12 | 168.00 |
| P | 3 | 31.00 |
| S | 6 | 96.00 |
| Ca | 8 | 160.00 |
| Mg | 3.5 | 42.60 |
| K | 2.0 | 78.00 |
| Fe (trivalent) | 1.3 | 24.21 |
| Mn (bivalent) | 0.02 | 0.55 |
| Cu | 0.002 | 0.06 |
| Zn | 0.003 | 0.10 |
| B | 2 ppm | 2.00 |
| Mo | 0.03 ppm | 0.03 |

Table 2. Characteristics of the green manure used

| Material | Carbon (%) | Nitrogen (%) | Phosphorus (%) | CN ratio | CP ratio |
|---|---|---|---|---|---|
| *Sesbania aculeata* | 40.0 | 3.04 | 0.2175 | 13.16 | 183.9 |

## 3.2 Incubation experiment

A laboratory incubation study was carried out to study the dynamics of P mineralization from green manure.

### 3.2.1 Collection and preparation of soil

Soil in the top 0-15 cm depth was collected from College of Horticulture farm and air dried, powdered with a wooden mallet and passed through 2 mm sieve. The soil was analysed for pH, total nitrogen, available P and available K. The chemical properties of the soil are given in Table 3.

### 3.2.2 Methodology

Ten gram of processed soil was thoroughly mixed with powdered $^{32}P$ labelled green manure (specific activity, 207 cpm $\mu g^{-1}$ P) at 0.25 and 0.5 per cent by weight of soil and transferred to 30 ml culture tubes. The soil was kept submerged by adding 10 ml water in each tube and incubated at room temperature (28-31 °C). Two replications per treatment was kept to allow destructive sampling at 0, 2, 5, 10, 20, 25, 30, 40 and 60 days after incubation for analysis.

### 3.2.3 Soil analysis

At the respective intervals soil was extracted with Bray-1 reagent (1:5 soil extractant ratio) and the soil suspension was centrifuged. Twenty millilitres of the clear extract was transferred into a scintillation counting vial and the radioactivity was measured in a liquid scintillation counter (Pharmacia LKB Wallac OY, Finland) employing Cerenkov counting technique. The $^{32}P$ activity in the extract was expressed as counts per minute (cpm) after making proper correction for the background activity and decay.

Table 3. Chemical properties of the soil

| Constituent | Content | Method used for estimation |
|---|---|---|
| Total N (%) | 0.14 | Micro Kjeldhal method (Jackson, 1973) |
| Available P (ppm) (Bray-1 extract) | 14.0 | Ascorbic acid blue method (Watanabe and Olsen, 1965) |
| Available K (ppm) (Neutral normal ammonium acetate extract) | 162.5 | Flame photometric method (Jackson, 1973) |
| pH (1:2.5 soil water ratio) | 5.4 | pH meter (Jackson, 1973) |

Using an aliquot of the extract, Bray-1 reagent extractable P was estimated by Ascorbic acid blue method using Spectro photometer. The intensity of the colour was measured at 670 nm (Watanabe and Olsen, 1965).

Using the data on Bray-1 extractable P, radioactivity of $^{32}P$ in the extract and specific activity of the green manure, the contribution of P from green manure and soil was worked out.

### 3.3 Pot culture experiment to study the phosphorus utilization by rice using $^{32}P$ labelled green manure and amophos.

Plastic pots of uniform size were used for the study. The pots were rinsed with dilute hydrochloric acid and then washed with deionized water. The soil used was the same as that in incubation experiment. The pots were filled with 1 kg of processed soil.

Soil was thoroughly mixed with labelled green manure/labelled fertilizer/unlabelled fertilizers as per treatments. Sufficient water was added to the pots to wet the soil and to bring out a puddled condition. The soil was kept in the puddled condition for five days before transplanting the seedlings.

Rice variety "Annapoorna" was used for the study. Seedlings were raised by wet method using the seeds obtained from the Agricultural Research Station, Mannuthy. Transplanting was done when the seedlings were 21 days old. One hill with three seedlings were planted in each pot. Two centimetre standing water was maintained. The pots were arranged in concrete benches inside the greenhouse wherein the sunlight was allowed to enter at about 50 per cent of the natural intensity and air temperature and humidity were non-limiting.

### 3.3.1 Experiment details

The experiment was laid out in completely randomised design with 6 treatments and 2 replications for destructive sampling for radio assay at specified intervals and 4 replications for growth and yield studies.

### 3.3.2 Treatments

$T_1$ - Soil alone

$T_2$ - Soil + $^{32}P$ labelled amophos

$T_3$ - Soil + $^{32}P$ labelled green manure at 0.25% by wt. of soil

$T_4$ - Soil + $^{32}P$ labelled green manure at 0.25% by wt. of soil + unlabelled amophos

$T_5$ - Soil + $^{32}P$ labelled green manure at 0.5% by wt. of soil

$T_6$ - Soil + $^{32}P$ labelled green manure at 0.5% by wt. of soil + unlabelled amophos

Labelled amophos with a specific activity of 0.3 mCi $g^{-1}$ $P_2O_5$ was applied at the rate of 17.5 mg $P_2O_5$ $pot^{-1}$ (35 kg $P_2O_5$ $ha^{-1}$).

Fertilizer application was done according to the package of practices recommendations (KAU, 1993) fo. .igh yielding short duration varieties. Phosphorus was applied as per treatments and N and K were applied at the rate of 70 and 35 kg/ha respectively in the form of Urea and MOP. Phosphorus and potassium were applied as basal dressing and nitrogen was applied in two split doses, 2/3 as basal and 1/3 as top dressing one week before panicle initiation.

### 3.3.3 Chemical analysis

The plant samples were analysed for radioactivity and total P at 10, 20, 40 and 60 days after planting. At the specified intervals, the plants were harvested by cutting them above the level of flood water, washed with distilled water, dried separately in a hot air oven to constant weight, and then finely cut into small pieces and analysed for radioactivity and total P. The radioactivity and total P of the labelled green manure and labelled amophos was also estimated along with the plant samples.

### 3.3.4 Radioassay

For the determination of $^{32}P$ in plant samples, the Cerenkov counting method developed by Wahid *et al.* (1985) was followed. This method consisted of wet digestion of the oven-dried and finely cut leaves with 2:1 nitric-perchloric acid mixture and determination of radioactivity in the digest after transferring it quantitatively into a 20 ml scintillation counting vial with distilled water. The radioactivity was determined in a microprocessor controlled liquid scintillation system (Pharmacia LKB Wallac OY, Finland) adopting channel settings and computer programme recommended for tritium counting by liquid scintillation technique. The count rates (cpm) were corrected for background and decay. No attempt was made to present the data in dpm as the counting efficiency of the instrument remained constant (32 per cent) during the period.

Total P in the plant tissue was estimated by Vanadomolybdo phosphoric yellow colour method using an aliquot of the diacid digest. The intensity of the colour was measured at 470 nm (Jackson, 1973).

Phosphorus uptake by the crop was computed from their respective chemical concentrations and dry matter production.

### 3.3.5 Interpretation of data for radioassaying of $^{32}P$ (Vose, 1980)

Using the data of total P content ($\mu g$) and radioactivity of $^{32}P$ (cpm) in plant samples, labelled green manure and labelled amophos, the following were worked out.

a. Specific activity of $^{32}P$ (cpm $\mu g^{-1}$ P) $= \dfrac{^{32}P \text{ activity (cpm)}}{\text{Total P content } (\mu g)}$

b. Per cent P in the plant derived from fertilizer (% Pdff) $= \dfrac{\text{Specific activity of plant sample}}{\text{Specific activity of fertilizer}} \times 100$

c. Per cent P in the plant derived from the green manure (% Pdfg) $= \dfrac{\text{Specific activity of plant sample}}{\text{Specific activity of green manure}} \times 100$

d. Per cent utilization of P from the fertilizer $= \dfrac{\text{\%Pdff x total P uptake}}{\text{Applied fertilizer P}} \times 100$

e. Per cent utilization of P from the green manure $= \dfrac{\text{\%Pdfg x total P uptake}}{\text{Applied green manure P}} \times 100$

## 3.4 Pot culture experiment for growth and yield studies

To study the effect of incorporated green manure on the growth and yield of rice, a pot culture experiment was done with the same soil as that described under Table 3. In this experiment, unlabelled amophos and sesbania green manure were used.

### 3.4.1 Crop growth characters

#### 3.4.1.1 Plant height

Plant height was recorded on 15, 30, 45 and 60 days after transplanting. Height was measured from the bottom of the culm to the tip of the longest leaf.

3.4.1.2 Number of tillers

Tiller production started after 15 days. Number of tillers on each hill was counted on 30, 45 and 60 days after transplanting.

3.4.2 Yield attributing characters

3.4.2.1 Number of panicles

Number of panicles on each hill was recorded at harvest.

3.4.2.2 Number of spikelets per panicle

Total number of spikelets were taken from the hill and spikelets per panicle was averaged out.

3.4.2.3 Per cent sterile spikelets

From the number of total spikelets and unfilled

cent was worked out.

$$\% \text{ sterile spikelets} = \frac{\text{Number of sterile spikelets}}{\text{Total spikelets}} \times 100$$

3.4.2.4 Test weight

One hundred filled grains were collected and their weight was multiplied by 10 and recorded in grams as 1000 grain weight.

3.4.3 Yield of grain and straw

The plants were separated by cutting them above the water surface, washed with water, dried separately in a hot air over to constant weight and the total dry matter yield was recorded. The grains were then separated and again dried for two days and weight was recorded. The straw yield was found out by substracting grain yield from total dry matter yield.

3.4.5 Root weight

After separating the top portion, the soil with root was transferred to a wire gauze and the soil was removed by washing repeatedly with water. The roots retained in the wire gauze was thoroughly washed, dried and then weight was recorded.

3.4.6 Shoot root ratio

Shoot root ratio was worked out from the total dry matter yield and root weight.

3.4.7 Plant analysis

The grain and straw were analysed separately. Kjelc

1973) was used to find out total nitrogen in plant sample. Total phosphorus and potassium were estimated by using the triacid digest (Johnson and Ulrich, 1959). Total phosphorus was estimated by Vanado-molybdo phosphoric acid method, while potassium was determined using flame photometer.

3.4.8 Nutrient uptake

Nitrogen, phosphorus and potassium uptake by grain and straw were computed from their respective chemical concentrations and dry matter production.

3.4.9 Soil analysis

Soil samples were collected from each pot after the harvest from a depth of 0-15 cm and were analysed for total nitrogen, available phosphorus and available potassium.

### 3.4.10 Statistical analysis

The data relating to each character were analysed statistically by applying the technique of Analysis of Variance and the significance was tested by 'F' test (Panse and Sukhatme, 1978).

# Results and Discussion

# RESULTS AND DISCUSSION

The results obtained from the study are presented and discussed in this chapter under the following heads.

1. Dynamics of phosphorus mineralization from green manure
2. Effect of incorporation of green manure on the utilization of applied fertilizer and native soil phosphorus
3. Effect of incorporation of green manure on the growth and yield of rice

## 4.1 Dynamics of phosphorus mineralization from green manure

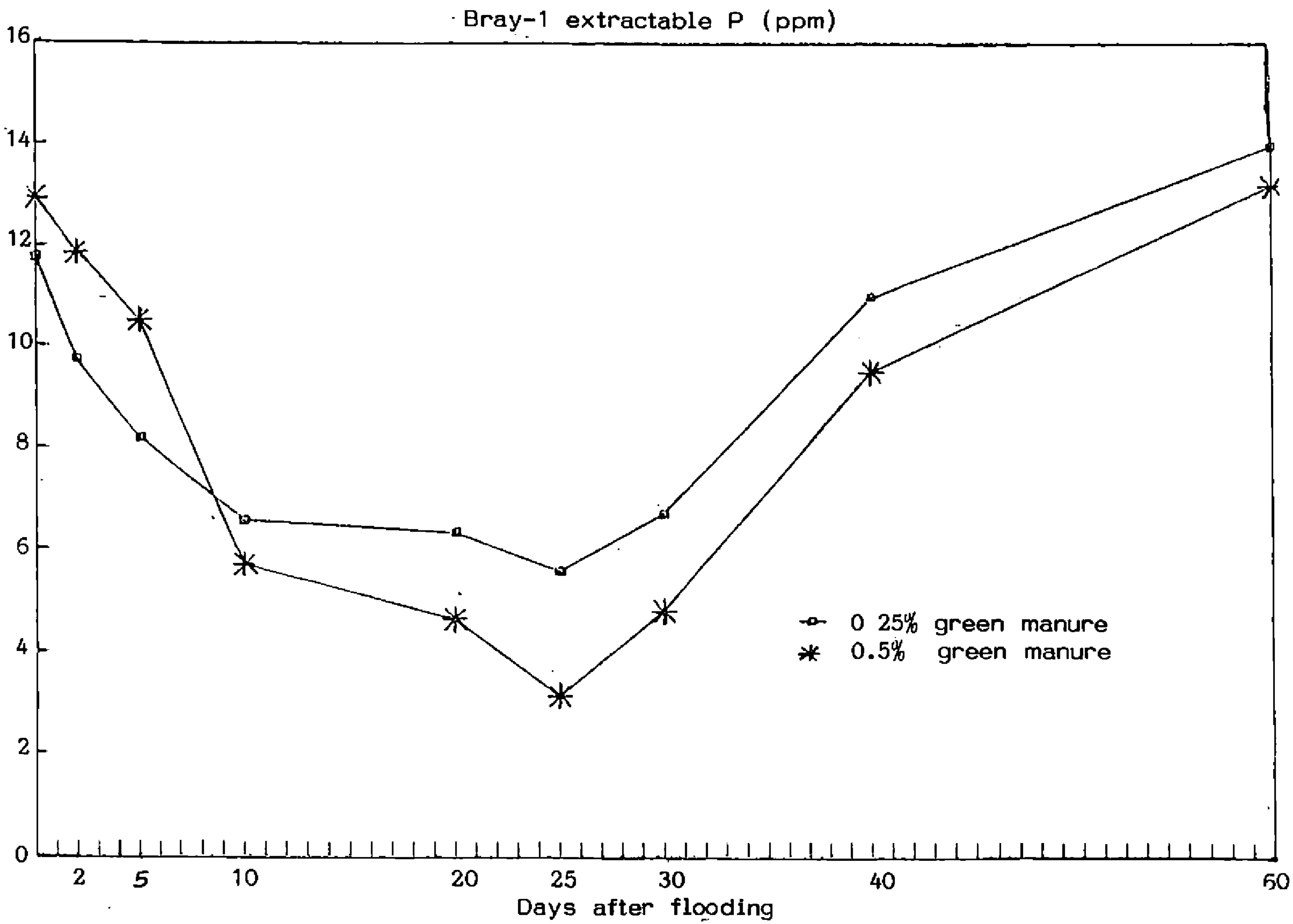
### 4.1.1 Bray-1 extractable phosphorus

The available phosphorus extracted by the Bray-1 method in the soil solution of green manure amended soil during an incubation for 60 days is presented in Fig.1. The release pattern of Bray-1 extractable P was similar both in 0.25 and 0.5 per cent green manure addition irrespective of the quantity of green manure added.. The quantity of $^{32}P$ extracted on zero day was relatively higher than at subsequent intervals. The quantity of extracted $^{32}P$ gradually decreased till 25th day and then increased to higher values as high as 13-14 ppm in both cases. However, during the first five days of incubation, the P release was more from the soil amended with 0.5 per cent green manure, by 10th day the release was levelled off, then upto 60 days of incubation period, the Bray-1 extractable P was more from the soil amended with 0.25 per cent green manure.

### 4.1.2 Contribution from green manure

The available P was released into the soil solution both from soil and

Fig. 1. Changes in Bray-1 extractable P in green manure amended soil following flooding



added green manure. The total P content in the added green manure was relatively less than that in soil. However, the P release from green manure was about 10.5 and 17 per cent of the total Bray-1 extractable P during the initial day of incubation for 0.25 and 0.5 per cent green manure amended soil respectively (Table 4). The per cent contribution further reduced in subsequent days in both cases. Till 20th day of incubation, the contribution was proportional to the quantity of green manure added, later the difference was levelled off, reaching to lower, but similar values from 30 days onwards.

The available P release from the soil incorporated green manure is shown in Fig.2. Keeping the similar trend as that of green manure amended soil, the P extraction from green manure was highest at the initial day of incubation and it further decreased. The least amount was noticed at the 30th day of incubation and then showed an increasing trend, for both levels of green manure incorporation. Till 30th day, more P was released from 0.5 per cent green manure incorporation later showing a reverse trend in absolute quantities.

A high as 25 per cent of the total P in green manure was extracted in the initial day of incubation itself in both cases (Table 5). However, it was drastically reduced to lower values in subsequent days of incubation. At 30 days after incubation, the per cent contribution reached the minimal values with both rates of green manure incorporation and then increased. The per cent release was greater at the lower rate.

### 4.1.3 Contribution of P from soil

Changes in the availability of native P in green manure amended soil is

Fig.2. Release of P from the soil incorporated labelled green manure following flooding

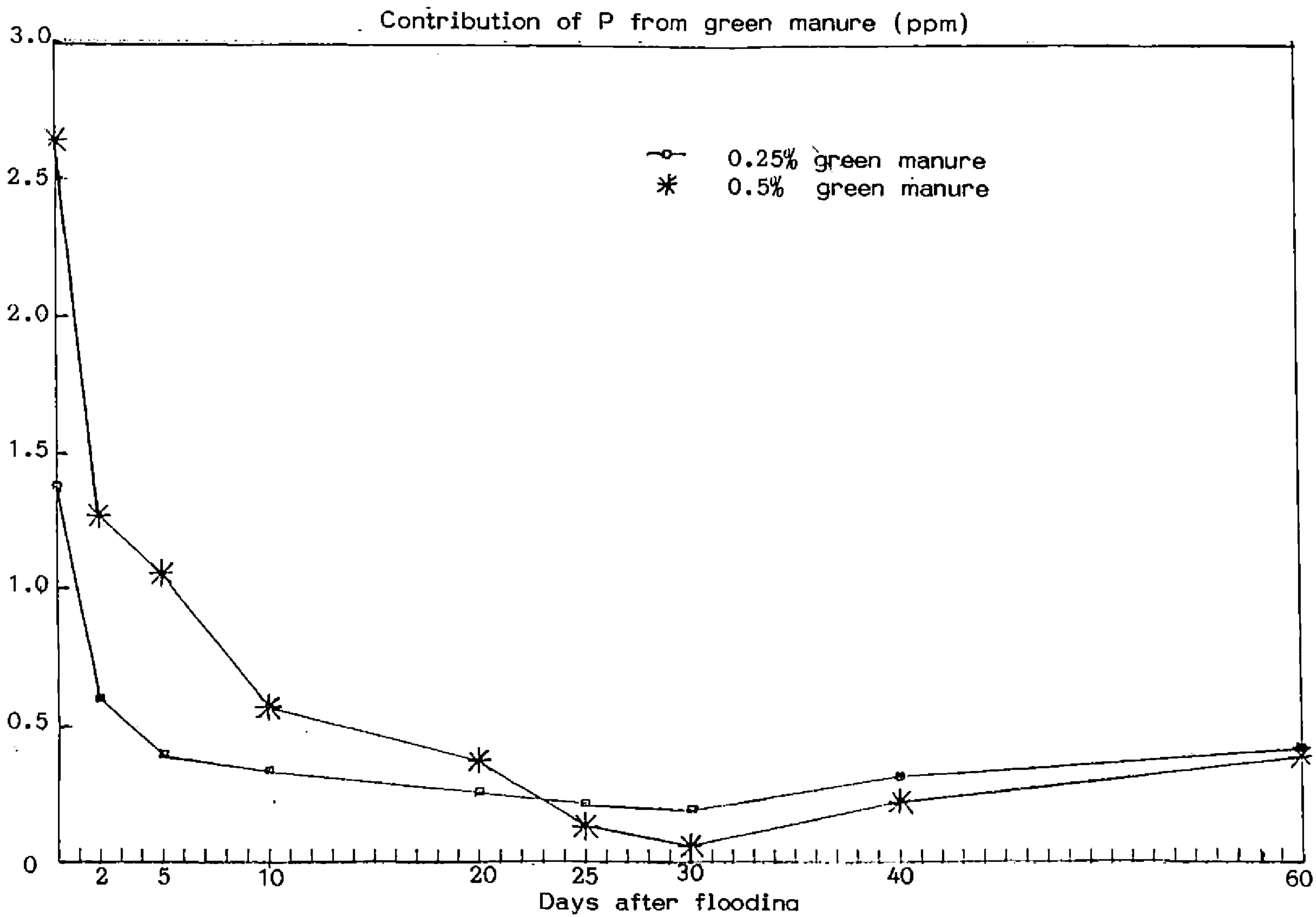


Table 4. Percentage contribution by green manure P to the Bray-1 extractable P in soil

| Days after incubation | Rate of green manure application | |
|---|---|---|
| | 0.25% | 0.5% |
| 0 | 10.50 | 17.30 |
| 2 | 5.84 | 9.70 |
| 5 | 4.60 | 9.20 |
| 10 | 4.40 | 9.12 |
| 20 | 4.00 | 7.50 |
| 25 | 3.80 | 4.22 |
| 30 | 2.84 | 1.30 |
| 40 | 2.93 | 2.37 |
| 60 | 3.00 | 2.87 |

Table 5. Per cent release of Bray-1 extractable P from green manure to the total P applied as green manure

| Days after incubation | Rate of green manure application | |
|---|---|---|
| | 0.25% | 0.5% |
| 0 | 25.35 | 25.38 |
| 2 | 11.07 | 11.71 |
| 5 | 7.24 | 9.77 |
| 10 | 6.21 | 5.25 |
| 20 | 4.84 | 3.46 |
| 25 | 4.04 | 1.27 |
| 30 | 3.59 | 0.58 |
| 40 | 5.88 | 2.11 |
| 60 | 7.22 | 3.58 |

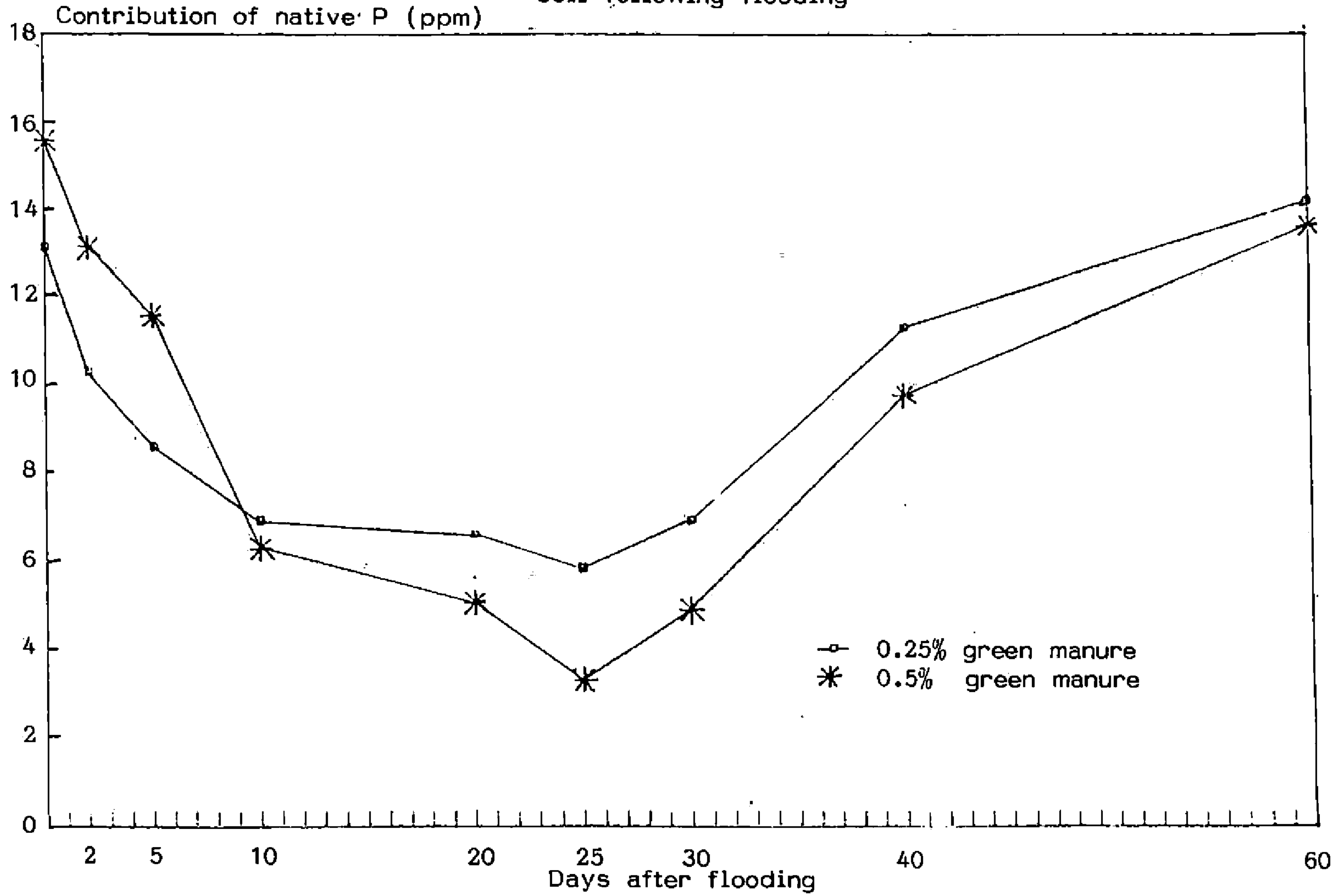
shown in Fig.3. Availability of native P also showed a decreasing trend upto 25 days and thereafter an increasing trend was noticed. Similar to the Bray-1 extractable P, during the first five days of incubation the P contribution from the soil was more from the one amended with 0.5 per cent green manure, by the 10th day, the difference was levelled off. The minimum contribution occurred at 25 days after incubation and thereafter the availability of native soil P increased, and at 60th day the contribution of native P was much higher than the initial level with both levels of green manure application.

In the present study, the decrease in Bray-1 extractable P noticed during the initial 25 days of incubation in the case of 0.25 and 0.5 per cent green manure amended soil may be explained on the basis of immobilization-mineralization relationship of P in soils. Goswami *et al.* (1961) also reported decrease in available phosphorus with days of incubation in green manure amended soil and attributed the reason towards soil and microbial fixation. A net increase in the level of soil inorganic phosphorus (mineralization) will occur if microbial demand is less than the quantity of nutrient mineralized, but a net decrease (immobilization) will occur if microbial demand exceeds the quantity mineralized.

During the first 30 days of acative decomposition, the micro organisms transformed all the organic P contained in the added material into inorganic forms, this is very likely with materials having C/P ratios lower than 200 (Kaila, 1954) as it was in the present case. The micro organisms probably used up the available phosphorus for their own requirements. This immobilization was more in soil amended with green manure at the higher rate (0.5 %).

The initial high contribution of P from green manure especially on the

Fig.3. Changes in the availability of native P in green manure amended soil following flooding



day of incubation may not be due to the mineralization of phosphorus from green manure. As the original soil did not contain any labelled material and as extracts of soil immediately after amending with labelled green manure showed $^{32}P$ activity, it should be logically assumed that the Bray-1 reagent extracted P from the green manure. The presence of soluble inorganic P in plant residues was reported by Friesen *et al.* (1988). Hence it is possible that Bray-1 reagent extracted inorganic P from the organic material.

Organic compounds present in the plant tissues vary greatly in their rate of decomposition. Tender plant parts like leaves contain more of easily decomposable compounds and these decompose rapidly and this accounts for the release of P from green manure till 30th day. Older plant tissues such as stems and other woody tissues decompose slowly and release P at a slower rate. In the present study, by about 25-30 days the decomposition had almost completed and that the contribution of P from green manure started increasing after 30 days.

Availability of native soil P was also low during 20 to 30 days of incubation and in this period a temporary locking up of the nutrient was observed, because of immobilization.

After 30 days, the Bray-1 extractable P showed an increasing trend, which can be explained on the basis of mineralization of P from the applied green manaure and increase in the availability of native soil phosphorus following decomposition of the organic matter. Organic anions such as citrate, oxalate etc. which were produced in soil during decomposition of organic matter were effective in preventing precipitation of phosphate as insoluble substances with Fe and Al in acid soils (Tisdale and Nelson, 1975).

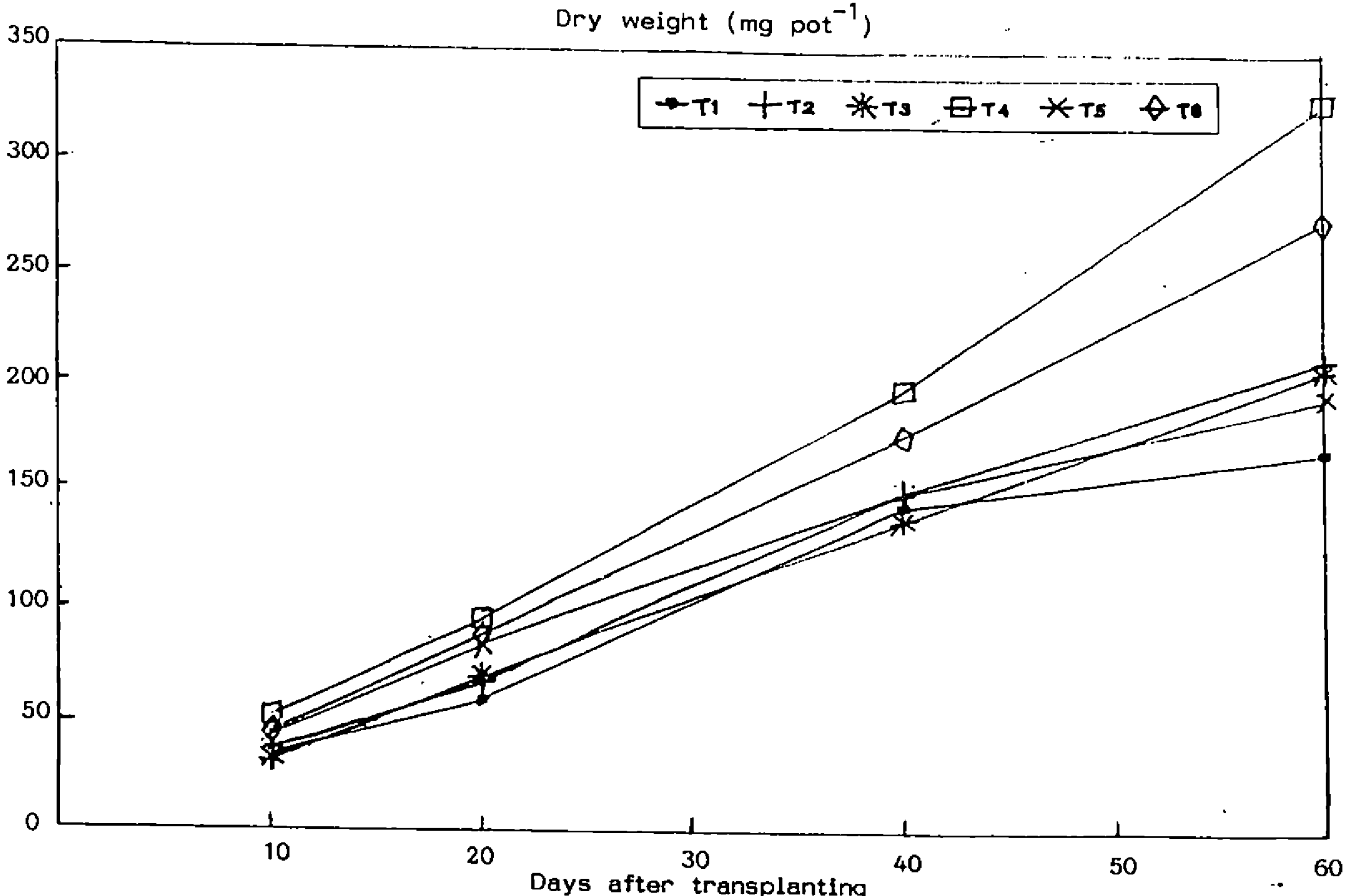
## 4.2 Effect of incorporation of green manure on the utilization of applied fertilizer and native soil phosphorus

### 4.2.1 Dry matter production of rice

The dry matter production of rice at various stages are presented in Fig 4. During the initial stages, application of green manure without amophos produced less dry matter. There was significant difference between treatments with respect to dry matter production at 60 DAP (Table 6). Highest dry matter production of rice was obtained with the application of 0.25 per cent green manure along with amophos. This was on par with 0.5 per cent green manaure + amophos. With green manure application alone, the dry matter yield was less than that of amophos application, even though there was no significant difference between these.

The beneficial effect of green manure on the dry matter production of rice was well documented (Shukla *et al.*, 1989; Kalidurai and Kannaiyan, 1990; Siddeswaran, 1992). In the present investigation also green manure application increased the dry matter yield of rice. The increase in yield with the application of green manure might be due to the greater availability of N and P to plants which might be caused by the supply of these nutrients from the applied green manure, increased availability of fertilizer and soil phosphorus and improved physical condition of the soil. As phosphorus is an essential plant constituent and is a major plant nutrient determining growth and yield quantitatively, it is expected that a greater uptake of P would reflect in higher yield. The comparatively low dry matter yield obtained by the application of green manure alone might be due to the initial set back in growth which occurred due to the temporary immobilization of N and P

Fig.4. Dry matter production by rice at different intervals




T1 -- Control, T2 - labelled amophos, T3 - labelled green manure 0.25%,
T4 - labelled green manure 0.25% + unlabelled amophos; T5 - labelled green manure 0.5%.
T6 - labelled green manure 0.5% + unlabelled amophos

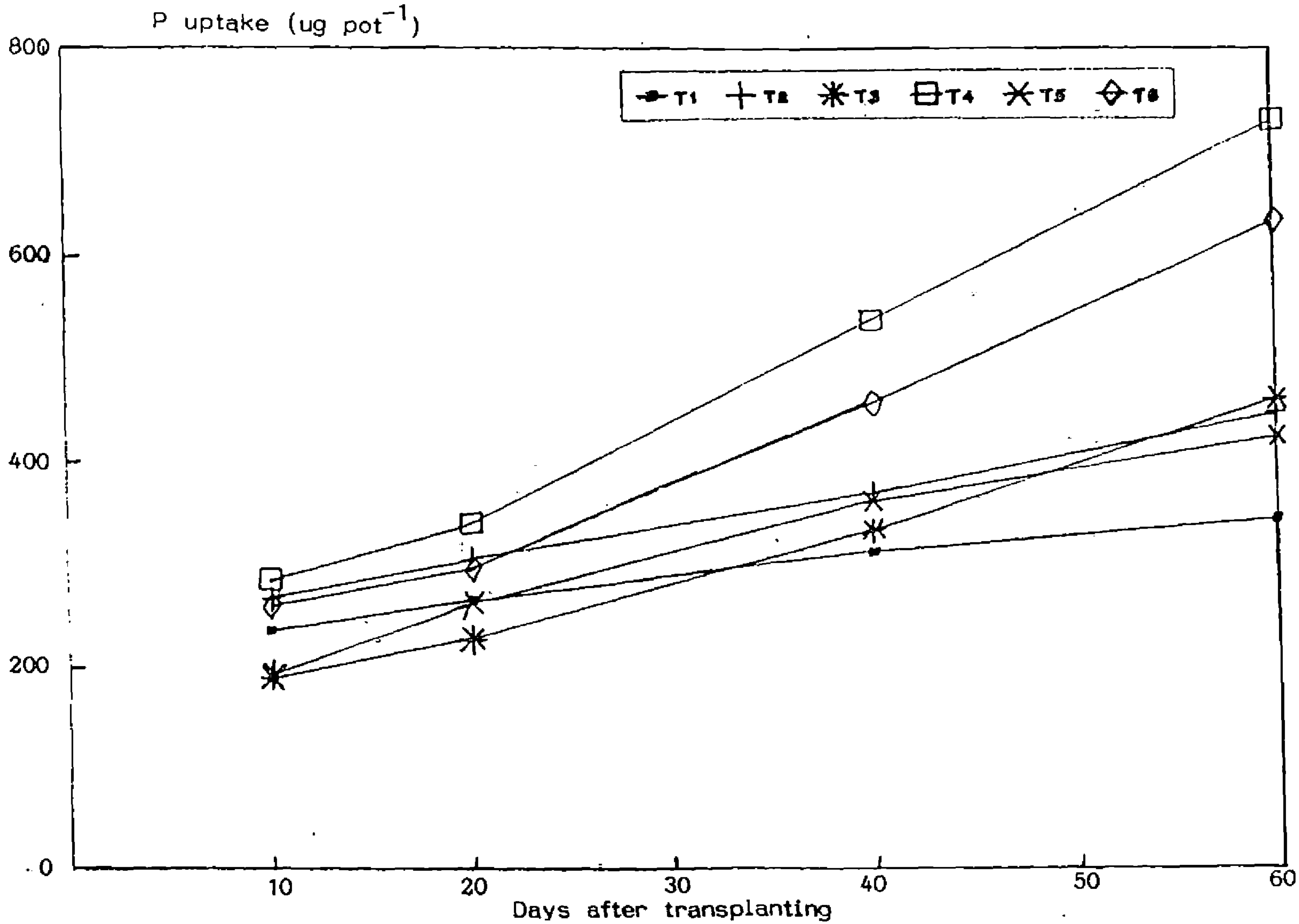
during microbial decomposition. The micro organisms probably used up the available nutrients in the soil for their own requirements.

4.2.2 Total P uptake

Phosphorus uptake by the crop increased considerably by green manure and amophos application. Maximum uptake of P was obtained with the application of 0.25 per cent green manure + amophos and this was significantly superior from the rest of the treatments (Table 6). It was seen that the increase in total P uptake at 0.25 and 0.5 per cent rate of green manure application with amophos was 62.5 and 40.9 per cent respectively over amophos application alone.

Phosphorus uptake by the crop increased considerably by green manure application. Increased availability of P due to green manure incorporation has been reported by several workers (Prabhakar *et al.*, 1972; Hundal *et al.*, 1987; Singh *et al.*, 1988). Walunjkar and Acharya (1955) observed an increase in total phosphorus as a result of application of superphosphate in conjunction with FYM and compost. The greater response of phosphatic fertilizers when applied with organic matter might be attributed to a multiplicity of factors. Readily available P in amophos might remain in the safe custody of organic molecules by absorption and adsorption and thus its reversion to unavailable forms would be prevented (Russel, 1964). It might also be possible that during the decomposition of organic matter, the mineral form of phosphorus added by way of amophos might be converted to organic phosphates through biological agencies which resist fixation and make it more available to plants (Alexander, 1977). Organic anions formed during the organic matter decomposition such as citrates, tartarates, acetates and oxalates might release

Fig. 5. Phosphorus uptake by rice at different intervals




T1 - control, T2 - labelled amophos, T3 - labelled green manure 0.25%,
T4 - labelled green manure 0.25% + unlabelled amophos, T5 - labelled green manure 0.5%,
T6 - labelled green manure 0.5% + unlabelled amophos

Table 6. Dry matter production, total P uptake, per cent P derived from fertilizer/ green manure and per cent utilization of P from fertilizer/ green manure by rice at 60 DAP

| Treatment | Dry matter mg $pot^{-1}$ | Total P $\mu g\ pot^{-1}$ | % Pdff/ %Pdfg | % utilization of P from fertilizer/ green manure |
|---|---|---|---|---|
| 1. Soil alone | 171.00 | 343.75 | - | - |
| 2. Soil + $^{32}P$ labelled amophos | 211.00 | 449.90 | 1.01 | 7.46 |
| 3. Soil + $^{32}P$ labelled green manure at 0.25% by weight of soil | 207.00 | 462.49 | 1.24 | 10.55 |
| 4. Soil + $^{32}P$ labelled green manure at 0.25% by weight of soil + unlabelled amophos | 326.00 | 731.18 | 1.11 | 14.93 |
| 5. Soil + $^{32}P$ labelled green manure at 0.5% by weight of soil | 195.00 | 424.27 | 1.75 | 6.83 |
| 6. Soil + $^{32}P$ labelled green manure at 0.5% by weight of soil + unlabelled amophos | 273.50 | 634.23 | 1.63 | 9.51 |
| SEm± | 16.450 | 24.900 | 0.033 | 0.50 |
| CD (0.05) | 56.955 | 86.170 | 0.116 | 1.60 |

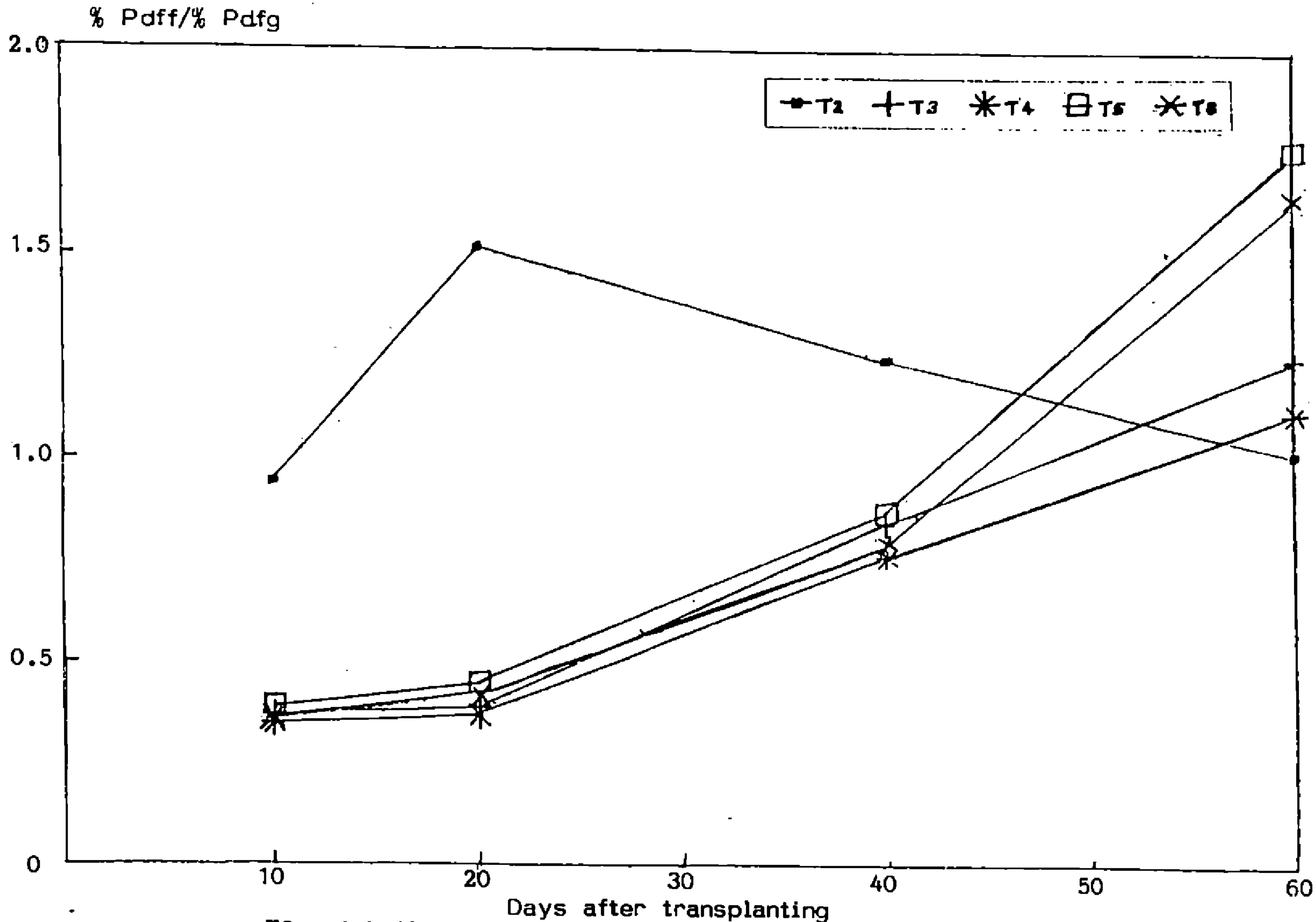
phosphate ions by anion exchange and would make it more available to crops. Some products of organic decay might also act as chelating agents forming complex compounds which would be available to plants (Tisdale and Nelson, 1975). Das (1945) showed that the combined action of decaying organic matter and phosphatic fertilizers produced organic phosphorus complexes, which being soluble in water, neutral in action and having colloidal properties were found to be more available to the plants than the inorganic phosphates which were usually rendered insoluble in the soil. Apart from that, decaying organic matter might form a coating on iron and aluminium compounds, which prevent reaction with soluble phosphate compounds (Buckman and Brady, 1971).

4.2.3 Percent P derived from fertilizer and green manure (% Pdff and % Pdfg)

With regard to P in rice derived from labelled amophos and labelled green manure, significant difference was noticed (Table 6). Phosphorus in plants derived from labelled amophos showed an increasing trend upto 20 days after planting and thereafter it decreased (Fig 6), whereas P derived from green manure showed an increasing trend throughout the period. Upto 20 days after planting '% Pdfg' was very low when compared to '% Pdff', but by 60 days after planting the % Pdfg both at 0.25 and 0.5 per cent was greater than '% Pdff'. Phosphorus in rice derived from the labelled green manure source increased with increasing rate of its application. But when both rates of green manure was applied along with amophos, '% Pdfg' was less.

It was revealed by the present study that there was a decrease in % Pdff with advancement in the stages of crop growth. The decrease in % Pdff would indirectly indicate that the absorption of P by the crop from the fertilizer source was of

Fig. 6. Per cent P derived from fertilizer/green manure by rice at different intervals



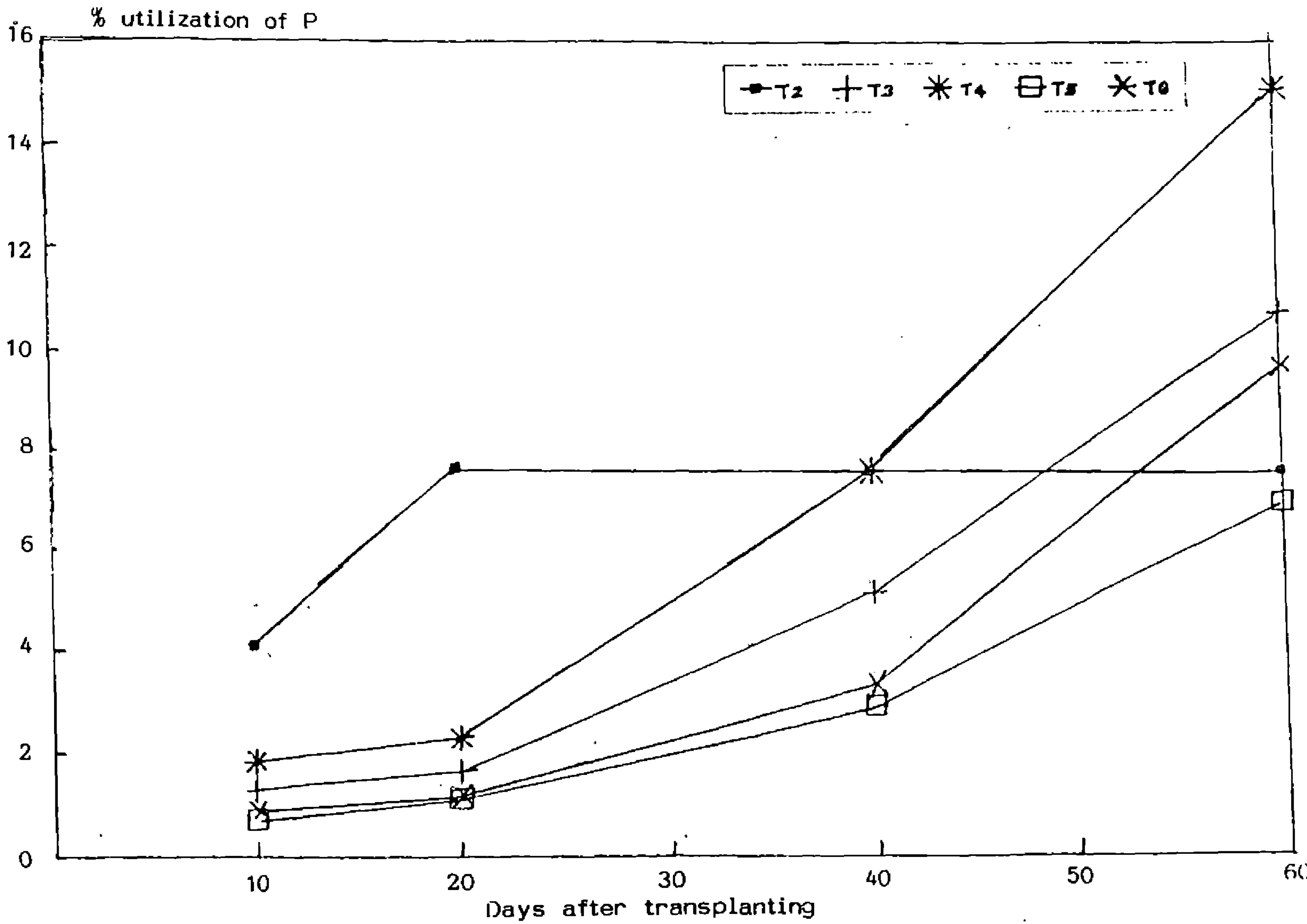

T2 - labelled amophos, T3 - labelled green manure 0.25%,
T4 - labelled green manure 0.25% + unlabelled amophos, T5 - labelled green manure 0.5%,
T6 - labelled green manure 0,5% + unlabelled amophos

greater magnitude at the early stage and decreased gradually with advancement in the crop growth. This might probably be due to the conversion of easily soluble form of P to difficulty available forms with passage of time. The information on the conversion of easily soluble form of P to difficulty available forms in submerged soil was well documented (Willet, 1979; Patrick *et al.*, 1985). Phosphorus derived from labelled green manure source increased with increasing rate of application. Similar results were reported in maize by Vig *et al.* (1989). When green manure was applied along with amophos, the '% Pdfg' was less compared to green manure application alone. This might be due to dilution of mineralized green manure P with added inorganic phosphorus (Blair *et al.*, 1978). The per cent P in rice derived from green manure showed an increasing trend throughout the period, which suggest that a green manure crop should be considered for its long-term rather than of short-term benefit as far as phosphorus availability is concerned.

## 2.4 Percentage utilization of phosphorus from fertilizer and green manure

The percentage utilization of applied fertilizer P and green manure P is presented in (Fig 7). There was significant difference between treatments with regard to the per cent utilization of P. The per cent utilization of P from the labelled amophos was increasing during the initial stages of crop growth, later it showed a decreasing trend, whereas the per cent utilization of P from green manure showed an increasing trend throughout the period. The per cent utilization of P from green manure was very low when compared to the P utilization from amophos during the initial stages of crop growth, but by 60 days after planting, the per cent utilization of P from green manure was more than from fertilizer. Highest utilization of P was obtained with the application of 0.25 per cent green manure along with amophos.

Fig.7. Per cent utilization of P from fertilizer/green manure by rice at different intervals




T2 - labelled amophos, T3 - labelled green manure 0.25%,
T4 - labelled green manure 0.25% + unlabelled amophos, T5 - labelled green manure 0.5%,
T6 - labelled green manure 0.5% + unlabelled amophos

This was significantly superior when compared to other treatments (Table 6). The utilization of P was 15 and 10 per cent respectively when green manure was applied at 0.25 per cent with and without amophos. Hashimoto and Tasuji (1973) also reported 10 to 15 per cent P recovery of organic P added through $^{32}P$ labelled farm yard manure by the first crop.

## 4.3 Effect of incorporation of green manure on the growth and yield of rice

### 4.3.1 Crop growth characters

#### 4.3.1.1 Height of plant

There was significant difference between treatments on the height of the plant at 15th, 45th and 60th day after transplanting (Table 7). Eventhough during the initial stages, plants grown in soil with amophos alone recorded the maximum height, at later stages, plants receiving sesbania green manure at both rates of application in combination with amophos showed the maximum height. The minimum height was observed till 45th day by the treatment receiving green manure alone at the higher dose, but with later stages it became on par with the other treatments. At harvest the lowest height was manifested by the plants in the control pot.

#### 3.1.2 Number of tillers

The data on the mean number of tillers per hill is presented in Table 8. There was no tiller production till 15th day. The number of tillers were lowest in green manure alone amended treatments both at 0.25 and 0.5 per cent at 30 days after transplanting, while the maximum number was observed in the treatment receiving amophos alone and this was on par with that of 0.25 per cent green manure

Table 7. Height of plant (cm) at different intervals

| Treatment | Days after transplanting | | | | |
|---|---|---|---|---|---|
| | 15 | 30 | 45 | 60 | Harvest |
| $T_1$ - Soil alone | 22.18 | 41.31 | 58.75 | 67.50 | 69.50 |
| $T_2$ - Soil + amophos | 24.70 | 42.06 | 64.00 | 70.50 | 73.00 |
| $T_3$ - Soil + green manure at 0.25% by weight of soil | 21.13 | 38.38 | 56.50 | 69.25 | 73.75 |
| $T_4$ - Soil + green manure at 0.25% by weight of soil + amophos | 22.25 | 40.75 | 66.25 | 75.38 | 76.50 |
| $T_5$ - Soil + green manure at 0.5% by weight of soil | 20.88 | 38.25 | 55.75 | 68.50 | 74.00 |
| $T_6$ - Soil + green manure at 0.5% by weight of soil + amophos | 21.13 | 40.75 | 65.25 | 74.00 | 75.00 |
| SEm± | 0.714 | 0.999 | 1.833 | 1.410 | 1.751 |
| CD (0.05) | 2.123 | NS | 5.446 | 4.190 | NS |

Table 8. Number of tillers (No. $hill^{-1}$) at different intervals

| Treatment | Days after transplanting | | |
|---|---|---|---|
| | 30 | 45 | 60 |
| $T_1$ - Soil alone | 4.75 | 4.75 | 5.00 |
| $T_2$ - Soil + amophos | 5.50 | 5.50 | 6.00 |
| $T_3$ - Soil + green manure at 0.25% by weight of soil | 3.25 | 5.00 | 5.50 |
| $T_4$ - Soil + green manure at 0.25% by weight of soil + amophos | 4.75 | 5.75 | 6.50 |
| $T_5$ - Soil + green manure at 0.5% by weight of soil | 3.25 | 4.75 | 5.25 |
| $T_6$ - Soil + green manure at 0.5% by weight of soil + amophos | 3.50 | 5.25 | 5.75 |
| SEm± | 0.354 | 0.289 | 0.323 |
| CD (0.05) | 1.051 | NS | 0.959 |

+ amophos. At 45th and 60th day after transplanting the tiller production was slightly more in plants receiving 0.25 per cent green manure + amophos compared to plants receiving amophos alone, even though they were on par. It was seen that application of amophos alone increased the number of tillers by 20 per cent over control, while 0.25 per cent green manure along with amophos increased the number of tillers by 30 per cent over control. Application of green manure at 0.25 per cent + amophos produced 13 per cent more tillers than green manure at 0.5 per cent + amophos.

4.3.2 Yield attributes and yield

4.3.2.1 Number of panicles per hill

The data on the number of panicles per hill is presented in Table 9. Eventhough there was no significant difference between treatments with respect tc the number of panicles produced per hill, plants grown with 0.25 per cent green manure with and without amophos produced more number of panicles than the rest of the treatments.

4.3.2.2 Number of spikelets per panicle

Significant difference between treatments was noticed with respect to the number of spikelets produced per panicle. From the data presented in Table 9, it was seen that maximum number of spikelets per panicle was produced from plants grown with 0.25 per cent green manure + amophos. This was on par with 0.5 per cent green manure + amophos and amophos application alone. Number of spikelets increased 14.72 and 6.79 per cent, respectively, when green manure was applied at 0.25 and 0.5 per cent along with amophos over amophos application alone.

Table 9. Yield attributes of rice

| Treatments | No. of panicles per hill | No. of spike-lets per panicle | Sterility percent-age (%) | 1000 grain weight (g) |
|---|---|---|---|---|
| $T_1$ - Soil alone | 4.50 | 34.50 | 28.15 | 20.53 |
| $T_2$ - Soil + amophos | 4.50 | 51.60 | 20.84 | 22.06 |
| $T_3$ - Soil + green manure at 0.25% by weight of soil | 5.25 | 48.20 | 24.42 | 22.54 |
| $T_4$ - Soil + green manure at 0.25% by weight of soil + amophos | 5.50 | 59.20 | 22.37 | 22.90 |
| $T_5$ - Soil + green manure at 0.5% by weight of soil | 4.25 | 50.20 | 24.61 | 21.86 |
| $T_6$ - Soil + green manure at 0.5% by weight of soil + amophos | 5.00 | 55.26 | 23.76 | 22.24 |
| SEm± | 0.363 | 3.063 | 3.421 | 0.735 |
| CD (0.05) | NS | 9.100 | NS | NS |

4.3.2.3 Sterility percentage

No significant difference was noticed between treatments with regard to sterility percentage. More sterility was noticed in control plants (28.15 per cent) and less in plants grown with amophos alone (20.84 per cent).

4.3.2.4 Test weight of grains

With respect to 1000 grain weight, no significant difference was noticed between treatments, even then the control pot showed a lower value and the highest value was noted in 0.25 per cent green manure + amophos applied pots.

4.3.2.5 Grain and straw yield

The data on grain yield and straw yield (g $pot^{-1}$) are presented in Table 10. Treatments showed significant difference with respect to grain yield and straw yield. Highest grain and straw yield was obtained with the application of 0.25 per cent green manure + amophos followed by 0.5 per cent green manure + amophos. Application of 0.25 and 0.5 per cent green manure + amophos increased grain yield by 40.7 and 26.9 per cent and straw yield by 34.4 and 20.9 per cent respectively over amophos application alone. Both grain and straw yield were significantly low when green manure alone was applied at higher rate.

4.3.3 Root weight and shoot root ratio

No significant difference between treatments was noticed with respect to the weight of roots per hill and shoot root ratio (Table 10). Weight of root was more in pots where green manure was applied along with amophos. Minimum weight of

Table 10. Yield (g pot$^{-1}$) and shoot root ratio of rice

| Treatments | Grain yield g pot$^{-1}$ | Straw yield g pot$^{-1}$ | Total dry matter g pot$^{-1}$ | Root weight g pot$^{-1}$ | Shoot root ratio |
|---|---|---|---|---|---|
| $T_1$ - Soil alone | 2.29 | 2.17 | 4.46 | 1.07 | 4.16 |
| $T_2$ - Soil + amophos | 4.05 | 4.45 | 8.50 | 2.26 | 3.76 |
| $T_3$ - Soil + green manure at 0.25% by weight of soil | 4.31 | 4.97 | 9.28 | 1.85 | 5.01 |
| $T_4$ - Soil + green manure at 0.25% by weight of soil + amophos | 5.70 | 5.98 | 11.68 | 2.76 | 4.23 |
| $T_5$ - Soil + green manure at 0.5% by weight of soil | 3.51 | 3.40 | 6.91 | 1.77 | 3.90 |
| $T_6$ - Soil + green manure at 0.5% by weight of soil + amophos | 5.14 | 5.38 | 10.52 | 2.67 | 2.75 |
| SEm± | 0.248 | 0.287 | 0.561 | 0.571 | 1.22 |
| CD (0.05) | 0.740 | 0.850 | 1.660 | NS | NS |

root was recorded for control plants. Shoot root ratio was higher for the treatment 0.25 per cent green manure alone followed by 0.25 per cent green manure + amophos.

Results obtained from the growth and yield characters of rice due to different treatments showed the beneficial effect of green manure application. Growth characters like height of plant and number of tillers were more with the application of amophos during the initial stage, but as the stage of growth advanced, plants receiving green manure along with amophos recorded comparatively higher values than plants receiving amophos alone. Phosphorus in amophos was readily available and this resulted in the better growth of plants receiving amophos during the initial stages. Earlier workers, Tiwari and Singh (1969) reported the positive significant response through increased plant height and tiller number for P application and reports by Katyal *et al.* (1975), Ittyavirah *et al.* (1979) support the positive response of rice to P. Phosphorus in green manure was available to plants after mineralization. The initial low growth noticed in the green manure treatments might be due to microbial immobilization. This immobilization was more with higher dose of green manure. As far as green manure is concerned, it is a slow but steady source of nutrients to plants. It acts as a repressor in the early growth stages and as a generator in the later growth stages. The reduced growth rate, particularly at the earlier stages, might have occurred due to anaerobic decomposition. The slow release of nutrients and growth depression at earlier stages induced excessive growth at later stages, which was detrimental to yield. Kamata *et al.* (1976) in a study on the effect of long term application of compost to rice fields in Japan indicated that dry matter production was nearly the same in compost treated and control plots. After heading, the dry matter in the compost treated plot increased more rapidly.

Application of inorganic fertilizers along ,with green manure ensure proper supply of available nutrients throughout the growth period. Phosphorus in amophos was readily available to crop immediately after application, but when applied alone, it was subjected to adsorption and other fixation mechanism in soil and converted to difficulty available forms with passage of time. The information on the conversion of easily available form of P into difficulty available form in submerged soil are well documented (Willet, 1979; Patrick *et al*. 1985). When green manure was applied along with amophos, the fixation of applied P was lowered. Mandal and Mandal (1973) and Bhattacharya and Das (1975) attributed the observed lowering fixation of applied P in the presence of organic matter in flooded acidic lowland rice soils to the complexation of soil Fe and Al by the decomposition products of organic matter.

Rice yield was also higher with the combined application of green manure and amophos. It might be due to the greater availability of N and P to plants caused by the direct supply and their indirect effect on availability of phosphorus from fertilizer and soil and improved physical condition of the soil. As phosphorus is an essential nutrient determining growth and yield quantitatively, it is expected that a greater uptake of P would reflect in higher yield. Eventhough, there was no significant difference, the growth and yield was much lower with higher rate of application of green manure (0.5 per cent) compared to 0.25 per cent with and without amophos. Similar results have also been reported by Biswas *et al.* (1971). Among the green manure treatments, lowest yield was recorded with the application of 0.5 per cent green manure alone, which could be attributed to the higher concentration of $CO_2$ produced during decomposition of green manure which lowered the uptake of nutrients and bringing about a consequent reduction in yield as reported by Ponnamperuma (1964).

4.3.4 NPK concentration and uptake

4.3.4.1 NPK concentration

The data on NPK concentration of rice grain and straw are presented in Table 11. With regard to NPK concentration no significant difference was noticed between treatments, but there was significant difference in uptake due to different treatments.

4.3.4.2 NPK uptake

4.3.4.2.1 Nitrogen uptake

The data on nitrogen uptake by rice is presented in Table 12. Nitrogn uptake of grain differed significantly between treatments. Maximum uptake of N was obtained from plants grown with 0.25 per cent green manure + amophos followed by 0.5 per cent green manure + amophos.

4.3.4.2.2 Phosphorus uptake

Treatments showed significant difference with respect to P uptake. The data on P uptake by rice grain and straw are presented in Table 13. Uptake of P was highest when green manure was applied along with amophos. Among the green manure applied pots, lowest uptake was obtained when highest dose was applied. The per cent increase in P uptake was 41.1 and 24.9 respectively when 0.25 and 0.5 per cent green manure was applied along with amophos, over amophos application alone.

Table 11. NPK concentration of rice grain and straw

| Treatments | N (%) | | P (%) | | K (%) | |
|---|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | Grain | Straw |
| $T_1$ - Soil alone | 1.02 | 0.60 | 0.30 | 0.13 | 0.25 | 2.88 |
| $T_2$ - Soil + amophos | 1.09 | 0.74 | 0.37 | 0.17 | 0.31 | 3.16 |
| $T_3$ - Soil + green manure at 0.25% by weight of soil | 1.19 | 0.84 | 0.37 | 0.15 | 0.31 | 3.06 |
| $T_4$ - Soil + green manure at 0.25% by weight of soil + amophos | 1.26 | 0.88 | 0.38 | 0.17 | 0.34 | 3.63 |
| $T_5$ - Soil + green manure at 0.5% by weight of soil | 1.26 | 0.95 | 0.36 | 0.16 | 0.31 | 3.28 |
| $T_6$ - Soil + green manure at 0.5% by weight of soil + amophos | 1.30 | 0.98 | 0.37 | 0.17 | 0.34 | 3.63 |
| SEm± | 0.179 | 0.224 | 0.024 | 0.017 | 0.038 | 0.200 |
| CD (0.05) | NS | NS | NS | NS | NS | NS |

Table 12. Nitrogen uptake by rice

| Treatments | Grain (mg $pot^{-1}$) | Straw (mg $pot^{-1}$) | Total (mg $pot^{-1}$) |
|---|---|---|---|
| $T_1$ - Soil alone | 23.36 | 13.02 | 36.38 |
| $T_2$ - Soil + amophos | 44.15 | 32.93 | 77.08 |
| $T_3$ - Soil + green manure at 0.25% by weight of soil | 51.29 | 41.75 | 93.02 |
| $T_4$ - Soil + green manure at 0.25% by weight of soil + amophos | 71.82 | 52.62 | 124.44 |
| $T_5$ - Soil + green manure at 0.5% by weight of soil | 44.23 | 32.30 | 76.53 |
| $T_6$ - Soil + green manure at 0.5% by weight of soil + amophos | 70.20 | 52.72 | 122.92 |
| SEm± | 4.77 | 9.74 | 11.97 |
| CD (0.05) | 16.07 | NS | 35.55 |

Table 13. Phosphorus uptake by rice

| Treatments | Grain (mg $pot^{-1}$) | Straw (mg $pot^{-1}$) | Total (mg $pot^{-1}$) |
|---|---|---|---|
| $T_1$ - Soil alone | 6.87 | 2.82 | 9.69 |
| $T_2$ - Soil + amophos | 14.99 | 7.57 | 22.56 |
| $T_3$ - Soil + green manure at 0.25% by weight of soil | 15.95 | 7.46 | 23.41 |
| $T_4$ - Soil + green manure at 0.25% by weight of soil + amophos | 21.66 | 10.17 | 31.83 |
| $T_5$ - Soil + green manure at 0.5% by weight of soil | 12.64 | 5.44 | 18.08 |
| $T_6$ - Soil + green manure at 0.5% by weight of soil + amophos | 19.02 | 9.15 | 28.17 |
| SEm± | 1.105 | 1.09 | 1.629 |
| CD (0.05) | 3.286 | NS | 4.840 |

Table 14. Potassium uptake by rice

| Treatments | Grain (mg $pot^{-1}$) | Straw (mg $pot^{-1}$) | Total (mg $pot^{-1}$) |
|---|---|---|---|
| $T_1$ - Soil alone | 5.73 | 62.50 | 68.23 |
| $T_2$ - Soil + amophos | 12.56 | 140.62 | 153.18 |
| $T_3$ - Soil + green manure at 0.25% by weight of soil | 13.36 | 152.08 | 165.44 |
| $T_4$ - Soil + green manure at 0.25% by weight of soil + amophos | 19.88 | 217.08 | 236.46 |
| $T_5$ - Soil + green manure at 0.5% by weight of soil | 10.88 | 111.52 | 122.40 |
| $T_6$ - Soil + green manure at 0.5% by weight of soil + amophos | 17.48 | 195.29 | 212.77 |
| SEm± | 2.039 | 14.204 | 13.502 |
| CD (0.05) | 6.058 | 42.200 | 40.118 |

4.3.4.2.3 Potassium uptake

The data on K uptake by rice is presented in Table 14. Significant difference was noticed between treatments with regard to K uptake by rice grain and straw. Potassium uptake was also high when green manure was applied along with amophos when compared to application of either of them. Maximum uptake of K was obtained from plants grown with 0.25 per cent green manure + amophos followed by 0.5 per cent green manure + amophos.

The non-significant variation observed in the NPK content of rice grain and straw might be attributed to the high availability of these elements in soil.

High N uptake observed in the case of green manure applied pots might be attributed to the significantly higher dry matter yield under these treatments. Significant difference noticed in the uptake value of N by grain indicates the greater influence of grain yield on uptake values as there was no significant difference in the N content of the grain. John *et al.* (1989) reported higher productivity of rice by the incorporation of legume biomass into the soil and attributed the benefit to N availability from green manure to rice.

Combined application of green manure and inorganic P fertilizer contributed considerably to the P uptake by the crop. Increased availability of P due to the incorporation of green manure into soil have been reported by several workers (Prabhakar *et al.* 1972; Hundal *et al.*, 1987; Singh, 1988). Highest uptake of P obtained by the application of green manure along with amophos was due to the higher dry matter yield and P content under the same treatments. The low uptake of P obtained by the application of 0.5 per cent green manure alone was due to the low dry matter yield as well as low P content, whereas the low P uptake in the treatment receiving amophos alone, was mainly due to the low dry matter yield.

Significant difference noticed in the K uptake by rice grain and straw indicated increase in availability of K due to the application of green manures. Many workers have reported increased availability of K in soils due to green manuring (Kute and Mann, 1969; Debnath and Hajra, 1972; Tiwari *et al.*, 1980; Nagarajah *et al.*, 1986; Swarup, 1987). Marked increases in soil solution K with the addition of sesbania green manure was reported by Nagarajah *et al.* (1986).

4.3.5 Nutrient status of the soil after harvest of rice

The NPK content of soil after the harvest of rice (Table 15) showed no significant difference between treatments. Application of 0.5 per cent green manure alone registered higher values of total N, available P and available K in soil. It was seen that in pots where green manure + amophos was applied, the values were much lower than that in pots where green manure alone was applied. Compared to amophos application alone, application of green manure with and without amophos produced higher amounts of total N, available P and available K in soil.

Higher dry matter production obtained by the combined application of green manure and inorganic P fertilizer might have caused higher amounts of N, P and K absorption by the crop, and hence have lead to the consequent decrease in the NPK content of the soil. During decomposition process of organic residues, though large amounts of N, P and K might be released (Nagarajah *et al.*, 1986), the crop uptake might have caused its subsequent depletion from the soil. The uptake of N, P and K have been found to be higher in green manure + amophos treatments and this

Table 15. Total N, available P and K in soil after harvest of rice

| Treatments | Total N (%) | Available P (ppm) | Available K (ppm) |
|---|---|---|---|
| $T_1$ - Soil alone | 0.13 | 13.0 | 165.50 |
| $T_2$ - Soil + amophos | 0.15 | 14.0 | 164.00 |
| $T_3$ - Soil + green manure at 0.25% by weight of soil | 0.16 | 15.5 | 170.50 |
| $T_4$ - Soil + green manure at 0.25% by weight of soil + amophos | 0.15 | 15.0 | 169.63 |
| $T_5$ - Soil + green manure at 0.5% by weight of soil | 0.18 | 16.0 | 173.50 |
| $T_6$ - Soil + green manure at 0.5% by weight of soil + amophos | 0.16 | 15.5 | 170.75 |
| SEm± | 0.018 | 0.76 | 4.82 |
| CD (0.05) | NS | NS | NS |

resulted in the lower content of these elements in the soil at the post harvest stage.

The slightly higher values of NPK content in green manure alone applied soil might be attributed to the low release and subsequent uptake of these elements by the crop. The low NPK content of the soil where only inorganic fertilizer was applied, might be due to the depletion of the nutrients from the soil.

# Summary

# SUMMARY

An investigation was undertaken at the College of Horticulture, Vellanikkara during 1993-'94 on the 'Utilization of phosphorus from green manure by rice'. The study involved a soil incubation experiment to study the dynamics of P mineralization from green manure and pot culture experiments to study the effect of incorporation of green manure on the utilization of applied fertilizer phosphorus and native soil phosphorus and on the growth and yield of rice.

The salient results of the investigation are summarised below:

The available P content in the soil solution of 0.25 and 0.5 per cent green manure amended soil showed highest values in the initial day itself; gradually decreased till 25th day and then increased. Though the P release was more from the soil amended with 0.5 per cent green manure for the first five days of incubation, the difference was levelled off by the 10th day and then upto 60 days of incubation period, the P release was more from the soil amended with 0.25 per cent green manure.

As high as 25 per cent of the total P in green manure was extracted in the initial day of incubation in both cases. The per cent release further reduced till 30th day of incubation and then increased. The P release was greater at the lower rate of green manure application. The contribution of native soil P was also minimum at the 25th day of incubation and thereafter increased. Much higher contribution of native P was observed by 60th day with both levels of green manure application.

Application of 0.25 per cent green manure in combination with amophos

considerably increased the dry matter production and P uptake by rice at 60 days after transplanting.

Per cent phosphorus derived from fertilizer (% Pdff) increased upto 20 days after planting and thereafter it decreased. Per cent phosphorus derived from green manure (% Pdfg) was very low upto 20 days after planting and thereafter it increased considerably. % Pdfg increased with increasing rate of application of green manure. When both green manure and amophos was applied, % Pdfg was less compared to green manure application alone.

Per cent utilization of P from amophos was high during the initial stages of crop growth later it decreased. The per cent utilization of P from green manure was very low during the initial stages, but after 20 days it increased considerably. The per cent utilization decreased with increasing rate of application of green manure. The utilization of P was 15 and 10 per cent respectively when green manure was applied at 0.25 per cent with and without amophos.

During the early crop growth stages, the treatment receiving amophos alone, recorded more plant height and tiller number than those receiving green manure. Later maximum plant height and tiller number were observed with the application of green manure along with amophos. Application of amophos alone increased the number of tillers by 20 per cent over control, while 0.25 per cent green manure along with amophos increased the number of tillers by 30 per cent over control. When green manure alone was applied at the higher rate (0.5 per cent) the height and tiller number were less.

Among the yield attributing characters, number of spikelets per panicle alone showed significant difference between treatments. Number of spikelets increased 14.72 and 6.79 per cent respectively, when green manure was applied at 0.25 and 0.5 per cent along with amophos over amophos application alone.

Grain and straw yield were also high with the application of 0.25 per cent green manure along with amophos. Green manure application at 0.25 and 0.5 per cent along with amophos increased grain yield by 40.7 and 26.9 per cent and straw yield by 34.4 and 20.9 per cent respectively over amophos application alone. Both grain and straw yield were significantly low when green manure alone was applied at higher rate.

Maximum uptake of N, P and K was obtained with the application of 0.25 per cent green manure along with amophos, eventhough there was no significant difference in the concentration of N, P and K due to different treatments.

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# UTILIZATION OF PHOSPHORUS FROM GREEN MANURE BY RICE

By

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## ABSTRACT OF A THESIS

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requirement for the degree of

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## ABSTRACT

An investigation was undertaken at the College of Horticulture, Vellanikkara, during 1993-'94 to study the utilization of phosphorus from green manure by rice. The main objectives of the study were to assess the contribution of phosphorus released from labelled green manure to the phosphorus nutrition of rice and to study the effect of incorporation of green manure on the utilization of applied fertilizer and native soil phosphorus. The effect of incorporated green manure on the dry matter yield of rice was also investigated.

The green manure used was *Sesbania aculeata*. $^{32}P$ labelled green manure was produced by growing sesbania in sand culture for 50 days. When the plants were 15 days old $^{32}P$ (carrier free) was applied with water at 30 $\mu Ci kg^{-1}$ sand. The labelled plant material was used for the incubation study and pot culture experiment.

The results obtained from the incubation experiment conducted to study the dynamics of P mineralization from green manure revealed that the release pattern of Bray-1 extractable P was similar both in 0.25 and 0.5 per cent green manure amended soil irrespective of the quantity of green manure added. The available P content of the green manure amended soil was relatively higher at the initial day of incubation, gradually decreased till 25th day and thereafter increased. The contribution of P from green manure and native soil also followed similar trend. As extracts of soil immediately after amending with labelled green manure showed $^{32}P$ activity, it is possible that Bray-1 reagent extracted inorganic P from the green manure. The P release from green manure and soil was the least at the 30th day of incubation and

then showed an increasing trend for both levels of green manure incorporation. Till 30th day more P was released from 0.5 per cent green manure incorporation, later showed a reverse trend.

To study the effect of incorporation of green manure on P utilization by rice, a pot culture experiment was done with $^{32}P$ labelled green manure and amophos. The results revealed that per cent P derived from fertilizer (% Pdff) increased upto 20 days after transplanting and thereafter it decreased, whereas the per cent phosphorus derived from green manure (% Pdfg) was very low during the initial stages, and thereafter it increased considerably. So a combined application of green manure and inorganic P fertilizer will meet the P requirement of the crop throughout the growth period. '% Pdfg' increased with increasing rate of application of green manure. Per cent utilization of P from amophos was high during the initial stages of crop growth, later it decreased while the per cent utilization of P from green manure increased considerably after 20 days of transplanting. The per cent utilization decreased with increasing rate of application of green manure.

With regard to crop growth characters, significant increase in plant height and tiller number were observed with the application of 0.25 per cent green manure along with amophos. Among the yield attributing characters, number of spikelets per panicle showed significant increase with the application of 0.25 per cent green manure in combination with amophos. Grain and straw yield were also the highest under the same treatment. Both grain and straw yield were significantly low when green manure alone was applied at the higher rate (0.5 per cent).